Pre-feasibility Study of Landfill Biogas for Electricity in Colombia

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Abstract. A technical and financial pre-feasibility study of an energy from waste project in Colombia is presented. The current situation in Colombia, the technologies available, and the tools for the simulation are described. A case study based on transforming an existing landfill to allow the collection of the landfill gas to generate electricity for sale to the grid as well as to nearby industry is presented. Two special variations of the case study are also presented to demonstrate the effect of Feed-in-Tariff (FIT) and Clean Development Mechanisms (CDM) incentives. Results demonstrate the importance of a sound FIT policy and the potential advantage of gaining CDM credits in the financial viability of the project. The project additionally may contribute to the reduction of GHG emissions.

Key words. Landfill, Green electricity, Colombia

1. Introduction

Landfill gas is considered to be not only a secondary resource but also a mixture of greenhouse-gases (GHG). The Kyoto Protocol commits for a 5.2% reduction of all GHG emissions relative to year 1990 emissions, by year 2012.

A landfill with energy recovery is a good way of treating the waste (see Fig. 1). We can recover the energy content of the disposed material that is conserved in a landfill.

Depending on the infrastructure of the landfill, they are releasing naturally produced landfill gas, containing CO₂ and CH₄, GHG, and other dangerous substances. Capturing these gases, and utilizing them as fuel is a solution for the reduction of GHG emissions, and at the same time for the reduction of the fossil fuels needed for energy production.

Colombia has performed an impressive development over the past two decades. In Latin-America in general, the most significant effect on the environment is originated from the evolving economy, rising energy demand, along with

urbanization. Meeting the energy demand and stay sustainable needs a higher ratio of renewable energies, which can be partially covered by LFG. Growing cities face the necessity of advanced waste management systems. These systems have to find the best mix of waste treating methods, among others, the landfill gas to electricity (LFGTE) projects. Ideally, the average size of the pertinent landfill sites are feasible for LFG projects, the organic content of the waste is also higher than needed, in general. The solution seems to be evident for the energy demand, in fact, covering it by renewable energy and at the same time reducing the number of needed landfill sites. By launching LFGTE projects Latin-American cities can also benefit from the developing market for carbon credits.

This paper aims to assess the viability of a LFG to energy project in *Praderas del Magdalena landfill*, which is located in Girardot, Colombia and currently captures the LFG, but does not have energy recovery system.

Fig. 1 LFGTE Scheme (source:www.greengas.net)

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A. *Social, economic and environmental impacts of LFG applications*

To apply the principles of sustainable development, and thus ensure the long time success of such a large project, the social, economic and environmental impacts are taken into account (see Fig. 2). Looking for only financial returns can lead to projects being accepted under an unrealistic premise.

1) *Social Impact*

Production of jobs. The landfill project will produce a number of jobs for the initial construction phase. More importantly, will produce a number of local jobs for the operation and maintenance of the landfill gas collection and energy production.

Production of Heat and Energy. There will be renewable energy produced which will be fed into the grid to offset energy created by other means. Since the typical combustion engine is about 35% efficient, the other 65% goes mostly to heat. Depending on the location of the landfill, this heat could be utilized as process heat for an industry, or alternatively for heating a building. It is also possible to pipe the landfill gas offsite if there is an industry in the vicinity that could utilize it [1].

Improved cleanliness due to a value in waste. The landfill gas will create an incentive to improve waste collection services, since all the wastes are now an income stream, rather than the previous model where they are only a cost by having to collect and dispose of them. This fundamental change in the value of garbage could create a stronger campaign for waste collection and proper disposal since people will be proud of the idea of generating power from their waste.

2) *Economic impact*

Waste as an income. This is surely the biggest driver behind the creation of the project. The power can be generated for as little at 1 cent per kWh and sold at a much higher rate, providing a direct income stream. Generally this income is set by having a contract with the local power provider, or else a large industry that would buy and use all the energy generated. There is also the potential of selling the waste heat from the process, although this will be small in comparison to the income from the electricity generation [1].

CDM credits. The global carbon market is active in various regions, and several LFG projects have shown that carbon credits can be a very significant income source for the project [2]. There are two streams of carbon reduction which need to be considered; the first is the reduction of greenhouse gases by converting the methane to carbon

dioxide. Since carbon dioxide is a much less harmful greenhouse gas, there is a huge reduction when compared to releasing methane into the atmosphere. This reduction can happen by simply capturing and flaring the LFG, or by burning the LFG in an energy generating process.

The second source of carbon credits is from the traditional energy that will be displaced by the energy that is created from the reciprocating engine. Some energy production in Colombia relies on non-renewables such as coal, natural gas and oil [3]. This means that any reduction in capacity required due to the generation of power from LFG will result in a significant reduction in greenhouse gases by displacing one of those fossil fuels [4].

3) *Environmental impact*

LFG as a GHG. As mentioned earlier in the report, the methane emission from landfills is a significant contributor to global warming. This is due to the vast quantities of methane released by the huge amount of waste produced all over the world, as well as the severity of methane, as a greenhouse gas. It is generally accepted in many countries that flaring landfill gas is the bare minimum acceptable in order to limit greenhouse gas emissions.

Reduction in GHG from other electricity generation sources. As mentioned above, the reduction of fossil fuels used in generating energy can be significant, due to the energy produced from the landfill.

Encouragement of proper Landfill practices. The landfill gas production will vary largely depending on the construction of the landfill and on the methods used in its further filling and maintaining. With the prioritization of the landfill gas collection as an income generator, landfill operators will have a large incentive to improve the methods that they are currently using for their landfill. They will also have more financial resources from the sale of the electricity to allow them to do this. Generally the improvement in the LFG collection pipes would go hand in hand with the improvement of the leachate collection pipes (which can also collect significant amounts of LFG). This improvement would result in very positive environmental impacts from the project [4].

B. *LFG generation*

Approximately 0.05 -0.40 m³ of LFG is being produced per kg of waste. The factors that influence the maximal potential volume of LFG are: (a) waste composition; (b) moisture content; (c) nutrient content; (d) bacterial content; (e) pH level; (f) temperature; (g) site design; and (h) operational features.

Municipal Solid Waste (MSW) is composed 75-80% (by mass) solid and 20-25% moisture. With the range of the

large population of LAC this adds up to a potential production of tens of millions of cubic meters of natural gas [5].

LFG composes of 50% methane – which in practical sense means that LFG has approximately half heating value than that of the natural gas. The remaining is composed of 49% CO2 and 1% other trace gases, H2S and mercaptans.

Fig. 2 LFG production pattern over time [5]

Figure 2 shows the phases of LFG production: (I) aerobic decomposition (produces CO₂, water and heat); (II) anoxic phase (produces acidic compounds, H₂ gas and CO₂); (III) unsteady methanogenic phase (declines CO₂ production due to change from aerobic to anaerobic decomposition); (IV) anaerobic phase (methane, water and heat are produced). The fourth phase is reached in 0.5-2 years and produces methane equivalent to 40-70% of total volume in (typical) steady conditions; and (V) decaying phase.

C. LFG collection system

A typical LFG collection system is comprised of: (a) LFG collection field (typical vertical wells or horizontal trenches for still active sites); (b) collection piping (laterals, subheaders, headers, etc.); (c) condensate drop-out and disposal system; (d) blower system and related appurtenances; and (e) LFG flare.

The collected LFG must be disposed in an environmentally sound manner; which can be an enclosed drum flare and/or utilization system. This pre-feasibility study is aiming the realization of the systems extension by a utilization system.

D. LFG processing: filtration

The landfill gas needs to be treated at least to some extent before utilizing it. Reducing moisture content, trace constituents and particulates will reduce corrosivity of the LFG, making the equipments work longer and reducing maintenance costs. Figure 3 depicts the basic steps of a

treatment procedure: (a) initial filtering; (b) compressing; (c) cooling; (d) second filtering; and (e) reheating.

Fig. 3 LFG Treatment, Filtering and Electricity Generation (source: Perry Equipment Corp.)

E. Electricity Generation technology

The chosen electricity generation technology for this project is the Reciprocating Internal Combustion Engine (RICE) since it is the most widely spread technology for LFGTE projects. Furthermore, a reciprocating engine is compact and easy to transport – which can be useful even during the operation of a particular LFG site-.

2. Case Study: LFG project in Colombia’s Praderas del Magdalena landfill site

The landfill Praderas del Magdalena is located in the city of Girardot (Cundinamarca). It has a total area of 84 has and disposes the solid waste of 1.750.000 habitants with an average waste production per capita of 0.65 kg/hab-day.

The Landfill is divided into cells that are filled as the solid waste is received. The bottom sealing systems comprise a 0.50 m thick clay layer, followed by a Bentofix layer and a geomembrane of 1.5 mm thick of high density polyethylene (HDPE). The bottom sealing avoid infiltrations mainly of leachate.

Once the height peak is reached a 60 cm thick layer of compacted soil is applied, followed by a 15 cm organic material layer in which grass-type species will be planted in order to mitigate landscape impacts. Leachate is drained to the pump systems. To capture the gases produced along the cells, a filter of HDPE perforated pipe of 6" placed vertically is installed. Currently the gases are collected and flared.

The landfill is located in tropical dry forest vegetation, with average temperatures of 27.7°C, ranging from 17°C to 40 °C.

The average annual precipitation is 95.08 mm. The average relative humidity is 65%, with monthly oscillations between 59% and 72%. Average composition of the solid waste of the landfill is: (a) organic, 50%; (b) paper, 4%; (c) cardboard, 5%; (d) plastic, 17%; (e) rubber, 1%; (f) textiles, 1%; (g) glass, 2%; (h) metal, 1%; and (i) other, 18%.

A. Pre-feasibility Assessment

The technical and financial assessment was performed with the software RETScreen, using site data, as well as previous studies on similar landfills in Colombia. Key input parameters for the study are presented in Table 1.

Table 1a. Key parameters for Praderas del Magdalena Landfill

Parameter	Value	Source / Reasoning
Years landfill is open	15	Provided by landfill.
Waste Disposal rate	93,750 t/yr	Based on capacity of 1.5M tones
Methane generation constant (k)	0.08	From SCS report [6] (6), based on highly decomposable waste in a wet environment
Methane by volume of LFG	50%	General assumption for typical landfill.
Methane generation factor (Lo)	100 m ³ /t	Using RETScreen and SCS reports. Considering that Colombian waste is highly organic.
Engine power capacity	1,000 kW	Adjusted to balance time-length with enough fuel with required investment.
Electricity export rate	43 \$/MWh	Based on commercial electricity rate in Colombia.
Total system cost	\$2,000,000	Figures from SCS reports based on South-America.

Table 1b. Key parameters for Praderas del Magdalena Landfill

Parameter	Value	Source / Reasoning
Annual maintenance cost	\$108,186	\$13 per MWh generated, from RETScreen.
Project life	18 years	Time to produce enough methane.
Debt ratio	70%	Typical for a large project with guaranteed income.
Debt interest term	7%	This is three percent higher than the interbank rate in Colombia.

Tax holiday	15 years	Renewable energy projects in Colombia.
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Figure 4 shows RETScreen estimation of methane production.

Fig. 4 RETScreen's landfill gas production vs. years

The blue curve shows the theoretical landfill gas production, while the red curve shows the effective (after collection losses) production and the green curve represents the landfill gas demand by the reciprocating engine.

B. Case study without incentives

Under no incentives, the financial outcome is an IRR on equity of 11.8% and an equity payback of 7.8 years. Figure 5 presents a summary of the financial outcome in RETScreen for this case.

To maximize the IRR outcome of this project, a small reciprocating engine was chosen to cover the largest period of time (the above mentioned 1 MW engine).

As appreciated in Fig. 5, this project is expected to earn \$357,846 from the sale of electricity with the assumption that this will be increased by 2% each year. This number is low compared to the amount of energy produced and it was estimated that a contract could be sought worth \$43 per MWh generated, based on previous projects by SCS engineers [4], [6], [7]. This is very low compared to the FIT programs offered in many OECD countries which are generally closer to \$150 per MWh. However this project is feasible as it stands, with a 10.8% after tax IRR, which is slightly higher than the 10% cash discount rate of the company. Figure 6 depicts the cumulative cash-flow as it crosses the break-even point after seven years, representing a 7.8 year equity payback. The NPV however is quite low at just \$38,633 for an investment of \$726,000.

Therefore, without incentives, the project produces a low IRR and an unattractive benefit Net Present Value (NPV).

Furthermore, a sensibility analysis was performed to find out which parameters are more important to the IRR. From this analysis, the feed in tariff (FIT) given as the electricity export rate, resulted the most relevant parameter in this project, as for example, a change of just 30% in the FIT can bring the IRR up to nearly 50%.

Project costs and savings/income summary			
Initial costs			
Engineering	8.3%	\$	200,000
Power system	82.6%	\$	2,000,000
Balance of system & misc.	9.1%	\$	220,000
Total initial costs	100.0%	\$	2,420,000
Annual costs and debt payments			
O&M		\$	108,186
Fuel cost - proposed case		\$	0
Debt payments - 18 yrs		\$	168,405
Total annual costs		\$	276,591
Annual savings and income			
Fuel cost - base case		\$	0
Electricity export income		\$	357,846
Total annual savings and income		\$	357,846
Financial viability			
Pre-tax IRR - equity	%		11.8%
Pre-tax IRR - assets	%		-2.3%
After-tax IRR - equity	%		10.8%
After-tax IRR - assets	%		-4.1%
Simple payback	yr		9.7
Equity payback	yr		7.8
Net Present Value (NPV)	\$		38,633
Annual life cycle savings	\$/yr		4,711
Benefit-Cost (B-C) ratio			1.05
Debt service coverage			1.50
Energy production cost	\$/MWh		42.50
GHG reduction cost	\$/tCO ₂		(4)

Fig. 5 RETScreen's financial summary for non-incentive case

Fig. 6 Cumulative cash flow without incentive

Additionally, considering that the landfill operators are already considering applying for carbon credits under the CDM program for the action of flaring the LFG, this was not considered to be an income stream. However, by using the methane in the reciprocating engine, there is an

additional reduction in greenhouse gases which could be added to the previous CDM program. This, however, is small, representing just 1,321 tonnes of CO₂ per year, compared with a 13,564 tonnes reduction from flaring the LFG rather than emitting the methane to the atmosphere.

Next, two variations in the case study will be presented: (a) using a FIT of 10 cents per kWh, which is similar to the current price for consumer electricity in Colombia; (b) using a CDM incentive of \$10 per tonne of CO₂.

C. Case study w/FIT 10 ¢/kWh

Figure 7 shows the cumulative cashflow for this scenario.

Fig. 7 Cumulative cash flow with FIT 10 ¢/kWh

It is shown that even a very modest FIT of 10 cents per kWh will have a huge impact on the project. The cash flow looks much more favorable with an equity payback after just 1 year and an after tax IRR on equity of over 84%. This makes the project an obvious success.

D. Case study with CDM 10\$/ton_CO₂

Figure 8 shows the cumulative cash flow for this scenario.

Fig. 8 Cumulative cash flow with FIT and CDM credits

This scenario improves the original outcome by making the simple payback to just under 3 years and the IRR to 30%. Nevertheless, the improvement is lower than obtained by increasing the FIT scheme.

3. Conclusion

The technical and economic pre-feasibility assessment of a landfill gas to electricity project in Colombia is presented. The study led to the following conclusions:

- Using a very conservative electricity export rate of \$43 per MWh the project produces an IRR over 10%.
- The most important factor to increase the IRR is the electricity export rate (Feed in tariff –FIT- rate).
- If the Colombian government were ever to offer a FIT from 8-10 cents per kWh, this project quickly becomes very favourable.
- Using CDM credits improves the viability of the project.

To improve the viability of the project, the following recommendations may be considered:

- Application for CDM credits.
- Consider using the waste heat of the reciprocating engine to provide a heating service (e.g., hot water service) since this will increase the overall efficiency and the project income.
- Measure the actual amount of LFG being generated and disposed through the current collector system and flares. Information can be obtained from local financial institutions to increase the level of confidence of the financial figures.

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