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# Power Generation in Future by Using Landfill Gases

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***Abstract — this paper describes an approach to power generation in future by using landfill gases. The present day methods of power generation are not much efficient & it may not be sufficient or suitable to keep pace with ever increasing demand. The recent severe energy crisis has forced the world to rethink & develop the landfill gas type power generation which remained unthinkable for several years after its discovery. Generation of electricity by using landfill gases is unique and highly efficient with nearly zero pollution. Landfill gas utilization is a process of gathering, processing, and treating the methane gas emitted from decomposing garbage to produce electricity. In advanced countries this technique is already in use but in developing countries it's still under construction. The efficiency is also better than other non-conventional energy sources. These projects are popular because they control energy costs and reduce greenhouse gas emissions. These projects collect the methane gas and treat it, so it can be used for electricity or upgraded to pipeline-grade gas. These projects power homes, buildings, and vehicles.***

**Keywords-*landfill gas process, LFG collection system, flaring, LFG gas treatment, gas turbine, and micro turbine.***

## I. INTRODUCTION

Landfill gas (LFG) is generated through the degradation of municipal solid waste (MSW) by microorganisms. The quality (higher percent methane gases signify higher qualities) of the gas is highly dependent on the composition of the waste, presence of oxygen, temperature, physical geometry and time elapsed since waste disposal. Aerobic conditions, presence of oxygen, leads to predominately CO emissions. In anaerobic conditions, as is typical of landfills, methane and CO are produced in equal amounts. Methane (CH) is the important component of landfill gas as it has a calorific value of 33.95 MJ/Nm^3 which gives rise to energy generation benefits. The amount of methane that is produced varies significantly based on composition of the waste. Most of the methane produced in MSW landfills is derived from food waste, composite paper, and corrugated cardboard which comprise 19.4 ± 5.5%, 21.9 ± 5.2%, and 20.9 ± 7.1% respectively on average of MSW landfills in the United States. The rate of landfill gas production varies with the age of the landfill. Figure 1 shows the common phases that a section of a MSW landfill undergoes after placement towards equilibrium (typically, in a large landfill, different areas of the site will be at different stages simultaneously).

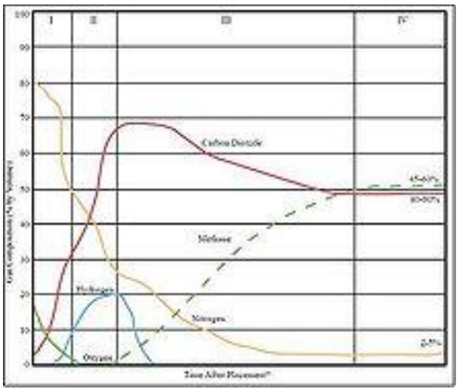


Figure 1: Percent composition of each major component of landfill gas with time.

The landfill gas production rate will reach a maximum at around 5 years and start to decline. Landfill gas follows first-order kinetic decay after decline begins with a k-value ranging 0.02 yr-1 for arid conditions and 0.065 yr-1 for wet conditions. Landfill Methane Outreach Program (LMOP) provides first order decay model to aid in the determination of landfill gas production named Land GEM (Landfill Gas Emissions Model). Typically, gas extraction rates from a municipal solid waste (MSW) landfill range from 25 to 10000 $m^3/h$ where Landfill sites typically range from 100,000 $m^3$ to 10 million $m^3$.MSW landfill gas typically has roughly 45 to 60% methane and 40 to 60% carbon dioxide. There are many other minor components that comprises roughly 1% which includes H2S,NOx,SO2,CO, non-methane volatile organic compounds (NMVOCs), polycyclic aromatic hydrocarbons (PAHs), polychlorinated dibenzodioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), etc. All of the aforementioned agents are harmful to human health at high doses.

## II. PROCESS

Landfill gas (LFG) is generated during the natural process of bacterial decomposition of organic material contained in municipal solid waste (MSW) landfills. A number of factors influence the quantity of gas that a MSW landfill generates and the components of that gas. These factors include, but are not limited to, the types and age of the waste buried in the landfill, the quantity and types of organic compounds in the waste, and the moisture content and temperature of the waste. Temperature and moisture levels are influenced by the surrounding climate.

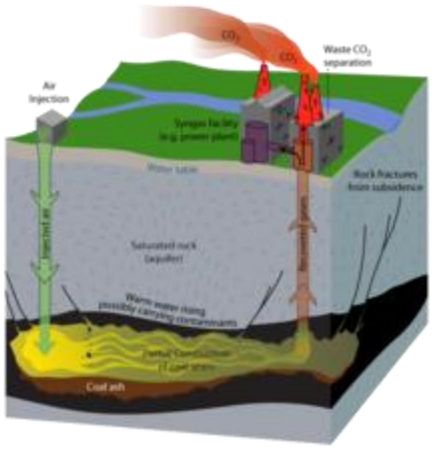

Fig2. Landfill gas process

By volume, LFG is about 50 percent methane and 50 percent carbon dioxide and water vapor. It also contains small amounts of nitrogen, oxygen, and hydrogen, less than 1 percent no methane organic compounds (NMOCs), and trace amounts of inorganic compounds. Some of these compounds have strong, pungent odors (for example, hydrogen sulfide). NMOCs consist of certain hazardous air pollutants (HAPs) and volatile organic compounds (VOCs), which can react with sunlight to form ground–level ozone (smog) if uncontrolled. Nearly 30 organic hazardous air pollutants have been identified in uncontrolled LFG, including benzene, toluene, ethyl benzene, and vinyl chloride. Exposure to these pollutants can lead to adverse health effects. Thermal treatment of NMOCs (including HAPs and VOCs) and methane through flaring or combustion in an engine, turbine, boiler, or other device greatly reduces the emission of these compounds.

## III. LFG collection systems

Landfill gas is gathered from landfills through extraction wells placed depending on the size of the landfill. Roughly one well per acre is typical. A typical gas extraction well is shown in figure 2.

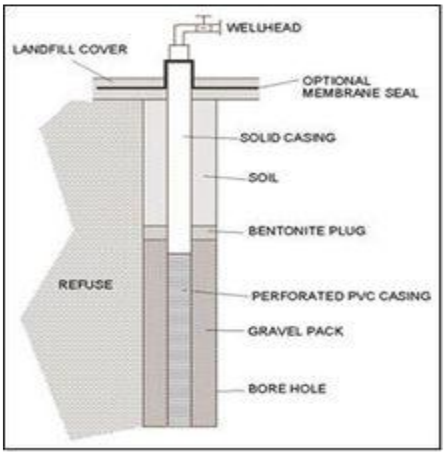


Figure 2: Gas extraction well

A layout of a landfill gas collection system is shown in figure 4. Landfill gas can also be extracted through horizontal trenches instead of vertical wells. Both systems are effective at collecting. Landfill gas is extracted and piped to a main collection header, where it is sent to be treated or flared. The main collection header can be connected to the leachate collection system, as shown in figure 3, to collect condensate forming in the pipes.

Figure 3: Gas Landfill gas blower.

A blower is needed to pull the gas from the collection wells to the collection header and further downstream. A 40-acre (160,000 $m^2$) landfill gas collection system with a flare designed for a 600 ft³/min extraction rate is estimated to cost $991,000 (approximately $24,000 per acre) with annual operation and maintenance costs of $166,000 per year at $2,250 per well, $4,500 per flare and $44,500 per year to operate the blower (2008).

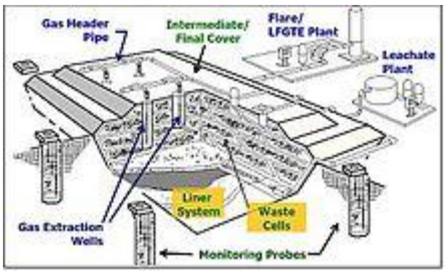

Figure 4: Landfill gas collection system.

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Figure 5: Open (left) and enclosed (right) flare.

One hundred m³/h is a practical threshold for flaring. Flares are useful in all landfill gas systems as they can help control excess gas extraction spikes and maintenance down periods. Flares can be either open or enclosed. Enclosed flares are typically more expensive, but they provide high combustion temperatures and specific residence times as well as limit noise and light pollution. Some US states require the use of enclosed flares over open flares. Higher combustion temperatures and residence times destroy unwanted constituents such as un-burnt hydrocarbons. General accepted values are an exhaust gas temperature of 1000°C with a retention time of **0.3 seconds** which is said to result in greater than 98% destruction **efficiency.**

## IV. Landfill gas treatment

Landfill gas must be treated to remove impurities, condensate, and particulates. The treatment system depends on the end use. Minimal treatment is needed for the direct use of gas in boiler, furnaces, or kilns. Using the gas in electricity generation typically requires more in-depth treatment. Treatment systems are divided into primary and secondary treatment processing. Primary processing systems remove moisture and particulates. Gas cooling and compression are common in primary processing. Secondary treatment systems employ multiple cleanup processes, physical and chemical, depending on the specifications of the end use. Two constituents that may need to be removed are siloxanes and sulfur compounds, which are damaging to equipment and significantly increase maintenance cost. Adsorption and absorption are the most common technologies used in secondary treatment processing.

## V. Electricity generation

If the landfill gas extraction rate is large enough, a gas turbine or internal combustion engine could be used to produce electricity to sell commercially or use on site.

Figure 6: IC engines.

More than 70 percent of all landfill electricity projects use internal combustion (IC) engines because of relatively low cost, high efficiency, and good size match with most landfills. IC engines (shown in figure 9) usually achieve an efficiency of 25 to 35 percent with landfill gas. IC engines have relatively high maintenance costs and air emissions when compared to gas turbines. Each IC engine requires 300 to 1100 cubic feet per minute (cfm) to operate. However, IC engines can be added or removed to follow gas trends. Each engine can achieve 800 kW to 3 MW, depending on the gas flow.

Figure 7: Gas turbines

Efficiencies drop when the turbine is operating at partial load. Gas turbines have relatively low maintenance costs and nitrogen oxide emissions when compared to IC engines. Gas turbines require high gas compression, which uses more electricity to compress, therefore reducing the efficiency. Gas turbines are also more resistant to corrosive damage than IC engines. Gas turbines need a minimum of 1,300 cfm and typically exceed 2,100 cfm and can generate 1 to 10 MW. A gas turbine (greater than 3 MW) can typically cost $1,400 per kW with annual operation and maintenance costs of $130 per kW. Estimates are in 2010 dollars.

Figure 8: Micro turbine.

Micro turbines can operate between 20 and 200 cfm and emit less nitrogen oxides than IC engines. Also, they can function with less methane content (as little as 35 percent). Micro turbines require extensive gas treatment and come in sizes of 30, 70, and 250 kW. A micro turbine (less than 1 MW) can typically cost $5,500 per kW with annual operation and maintenance costs of $380 per kW. Estimates are in 2010 dollars.

## VI. Fuel cell

Research has been performed indicating that molten carbonate fuel cells could be fueled by landfill gas. Molten carbonate fuel cells require less purity than typical fuel cells, but still require extensive treatment. The separation of acid gases (HCl, HF, and $SO_2$), VOC oxidation ($H_2S$ removal) and siloxane removal are required for molten carbonate fuel cells. Fuel cells are typically run on hydrogen and hydrogen can be produced from landfill gas. Hydrogen utilized in fuel cells have zero emissions, high efficiency, and low maintenance costs.

## VII. Pros

- Truly a renewable fuel
- Widely available and naturally distributed
- Generally low cost inputs
- Abundant supply
- Can be domestically produced for energy independence

- Low carbon, cleaner than fossil fuels
- Can convert waste into energy, helping to deal with waste

## VIII. Cons

- Energy intensive to produce. In some cases, with little or no net gain.
- Land utilization can be considerable. Can lead to deforestation.
- Requires water to grow
- Not totally clean when burned (NOx, soot, ash, CO, CO2)
- May compete directly with food production (e.g. corn, soy)
- Some fuels are seasonal
- Heavy feedstock require energy to transport.
- Overall process can be expensive
- Some methane and CO2 are emitted during production
- Not easily scalable

## XI. CONCLUSION

Improvement in landfills gases can make rapid commercialization possible. Hence it will be most significant in upcoming decade. The use of LFG for generating electricity is a promising approach both in terms of conserving energy and also for reducing air pollution. It was found that the amount of power produced in 2010 was 50.50 GWh It would be worth pointing out that both the landfill gas production and power produced reached a peak value in 2016. It can therefore be concluded that LFG is a good source for power generation and it can be used to displaced Fossil fuel.

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