# LANDFILL-GAS-TO-ENERGY PROJECT
# STUDY CASE: THE GAMPONG JAWA LANDFILL, BANDA ACEH, INDONESIA

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**ABSTRACT**

Banda Aceh, Indonesia, populated with 250.000 inhabitants, produces 180 tons of waste daily. But only 165 tons are delivered to its 21 ha area of municipal landfill facility, the Gampong Jawa Landfill (GJL).

Since 2009, GJL stopped the open dumping practice and switched to sanitary landfill system. However, landfill gas (LFG) generated is still naturally venting out into the atmosphere.

For leachate treatment, GJL has an anaerobic, an aerobic, and a maturation pool. There is also an advanced biogas reactor, namely the Intermediate Treatment Facility (ITF), which has 40 kW electricity generating capacity. Two Waste Water Treatment Plant (WWTP) systems also available, functioned to process human excrements with total capacity of 130 cubic meter.

This research is conducted to study the potential electricity generation from all-combined available resources in GJL. It includes potentials from landfills, ITF, and WWTPs. Literature review, in-depth interviews, field survey, and spread-sheet simulation are methods that have been conducted to achieve the objectives. The result shows that GJL could benefit more than sufficient electricity for its own operations, and transmit the rest to the National Power Grid.

Furthermore, all potential is then monetized by utilizing the new Indonesian Feed-in Tarif (FiT) regulations. And the Certified Emision Reductions (CERs) is also expected to be traded through Clean Development Mechanism (CDM). Life Cycle Cost Analysis (LCC) was utilized to examine future projections through a comprehensive financial analysis.

*Keywords: Certified Emission Reductions, Feed-in Tariff, Landfill Gas to Energy, Life-Cycle-Cost Analysis, Sanitary Landfill*

## INTRODUCTION

Banda Aceh city, the capital of Aceh Province, Indonesia, located in the very north-end of Sumatra Island, has a quarter million of population. The city owns two municipal solid waste landfill facilities: the Gampong Jawa Landfill (GJL) and the new developed one, Blang Bintang Landfill (BBL).

GJL is operated by Dinas Kebersihan dan Keindahan Kota (DK3), the municipality waste department, while the BBL is managed by the provincial Public Work Department.

**Figure 1 Lanscape overview of the GJL (DK3, 2014)**

However, at the moment, only GJL is fully functioned to receive all waste from the city and parts of neighbouring district. GJL was constructed in 1994. The early area was 12 Ha and then extended to be 21 Ha in 2006.
The BBL is still not operated yet, its facilities allocated and prepared for the future provincial/regional waste.

## REVIEW OF THE LANDFILL, AND RESEARCH JUSTIFICATION

From the total 180 tons of waste generated everyday in Banda Aceh, only 165 tons of them are able to be delivered to GJL, which consist of 92 tons of organic waste and 73 tons of non-organic matters (DK3, 2014).

The non-organic matters (such as bottle, plastic, glass, metal, cans, paper, etc) then sorted for reusing and recycling. Plastic bottle will be further processed in the Plastic Fabrication Unit belongs to GJL in Panteriek Station, around 10 km from the landfill. Other recycleable material will be traded with some 50 metal and other material traders around the GJL. Around 20 ton of recycleable materials are being delivered to Medan everyday (DK3, 2014).

Wood and tree branches (4 tons on average everyday) from the bulk of 92 tons organic waste are then separated and processed in the composting house, where there is a mobile waste shredding machine, with capacity of 16 ton/hour. 15 cubic meter of organic waste (wood, triplex, etc) is chopped everyday. Most of these compost then used as bio-filter in the landfill, to substitute some soil requirement for cover the waste on daily basis.


**Figure 2. Mobile waste shredding machine in operation in GJL (Faisal, 2014)**

Another 2 tons of organic waste (8 cubic meter) are allocated to feed the Intermediate Treatment Facilities (ITF) everyday. The ITF has 16 chambers, 16 cubic meter each. So every 2 days there is one chamber to fill-up. And in one month, all the chambers are full-filled, and the rotation is started again. Those chambers are directed to the digester to produce biogas, which will be utilized to run a generator. There is an electricity generator with maximun capacity of 40 kW installed which is more than enough to substitute the 35 kW demand capacity in the facilities.

**Figure 3. DK3 Personel explains the new ITF system (Faisal, 2014)**

The rest of organic waste (more less 86 tons) is then delivered to the final landfill system. There are 2 blocks of sanitary landfill systems in GJL, 2.5 ha each. The Block A is already full and closed, the Block B is currently still in utilization progress.
For the sanitary-landfill operations, GJL demand 5000 cubic meters of soil and 3500 cubic meters of compost for the covering purpose annually.

**Figure 4. GJL wheel loader prepares soil and compost to cover the sanitary landfill (Faisal, 2014)**

Six vertical HDPE pipes are installed, 3 in each block. The vertical height is always adjusted to the high of landfill. The horizontal HDPE pipe for leachate and gas collecting have been already installed during the early construction. However, it is very unfortunately, that LFG generated for years in GJL is still naturally venting out into the atmosphere.
Globally, landfill gas consisting of Methane Gas ($CH_4$) and Carbon Dioxide ($CO_2$) is considered as green house gases (GHSs). And LFG, if it's not well

managed, has the potency to develop explosion and burning. The value of Global Warming Potential (GWP) of $CH_4$ molecule itself is believed to be 21 times of that of $CO_2$ molecule (Eggleston, 2006). And Inter Governmental Panel on Climate Change (IPCC) reported in 2006 that emission of $CH_4$ from refuse management sector contributes 3-4% of the global GHG emission.

The Agency for Assessment and Application of Technology (Badan Pengkajian dan Penerapan Teknologi, BPPT) had successfully investigated that LFG generated in GJL consist of 57% methane gas and has the potential to operate a 195 kW capacity of electricity generator.

The GJL also received around 20 cubic meters of sewage (human excrements) every day. There are two facilities for treatment of the waste, the 50 cubic meter of open Waste Water Treatment Plant (WWTP) and the 85 cubic of closed WWTP developed by UNICEF.

**Figure 5. Closed WWTP utilizing DEWATS System, 85 $m^3$ Cap. (DK3, 2013)**

For the leachate treatment, the TPA has 3 pools: anaerobic pool, aerobic pool, and maturation pool. The process work properly through natural gravity forces.

**Figure 6. Pools for leachate treatment (Faisal, 2014)**

Beside of that, more facilities are available in GJL, such as: weighbridge with 40 ton max; fence system; integrated water channels; units of aerator; and a comprehensive mechanical workshop for maintenance and services of fleets, equipment and tools, included heavy equipments.

GJL annual budget for operations and maintenance is IDR 1,500.- million. It includes the salary for the workers, electricity bills, fuel for bulldozer and excavators, tools and equipments, soil supply for daily cover, piping, etc. But excluding fuel for waste collection fleet (dump-trucks, armroll trucks, compactors, pick-up, and tricycle).

Beside of collecting comprehensive taxes, the Municipality of Banda Aceh, through DK3, also collecting tipping fee (in the form of waste retribution) from all GJL clients. However, those income are not directly utilized by DK3, but instead managed centrally by another instititution as city's integrated annual revenue.

Based on Law No. 30 Year 2007 on Energy and Law No. 30 Year 2009 on Electricity, the Government of Indonesia (GoI) just re-launched a more tempting Feed-in Tarif regulations for electricity generated from municipal solid waste based, namely Energy and Mineral Resource Ministry Regulation, Permen ESDM No. 19 Year 2013, in August 2013.

Especially for energy from municipal solid waste category, the laws and regulation order the National Electricity Company (PLN) to purchase all electricty produced by any under 10 MW capacity Independent Power Producer (IPP), with a fixed prices, ranging from IDR 1.250 – IDR 1.798/kWh, depend on low or high voltage grid connection, as well as utilized technologies, sanitary landfill or zero waste technology.

The law also consider and utilized various incentive factor based on regions:

- Jawa, Madura, Bali, Sumatra: 1
- Sulawesi, Kalimantan, NTB, NTT: 1.2
- Maluku, Papua: 1.3

## METHODOLOGY

Based on these circumstances, and in order to evaluate the potential of utilizing LFG for power generation in GJL, the DK3, together with Yayasan Kemaslahatan Ummat (YKU) Foundation and Kuala Gruentech Energia (KGE) Consultant Inc., established a comprehensive research to determine the feasibility of operating a biogas power plant.

The objective of the research is to calculate total power generating potential from all the waste treatment facilities available, it include the two blocks of sanitary landfill systems, an ITFs, and the two WWTPs.

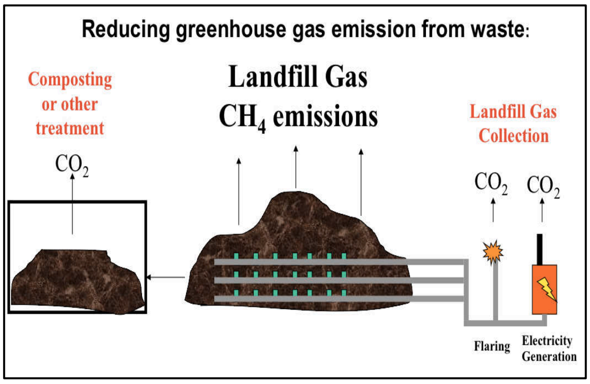


**Figure 7. Methane gas from sanitary landfill utilized to generate electricity (Morton, 2005)**

To achieve the objectives of the research, various methods for retrieval and analytical purposes are conducted. Primary data were collected through interviews, field survey, and spread-sheet simulation. However, the secondary data retrieved from literatures and various institutional reports had a very significant contribution in the overview stage.

For the purpose of long-term situations comparison, this study uses Life-Cycle Cost (LCC) analysis to assess the economic viability of the power generating possibilities. This financial analysis is executed, considering the difficulty of identifying all direct and indirect benefits associated with this Landfill Gas to Energy (LFGTE) Projects.

The total cost is calculated by considering all new investments, annual operation and maintenance cost for waste treatment, power generating cost and its FiT benefits. Various indicators, such as the Payback Period (PBP), Net Present Value (NPV), and Internal Rate of Return (IRR) are exercised to determine the feasibility of alternatives.

Furthermore, since the LFGTE from municipal solid waste is highly valued in the Clean Development Mechanism. The comparison also includes the trading of Certified Emission Reductions (CER's) in the international carbon market, which will increase the profitable of the project.

## POWER GENERATING CALCULATION

### Annual Operation and Maintenance Cost, including Current Expenses for Electricity

Currently, GJL spend IDR ***1,500.00- millions*** for operations and maintenance annually. It includes the electricity bill for the installed ***35 kW*** of supply capacity from PLN.

For the electricity, with assumption that only 75% of capacity is used on annual basis. Thus,

75% x 35 kW x 8760 hours = ***229,950 kWh*** of electricity consumed every year.

And the total expenses is calculated based on the new electricity tarif from National Electricity Company (PLN), date 01 July 2014 (The PLN charges IDR 1,571.08 / kWh for public service companies). Thus,

229,950 kWh x IDR 1,571.08 = ***IDR 361,269,846.00-***

IDR 361.27 millions has to be paid by GJL to PLN on annual basis.

### Amount of Electricity Generating Potential from the Landfill

There is a total potential ***195 kW*** electricity generating capacity from Block A and Block B of the sanitary landfill (BPPT-USAID, 2012). It is the potential of installed capacity, after transfer loss and gas cleaning. And with assumption that only 75% of capacity effectively used annually, thus the amount of generated electricity:

75% x 195 kW x 8760 hours = ***1,281,250 kWh*** annually

### Amount of Electricity Generating Potential from the ITF

There is an installed ***40 kW*** of electricity generator for biogas produced in ITF. So, with 75% effective assumption, the potential electricity generated:

75% x 40 kW x 8760 hours = ***282,800 kWh*** annually

### Amount of Electricity Generating Potential from WWTP

From the two WWTP systems, it is assumed that only the closed system (85,000 L) to be utilized for fueling the electricity generator.

In the closed biogas reactor, the volume of gas produced during the digestion process can fluctuate over a wide range; with typical values varying from 0.5 – 0.9 $m^3$/L (Bolzonella, 2005). This range depends on the volatile solids concentration of the sludge feed and the biological activity in the anaerobic digestion process.

With the energy contents 0.0106 kWh/L of sewage biogas (EBI, 2009), and the defined 20% thermal efficiency for chemical-mechanical-electricity conversion in the internal combustion engine (gas engine or gas turbine), and 75% of annual working assumption. So, by using the lower gas production limit (0.5 $m^3$/L), amount of potential electricity produced are:

75% x 20% x 85,000 L x 0.5 $m^3$/L x 0.0106 kWh/L x 8760 hours = ***591,957 kWh*** annually which could be achieved by utilizing electricity generator with minimum ***67 kW*** capacity.

**Total Amount of Potential Capacity and Potential Electricity Generated from all Facilities**

Hence, the potential total capacity of electricity generators to be installed in all facilities:

195 kW + 40 kW + 67 kW = ***302 kW***

and the total amount of potential electricity to be generated from all facilities:

Electricity from Landfills + Electricity from ITF + Electricity from WWTP = 1,281,250 kWh + 282,800 kWh + 591,957 kWh = ***2,156,007 kWh***

## FEED IN TARIFFS AND CERTIFIED EMISSION REDUCTIONS CALCULATION

**FiT Calculation**

Referring to the criterias in the Indonesian new FiTs Regulation (Permen ESDM No 19, Year 2013). GJL, as the municipal waste department, operating sanitary landfills system, and with a low voltage (20 KV) grid connection, is entitled to claim ***IDR 1,598*** for any kWH of generated electricity supplied to PLN's national grid.

GJL is expected to generate totally 2,156,007 kWh annually. But from those amount, there is 229,950 kWh to be utilized for internal consumption, therefore, GJL could supply as much as ***1,926,057 kWh*** to the national grid every year.
Hence, the annual income just from the PLN is:

1,926,057 kWh x IDR 1,598 / kWh = IDR 3,077,839,086,- = ***IDR 3,077.84 millions*** annually.

**CERs Calculation**

According to the Center for Research and Development of Cipta Karya, an institution under Indonesian Ministry of Public Works, the amount of $CO_2$ emissions out of human activity is calculated by a formula as follows:

$$ECO_2 = A \times FE$$

- $ECO_2$ = $CO_2$ Emission (kg)
- A = Activity data (total kWh of electricity generated)
- FE = Emission Factor (kg $CO_2$/kWh → for Indonesia region = 0,719 kg $CO_2$/kWh)

Thus, the value of carbon emission ($ECO_2$) that can be substituted through the operations of these facilities is:

$ECO_2$ = 2,156,007 kWh x 0.719 kg $CO_2$/kWh = ***1,550,169.33 kg $CO_2$*** every year.

So, with the current world price of $ECO_2$: ***25 EUR per metric ton*** (BEF, 2014), GJL could trade its CERs units in the world carbon market through Clean Development Mechanism (CDM) and enjoy the benefit of:

1,550.17 tonne $CO_2$ x EUR 25 = EUR 38,754.23 ≈ IDR 605,844,877.00- = ***IDR 605.84 millions*** every year (with conversion rate of IDR 15,633 per EUR 1).

So, annual accumulative income from FiT and CDM:

IDR 3,077.84 millions + IDR 605.84 billions = ***IDR 3,683.68 millions***

## INVESTMENT AND LIFE-CYCLE-COST ANALYSIS

The GJL is an old landfill system, constructed in 1994, re-developed in 2006 after the 2004 Tsunami hit Banda Aceh, and then switched into sanitary landfill system since 2009.
The ITF was constructed through Multi Donor Fund (MDF)/United Nations for Development Programs (UNDP) program in 2013.
The LFG vents in both sanitary landfill blocks (both horizontal and vertical HDPE pipes) have been already installed since the re-development.
Thus, to implement all the planned projections above, the only investments required are to install the collecting and connecting pipes of all biogas from those separated facilities to the combustion engines (electricity generators) facilities.

Based on survey of current Indonesian market, the investment for thermal conversion (chemical-mechanical- electricity) by utilizing electricity generators (gas engine or gas turbine) could cost ***USD 0,8 million per MW*** electricity generating capacity (including all secondary and accessories costs).
Hence, the total capacity of 302 kW demands amount of investment as much as:

0.302 MW x USD 0.8 million = USD 0.1812 million ≈ ***IDR 2,821.40 millions*** (with conversion rate of IDR 11,678 per USD 1).

Since it is the renewable resources, there is no fuel-cost for this investmet. And the only running cost is the Operation and Maintenance Cost (O&M Cost), which is in this case, refers to the basic annual requirement of GJL, which is IDR 1,500 million. But minus the IDR 361.27 million charges from PLN for its 35 kW, because the 35 kW capacity from PLN could be turned-off since the operating of the new installed biogas electricity generator.

So, the new O&M Cost is expected at:

IDR 1,500 millions – IDR 361.27 millions = ***IDR 1,138.73 millions*** annualy.

However, it must be noted, these calculations do not coverage the tipping fee (sanitary taxes) collecting by the Municipality of Banda Aceh from all GJL clients. And so does the fuel for all the fleets (hundred of dump trucks, pick up, cars, etc) which is separately financed by the municipality.

Both of those revenue & expense, which could cost billions of Indonesian Rupiahs, are organized and financed by other department of the municipality.

Then, the LCC Analysis is summarized as table below:

**Table 1 Advanced Projection (in million of IDR)**

| Yr | Investment | O&M Cost | FiT | CERs | Balance |
|---|---|---|---|---|---|
| 1 | (2,821.40) | (1,138.73) | - | - | (3.960,13) |
| 2 | - | (1,138.73) | 3,077.84 | 605.84 | (1.415,18) |
| 3 | - | (1,138.73) | 3,077.84 | 605.84 | 1.129,77 |
| 4 | - | (1,138.73) | 3,077.84 | 605.84 | 3.674,72 |
| 5 | - | (1,138.73) | 3,077.84 | 605.84 | 6.219,67 |

Based on the LCC Table, there is no doubt, the investment to utilize biogas for electricity generation is a profitable option.

The current operation scheme gets no revenue. It only spend annual budget of ***IDR 1,500.00 millions*** for O&M Cost.

But with the new investment of ***IDR 2,821.40 millions***, the annual O&M Cost is expected to decrease to be ***IDR 1,138.73 millions***. And furthermore, GJL is entitled to claim annually ***IDR 3,077.84 millions*** from PLN as the result of electricity sales under FiT regulations, as well as an annual benefit of ***IDR 605.84 millions*** from CERs trading under CDM scheme.

The LCC table also shows that, with the total expenses IDR 3,960.13 millions in first year (investment & O&M Cost), the net revenue is expected to start in the second year as much as IDR 2,544.95 millions (ince from FiT and CER minus O&M Cost). Hence, the Payback Period (PBP) could be achieved after ***2.55 years***. And then the project continues with a regular net-revenue from FiT and CERs, minus its depreciation and O&M Cost, until the new investment is required, or until the end of methane-flaring period, before the compost harvesting period in the landfills.

And referring to the current Indonesian Interest Rate, 7.5% (BI, 2014), after the 3$^{rd}$ year, this project could achieve a Net-Present Value (NPV) of ***IDR 290.68 millions***. As well as the Internal-Rate of Return is at ***10,6%,*** which means it is a very prospective project, as it could earn 10,6% benefit just after 3 years.

However, its need to be considered, due to limited budget available in the municipality level, it would be too optimistic to expect these projections to reach the target in the near-coming years.

But indeed, it is very highly recommendate to the GJL operator, to utilize the biogas for electricity generation, to prevent the harmfull free-releasing of methane to atmosphere, as well as, at the very minimum objective, to substitute the 35 kW electricity demand from PLN.

## CONCLUSIONS

Amount of GJL regular expenses for O&M Cost is IDR 1,500.00 million annually.

The study shows that, methane gas generated in GJL's 3 main facilities (landfills, ITF, and WWTP) has total potential electricity generating capacity of 302 kW, which is much bigger than the 35 kW internal consumption demand capacity supplied by PLN.

By utilizing that total potential capacity, amount of electricity to be produced could reach 2,156,007 kWh on annual basis. From that amount, as much as 229,950 kWh could be utilized to substitute the internal consumption demand, thus decreasing the regular annual O&M Cost.

The rest of electricity could be transmitted to national grid, and based on Indonesian new FiT regulations, GJL is entitled to claim IDR 3,077.84 millions every year.

Due to its 1,550.17 tons of $CO_2$ emission reduction every year, GJL could trade its CERs in world CDM scheme, and enjoy the benefit as much as IDR 605.84 millions annually.

The financial analysis shows that IDR 2,821.40 millions investment to realize this project has 2.55 years PBP. And in 3 years, the NPV is IDR 290.68 millions and IRR at 10.6%.

Moreover, GJL is expected to enjoy further regular net-revenue in the years to come, both from its FiT and CERs, minus its O&M Cost and depreciated value, and until the new investment is necessary, or until the end of landfills methane-flaring period.

Overall, LFGTE in GJL is a profitable option, therefore it is highly recommended for DK3 to start utilizing it, at the minimum target is to satisfy the internal electricty demand, as well as to prevent the GHG emission caused by methane gas from its landfills.

## REFERENCES

BEF. (2014): Bloomberg Energy Finance, http://about.bnef.com/, retrieved 9 August 2014

BI. (2014): Bank Indonesia, http://www.bi.go.id/, retrieved 9 August 2014

Bolzonella, D., Pavan, P., Battistoni, P., and Cecchi, F., (2005): Process Biochemistry 40-1453.

BPPT – USAID (2012): Feasibility study of LFGTE in Gampong Jawa Landfill, Agency for the Assesment and Application of Tehnology (BPPT), and USAID.

Damanhuri, E., Padmi, T., Chaerul, M., and Shobari (2000): Potensi Gasbio dari Lahan-Urug Sampah Kota di Indonesia. Studi Kasus TPA Grenjeng dan TPA Sukamiskin, Jurnal Teknik Lingkungan ITB Bandung, 6-1.

DK3 Banda Aceh (2014): Instalasi Pengelolaan Limbah Tinja, IPLT. Dinas Kebersihan dan Keindahan Kota Banda Aceh.

DK3 Banda Aceh (2014): Pengelolaan Sampah dan RTH di Kota Banda Aceh. Dinas Kebersihan dan Keindahan Kota Banda Aceh.

DK3 Banda Aceh (2012): TPA Kota Banda Aceh: Transisi Dari Open Dumping Menuju Sustainable Sanitary Landfill. Dinas Kebersihan dan Keindahan Kota Banda Aceh.

Eggleston, S., Buendia, L., Kyoko, M,, Ngara, T., (2006): IPCC Guidelines for National Greenhouse Gas Inventories, Vol 5 Waste, IGES.

Kardono, and Wahyu Purwanta (2007): Landfill Gas To Energy: Its Status and Prospect in Indonesia, Agency for the Assesment and Application of Tehnology (BPPT), Indonesia.

Mawardy Nurdin, Ir., (2013): Banda Aceh at a Glance - Continues Efforts for Sustainable Eco-City.

Morton, J., (2005): World Bank Experience in Landfill Gas and Prospects for Indonesia, The World Bank.

Oo Abdul Rosyid (2013): Government Policies and Strategies to Encourage New and Renewable Energy in Indonesia. Renewable Energy as Future Sustainable Energy Sources, Agency for the Assesment and Application of Tehnology (BPPT), Indonesia.

Syakur, T., Ir., (2013): Potensi Energi Primer sebagai Pembangkit Tenaga Listrik di Aceh. Skenario Kebijakan Energi Indonesia Menuju Tahun 2050, Dinas Pertambangan dan Energi Aceh.

Tchobanoglous, G., Theisen, H., and Vigil, SA., (1993): Integrated Solid Waste Management, McGraw-Hill Inter, NY.

UK: EBI. (2009): Chemical Entities of Biological Interest. UK: European Bioinformatics Institute.

UN Habitat (2010): Solid Waste Management in the World's Cities.

UNDP and UN-Habitat. (2012): Rencana Operasional Pengelolaan Sampah – Kota Banda Aceh. Training for improved Municipal Solid Waste Management Project, UN-Habitat Indonesia.