Caribbean Renewable Energy Development Programme (CREDP)

CARICOM Secretariat

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Landfill Gas Technology Brief

Creating Value for Early Stage, High-risk Financing, RET Projects

MAJOR FEATURES AND BENEFITS

- Energy recovery from LFG is a mature technology with regard to the collection and utilization concerns.
- Landfill gas fuels engines, boilers, kilns, heaters and furnaces.
- It may be upgraded to natural gas quality.
- When the energy recovery is done for environmental reasons, plant need not always account for the cost of collection.
- LFG flares and energy recovery plant should be regularly maintained and correctly operated to minimize potentially harmful emissions.
- Different waste composition, landfill design and landfill operation will influence the extent and rate of the waste degradation in landfills

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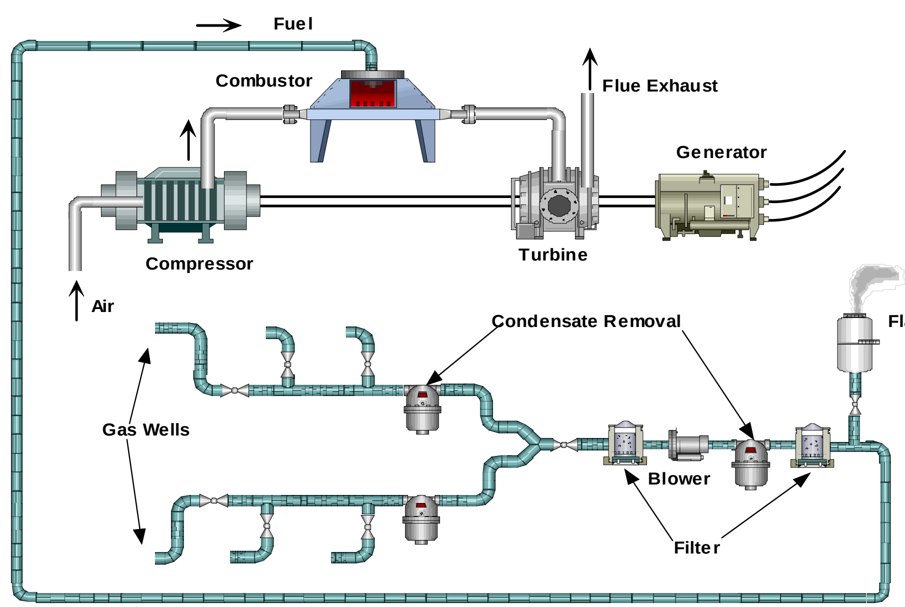

Figure 1: LFG Collection System and Power Plant

Landfill Gas Resource:

Landfill gas (LFG) is a mixture of mainly methane and carbon dioxide resulting from the biodegradation, in the absence of oxygen, of organic landfill waste. Landfills are a significant source of anthropogenic methane emissions.

- LFG is also potentially flammable or explosive in air, and its odour can cause a nuisance to people living or working near a site.
- Unprocessed LFG typically has a lower heating value (LHV) per unit volume approximately one-half that of natural gas.
- The LHV of typical unprocessed LFG (50%CH_4/ 50%CO_2) is roughly 16.8 MJ/m^3 (450 Btu/cf).
- A significant share of the LFG emissions may occur early in the life of a landfill; thus LFG extraction should start as soon as possible after waste is deposited. Early gas recovery should be considered in the design and operation of new landfills.

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Environmental Impact:

- Methane is the second most important greenhouse gas after carbon dioxide. Over a 100-year horizon, methane has a global warming potential 21 times greater than that of carbon dioxide by weight.
- Recovery and utilization of landfill gas (LFG) can contribute significantly to a reduction in greenhouse gas emissions and is considered to be one of the most cost-efficient ways to combat global warming.
- In addition to global environmental impact, uncontrolled escape of landfill methane can be a local safety hazard, with a risk of explosions and fires.
- Measurements of landfill methane fluxes fall in the range 0.0002 to >4,000 g/m^2.
- Wherever possible, LFG collection and, where economic, energy recovery should be integrated into the design and operation of new landfills

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Landfill Gas Characteristics:

Landfill gas (LFG) is generated in landfill sites by the anaerobic decomposition of organic waste, mainly from domestic refuse. The decomposition produces a mixture of gases which is colourless with an offensive odour due to traces or organosulphur compounds. The main gas components are typically methane and carbon dioxide, together with a number of trace constituents.

- The composition of the degraded waste determines the methane to carbon dioxide ratio of the formed LFG—the LFG potential stems from carbohydrates, proteins and fats in the food waste and paper waste fraction.
- The pH of the waste and leachate significantly influences the rate of gas production. The generation of methane in landfills is greatest when neutral pH conditions exist.
- LFG densities range about 1.2-1.4 kg/m^3—a LFG potential of less than 650 m^3/tonne would be expected for the case when the volatile substances (VS) of the Municipal Solid Waste (MSW) is about 50%, and less than 400 m^3/tonne would be expected for the case when the VS of the MSW is about 30%.

Landfill Gas Components	
Compound	**Value (v/v %)**
Methane (CH_4)	30 - 60
Carbon Dioxide (CO_2)	20 - 50
Oxygen (O_2)	< 2
Nitrogen (N_2)	< 10
Moisture (H_2O)	Saturated
Trace Compounds	*< ~4,000 ppm*

Table 1: Typical Landfill Gas Components

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Policy Issues:

- CREDP encourages regulators and legislators to recognize the economic, energy resource and global environmental benefits of energy recovery from LFG.
- Caribbean countries, recognizing the global environmental benefit of LFG energy recovery, should actively encourage its use. This may come about by some form of market support or demanding appropriate environmental protection measures, such as full-site LFG collection, that improves the economic prospects for using LFG.
- There are many potential pitfalls to successfully developing LFG plants. Owners of landfill gas collection and use schemes should employ contractors and staff with the necessary experience and skills to design, install, commission and operate schemes successfully.

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LFG Collection System:

LFG collection systems usually include the following components: a collection field; collection piping; a LFG extraction plant; LFG flare or treatment; process control systems

Vertical Wells	Horizontal Trenches
Improved localized extraction control	Allow for collection of LFG during active filling
Extraction at full depth of waste possible	Cost effective
Not as susceptible to moisture build-up	Less interference with after-use
Flexibility to add wells after site closure	Requires co-ordination with disposal operation
	Arrangement may be limited by site filling plan
	More common at large landfills

Table 2: Comparison of LFG Collection Systems

On-Site Header		Off-Site Header	
Ring Layout	Herringbone Layout	Ring Layout	Herringbone Layout
Settlement concerns	Cost effective	Maximizes condensate removal	Cost effective
Enhanced operational flexibility	Minimize condensate removal	Grading limitations may exist	Grading limitations may exist
	Settlement concerns	Off-site land requirements	Off-site land requirements
		Multiple liner/sidewall crossings	
		Operational flexibility	

Table 3: Comparison of LFG Collection Piping Arrangements

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TECHNOLOGY ISSUES:

- **Fuel injected lean-burn** engines (reciprocating) provide both greater engine power output and fewer NOx emissions than a comparable naturally aspirated engine.
- Exhaust gases from gas turbines may contain products of incomplete combustion. Reuse of the waste heat gases in Combined-Cycle plants improves plant air emissions.

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TECHNOLOGY OPTIONS:

1. **Low-Grade LFG:** Minimal levels of gas processing—used for space heating, process heating, boiler feed
2. **Medium-Grade LFG:** increased levels of processing to remove volatile organic compounds, sulphur and moisture—used in a wider variety of boilers and process heating applications; electricity generation with reciprocating engines and, simple and combined cycle gas turbines
3. **High-Grade LFG:** processing extends beyond that of medium-grade LFG and includes the separation of the gas into its two major components, methane and carbon dioxide—uses include: pipeline quality gas; electrical generation; sale of CO_2; methanol production; fuel cells; vehicle fuel

Technology	Preferred plant size (MW)	Fuel grade	LFG heating value (MJ/m3)	Min.CH4 content (% v/v)	Gross plant efficiency (%)	Net plant efficiency (%)*
Combined cycle	>10	Medium	13.4 (LHV)	40	~37	~35
LFG-fired boiler with steam turbine	10 to 50	Low Medium	7.5 (HHV)	20	~33	~30
Gas turbines	3 to 18	Medium	13.4 (LHV)	40	~27	~21
Reciprocating gas Engines	0.5 to 12	Medium	15 (LHV)	45	~35	~30

Table 4: Landfill Gas Technology Application Guide

Economics:

- Capital costs vary widely and depends on site, collection system employed, LFG processing and grade, type of generation (reciprocating engines, gas turbines, combined-cycle, steam turbines.
- O&M also varies with technology employed and typically is in the range US$0.015/kWh to US$0.042/kWh for reciprocating gas engines. Technical solutions for minimizing the aggressive nature of LFG in engines influence the operating costs of engines in a power plant project.
- The economics of LFG use are directly tied to the price of fossil fuel, unless cost or price incentives are in place.