

Case Study - Landfill Power Generation

1. Introduction to Global Change

In the past decade, nations have begun to better understand the relationship between human activities and global climate change. One of the most important issues in this area is that the combustion of fossil fuels releases greenhouse gases into the atmosphere, which seems to be causing the global temperature to increase. This occurs because the additional carbon dioxide and other greenhouse gases that we emit into the atmosphere 'trap' the energy on the planet, causing it to get warmer. The warming effect has many side effects, such as the melting of polar ice caps, changes in weather patterns, and increases in sea levels. However, burning fossil fuels is not the only way in which greenhouse gases end up in the atmosphere.

The main greenhouse gases are carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O). Each of these gases has a different impact in the atmosphere – i.e. each has a different 'global warming potential'. If we use carbon dioxide as a baseline unit, one ton of methane released into the atmosphere is counted as 21 tons of carbon dioxide– so methane has a potential to warm 21 times higher than carbon dioxide.

All of this is especially important due to recent international conferences trying to find ways to decrease the amount of greenhouse gases being emitted. For example, the Kyoto Protocol meetings in 1997 attempted to have countries agree to reduce their emissions of greenhouse gases. Specifically, the United States agreed to reduce emissions from 1990 levels by 7 percent during the period 2008 to 2012.

Since the Kyoto meetings, there have been attempts to implement the Protocol (even though some countries like the U.S. have not ratified it yet). The meeting in The Hague, Netherlands in late 2000 inevitably failed because nations could not agree on how to consider the effects of greenhouse gas 'sinks' like forests, which remove carbon dioxide from the atmosphere, and thus lead to an overall lower net amount of emissions for a country. This failure happened because the original intent of these meetings was to seek ways to reduce emissions rather than finding alternatives (or "loopholes" as some would say), which would increase the benefits of sinks.

2. Methane Emissions

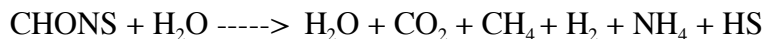
As stated above, burning fossil fuels is not the only source of greenhouse gases. The U.S. currently produces more than 20% of the world's greenhouse emissions, making it the largest emitter in the world. In 2002, the U.S. emitted about 7,644 million tons of CO₂ equivalents, of which 659 million were methane (CH₄) emissions. Landfills contributed approximately 32% of these methane emissions, or 3% of the total greenhouse gas emissions of the country.

As often the case in the United States, municipal solid waste (garbage), demolition waste, and some industrial waste are collected by trucks and brought to nearby landfills. In addition, depending on the cost of landfill disposal (also known as the 'tipping fee,' which may vary between landfills), the waste may be transported to a landfill where the total cost of disposal

(including trucking time) is lower. An important shift over the last two decades has been from generic 'dumping' of waste to well-engineered landfilling. The engineering of landfills enables more sophisticated processes like monitoring and pollution control.

A natural result of waste decaying in landfills is the production of byproduct gases. This occurs because of the anaerobic degradation of biodegradable organic wastes. One of the byproducts of this decay process is the production of methane (CH₄). While there are several phases with unique characteristics, the most important is the methane production phase, which is generally the steady state.

The methane production phase can be described by the following stabilization equation:



where the transition is driven by the presence of anaerobic bacteria. The average composition of this landfill gas is about 50% methane (CH₄), 45% carbon dioxide (CO₂), and 5% nitrogen (N₂) and other gases (4). However, the actual composition of gases depends upon the amount of organic matter feedstock, rain infiltration, the anaerobic environment, and the age of the landfill.

In 1996 the Environmental Protection Agency (EPA) established the New Source Performance Standards and Emission Guidelines for Municipal Solid Waste Landfills. Under these standards, large landfills (that have the potential to emit more than 50 Mg/year of non-methane volatile organic compounds) have to collect and combust the landfill gas. Traditionally these landfills have flared the gas to comply with the standards. A flare is a device that burns the landfill gas to reduce odors, safety concerns, and methane emissions. An alternative to flaring is using the landfill gas to generate electricity instead of just burning it off. Reciprocating internal combustion engines (IC engines) are the most widely used technology for generating electricity at landfills. More than two thirds of the operational landfills where electricity is generated use this type of equipment. Gas turbines and steam turbine can also be used.

However, generating electricity from landfill methane is not free (or even cheap). To start, a collection system must be built to guide the methane from underground (representing old layers of waste deposited in the landfill) to the internal combustion engines that will turn electric generators and create excess energy to sell back to the utility. This requires the construction of wells to go down into the landfill and a fairly extensive series of pipes to lead to the engines. Of course, the engine/generator units must be purchased as well, and they must be controlled and maintained.

3. A Specific Landfill's Parameters

Let's consider the West County landfill, located near St. Louis. This landfill produces an average of 1,155 mmcf of landfill gas over a 25 year period, starting in 1999. The capital cost of the collection and flaring system is \$2,088,000 and the annual operation and maintenance costs are \$89,000. These costs will also be present when electricity-generating equipment is installed.

Characteristics for the different types of electricity generating equipment can be seen in the table below.

Equipment	Average Nominal Capacity (kW)	Annual Electricity Generation Potential (kWh)	Heat Rate (BTU/kWh)	Typical Capital Costs (1999\$/unit)	Typical O&M Costs (1999\$/kWh)
IC Engine	3,000	23,652,000	9,492	\$2,757,000	\$0.0093
Gas Turbine	5,000	39,420,000	12,590	\$5,050,000	\$0.0059
Steam Turbine	3,000	23,652,000	13,000	\$1,155,000	\$0.0040

Currently the average wholesale price (the revenue the firm could expect to receive by selling electricity back to a utility) of electricity is 5 cents per kilowatt-hour. There is also a renewable energy production tax credit (that can only be used to offset profits, not losses) of 1.5 cents per kilowatt-hour of electricity produced from landfill gas.

However, there is a catch. While there are no environmental laws in restricting the production of greenhouse gases, the combustion of the methane will produce conventional pollutants, namely Sulfur dioxide, nitrogen oxide, carbon monoxide, and particulate matter. Releases of these pollutants are regulated by the state, and permits are required if emissions levels go over certain amounts. To calculate the social net present value we will compare the electricity generating equipment emissions to the flare emissions, since most landfill are already required to have a flare. Sulfur dioxide emissions can be ignored because they all have the same emissions. Emission factors can be seen in the table below.

Equipment	NOx (lb/10 ⁶ cf Methane)	CO (lb/106 cf Methane)	PM (lb/106 cf Methane)
Flare	40	750	17
IC Engine	250	470	48
Gas Turbine	87	230	22
Steam Turbine	33	5.7	8.2

4. Case Study Questions

- 1) Consider the base case of a landfill that is only venting (releasing) the gas into the air. Using the average landfill gas generation, the CO₂ and CH₄ uncontrolled and controlled emission factors presented below, calculate the global warming potential emission savings obtained by installing a flare. This emissions savings would also be obtained by installing electricity-generating equipment. Note that Collection Efficiency (η_{col}) is 85%

$$U_{\text{CO}_2} \text{ (lb/yr)} = 0.45 \times 0.112 \times \text{LFG}$$
$$U_{\text{CH}_4} \text{ (lb/yr)} = 0.55 \times 0.040851 \times \text{LFG}$$

$$C_{\text{CO}_2} \text{ (lb/yr)} = U_{\text{CO}_2} + (2.75 \times \eta_{\text{col}} \times U_{\text{CH}_4})$$

$$C_{\text{CH}_4} \text{ (lb/yr)} = (1 - \eta_{\text{col}}) \times U_{\text{CH}_4}$$

- 2) Using the attached spreadsheet and assuming a tax rate of 40% on income and a discount rate of 15% perform a 25 year cash-flow analysis for all the alternatives. Which alternative has the highest private net present value?
- 3) Using the emissions costs shown in the spreadsheet, calculate the social net present value. If you include this social net present value, which is the best alternative?
- 4) Perform the same cash flow analysis ignoring the \$0.015/kWh tax break. How would this change your decision? What would the optimum tax break for these projects be?
- 5) Using the optimum tax rate you calculated, perform a sensitivity analysis on the price of electricity, the tax rate, and the discount rate? How would this affect the results of your cash flow analysis?
- 6) Discuss some policy implications of your results.

5. References

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