Solid Waste Landfills as a Source of Green Energy

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ABSTRACT: As the consumer consumption and the urbanization rises more solid waste is created. Solid waste generation has increased over the last century to more than 3 million tons per day, with the figure projected to double by 2025. In contrast, waste to energy (WtE) is a very appealing choice for solid waste removal with energy recovery. Due to many benefits associated with landfill gas, it is one of the most important fields of clean energy. Using landfill gas as a green energy source helps to satisfy energy demands while also addressing environmental and health issues. Present study has discussed about the production of green energy from solid waste landfills, landfill gas energy collection and processing system, its different projects and the issues related with solid. Despite the fact that landfill gas energy is profitable in itself there is still space for growth. The future must prioritize the development of this clean energy supply, both in terms of technical advancement and landfill programmes. EFW (energy from waste) facilities would be able to do more than they were planned to do as a result of these continuing developments. This potential commitment to recycling would minimize the amount of manufactured waste that could be disposed of in landfills in a traditional urban environment, bringing us closer to the elusive "zero waste" target.

KEYWORDS: Gases, Greenhouse, Landfills, Renewable, Waste.

INTRODUCTION

Landfills, which have long been vilified by environmentalists as sources of air and water emissions, have recently benefited from a slew of subsidies tied to alternative energies and clean energy. Landfills that capture and use landfill gas for heat or power storage are also eligible for federal and state tax exemptions and payments. Three issues have been addressed in relation to these benefits. For starters, others have expressed worries about the health effects of landfill gas exhaust. Second, others have cited the significant environmental and public health harm created by landfills, raising concerns about the long-term viability of landfills and therefore landfill gas. Eventually, others argue that these subsidies are yet another stepping stone for landfilling over reuse[1].

Landfills are the single greatest source of methane generated by humans, accounting for almost one-third of all anthropogenic carbon emissions. LFG (Landfill Gases) can also contain ozone-forming volatile organic compounds (VOCs) and poisonous or carcinogenic harmful air contaminants in small but important concentrations (HAPs). Any trace compounds in LFG often lead to foul odors, which may be a nuisance for residents living near landfills[2]. There are two ways to bury trash: tossing it in an open pit in the field with assorted creatures (rats, rodents, birds) swarming around it, or burying it in a sealed container. Landfill is a specially engineered structure constructed into or on top of the ground that isolates garbage from its surroundings (groundwater, air, rain). A bottom liner and regular soil coverings are used to ensure this separation. The garbage is isolated from the atmosphere in a sanitary landfill by a clay liner. A synthetic (plastic) lining removes the refuse from the atmosphere in a municipal’s solid wastes (MSW) landfills. The aim of a landfill is to bury garbage in a manner that separates it from groundwater, keeps it dry, and prevents it from coming into contact with air. In these conditions, trash does not decompose easily[3].

Landfills are still and will continue to be a popular means of landfill disposal, but once they are well handled, they pose significant environmental and health hazards. In a hazardous waste landfill, the decomposition of organic materials produces some gases. The quality, quantity, and production speeds of the gases are influenced by a variety of factors, including the volume, density, and composition of the waste, the landfill's location characteristics, the depth of the landfill, the moisture content of the refuse, the temperature, and the amount of oxygen available. Landfill gas is produced by three processes: microbial decomposition, vaporization, and chemical processes. A standard landfill gas composition is shown in Table 1. It is clear that methane is the most abundant gas released from the landfill, followed by carbon dioxide[4].

Table 1: Typical Composition of a Landfill Gas[4].

Component	Concentration range (%)	
	Lower limit	Upper limit
Methane	40	70
Carbon dioxide	30	60
Carbon monoxide	0	3
Oxygen	0	5
Nitrogen	0	3
Hydrogen	0	5
Hydrogen sulfide	0	2
Trace compounds	0	1

1. *Health Impacts:*

Landfill gases typically follow the shortest and most convenient route to the surface. On rare occasions, the presence of fissures in or near the filled soil, presumably combined with the presence of a surface barrier, may allow the evolved gases to migrate long distances horizontally. Since these gases made their way into basements of houses and homes, asphyxiation, toxicity, and bursts of air methane mixtures have contributed in injuries and deaths under certain cases. Although landfill gas, which is rich in methane, has the capacity that provide energy recovery, it has long been considered a danger due to its reactivity and ability to form volatile mixtures with air at concentration ranging from 5 to 15% by volume. Methane is transported away from landfill borders by two mechanisms: diffusion and advection. The key factors that affect diffusion and advection rates are the main attributes and generation rates of landfill gas, refuse permeation, internal dump temperature, moisture levels, surrounding soil formation, and fluctuations in barometric pressure [4].

2. *Environmental Impact:*

The greenhouse effect is caused by methane and carbon dioxide pollution from landfills. Methane has recently been recognized as a contributor to global warming because it is more effective at removing ultraviolet radiation and survives longer in the atmosphere compared to other organisms with a greater affinity for hydroxyl ions, the oxidizing agent for methane. On average, methane emissions in the atmosphere are that at a rate of 1 to 2 percent each year. Methane is believed to be accountable for about 18 percent of climate change. As a result of continued population development and urbanization, solid waste landfills will become a important funder to atmospheres carbon dioxide except retrieval management schemes are applied. The main source of odors is the presence of tiny amounts of odorous components in waste gas released into the atmosphere. While certain odorous trace compounds are poisonous, they have generally been treated as an annoyance rather than a direct health threat. The degree to which odors travel outside landfill borders is largely determined by environmental factors such as wind, temperature, pressure, and humidity [4].

3. *Methane Emission from Landfills:*

Landfills for municipal solid waste (MSW) come at number third being the largest origin of human's related methane pollution, responsible for about 15.1 percent of total emissions in 2018. In 2018, greenhouse gases from MSW landfills is roughly equal to GHG emission from more than 20.6 million motor cars powered for a year, or Carbon dioxide emissions from additionally 11 million households' electricity usage for years. Methane pollution from MSW landfills, on the other hand, reflects a missed chance to harness and utilize a major vitality reserve. The minute MSW is dumped in a landfills, it goes through an aerobical (oxygen) decay cycle, which produces very little methane. After that, anaerobic conditions are formed in less than a year, and methane generating microbes initiate to break down the wastes and produce methanes. Figure 1 illustrates alternative means of methane emissions.

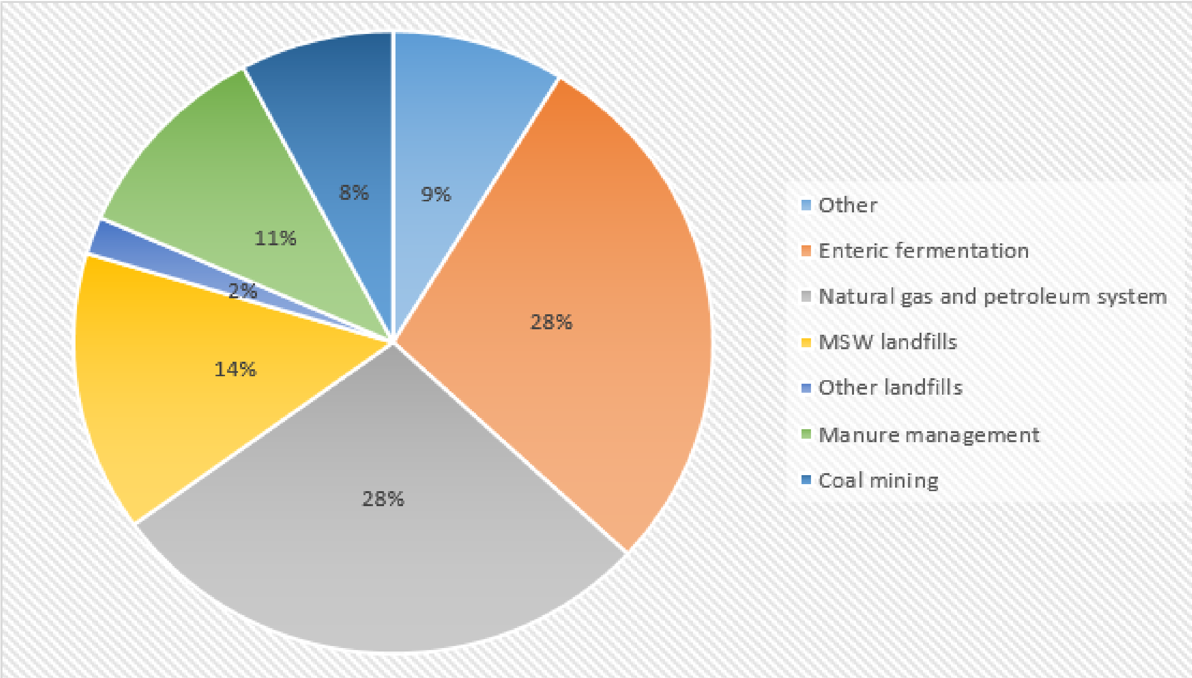

Figure. 1: Various Sources of Methane Emission[5].

A collection of bores and a vacuum device are used to remove landfill gas (Figure 2). The extracted gas is directed to a dominant location where it could be stored and handled, based on the gases eventual application. From here, the gases is flared or put to good use in an LFG energy project. A landfill for urban solid waste (MSW) is a dedicated zone of lands or landfill which accepts recyclable wastes and possibly additional non-hazardous waste. LFG group normally starts after a share of landfills, recognized as a "cell," is shut to garbage assignment. Vertical wells or horizontal pits are two different ways to collect LFG.

The utmost popular technique is to drill perpendicular bores in to the contaminated media and attach them to adjacent pipe that transfers the gases to a storage heading utilizing a blower or vacuity stimulation systems. A basic landfill gas manufacturing skid comprises a knock-out barrel to extract dampness, blower with a vacuity to “yank” the gases and force to disperse it, and a flash. Device operatives keep an eye on the parameters in order to improve system efficiency. Before being used in an energy recovery system, surplus dampness, particulate, and other filths are usually removed from LFG. The form and extent of treatment are dictated by the characteristics of the landfill gas at each site, as well as the type of energy storage system used. Extra LFG cleaning and compression is needed for certain applications, such as pipelines insertion and vehicle fuel schemes.

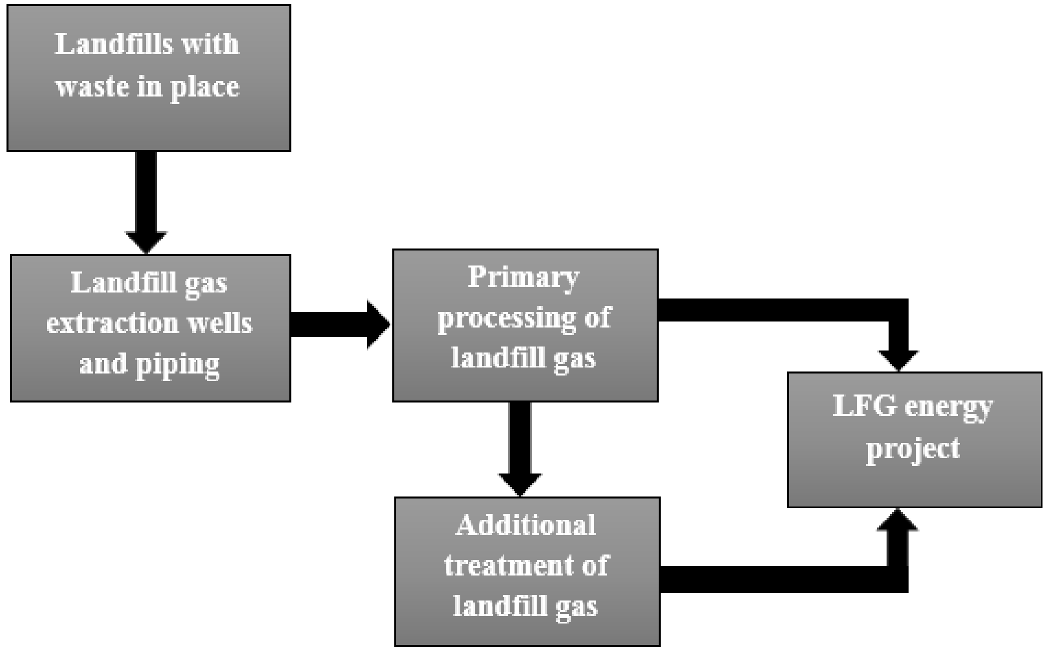

Figure 2: Flowchart of A Basic LFG Assortment and Dispensation Arrangement[5]**.**

LANDFILL GAS ENERGY PROJECT TYPE

LFG's can be transformed into power in a diversity of ways. Landfill gases vitality schemes fall into three different classes: electrical generations, undeviating utilization of intermediate btu gases, and clean natural gases. An LFG energy project's aim is to turn landfill gas into a useful source of energy. Hundreds of landfill gas energy programmes are currently in operation in the United States, including public and private agencies, small and large landfills, and numerous technologies.

i) *Electricity Generation:*

In the United States, about 70% of proposed LFG energy ventures produce energy. A diversity of systems, such as responding interior combustions, batteries, micro-turbine, and fuels batteries, could be utilized to produce power for on sites utilization as well as sales to the grid. The responding engines is by far the maximum usually utilized adaptation expertise for landfill gas power generation due to its cost effectiveness, high effectiveness, and size series that balance the gases production of numerous landfill. Micro-turbine are primarily utilized for smaller LFG volumes and advanced applications, while gases turbine are commonly utilized in bigger LFG vitality plans. Combined heat and power (CHP) systems uses landfill gas to produce both power and thermal power, which is typically delivered as steam or hot water. Multiple cogeneration schemes focused on generators or turbines have been implemented in engineering, private industry, and academia. This proposal would be very promising due to the advantages of gathering thermal power in adding to electricity generation.

ii) *Undeviating utilization of Medium-Btu Gases:*

Approximately 17% of currently running programmes utilize LFG directly to counterbalance the uses of other power (such as natural gases, coals, or fuel oils). Landfill gases may be utilized straight in a refrigerator, dryers, greenhouses, or other heat source. In these programmes, the gases is delivered straight to a local user and used as a supplemental fuel in combustion equipment. Leachate vaporization utilizing LFG is a viable choice for garbage dumps where leachate removal at a water resources treatment convenience is either inaccessible or prohibitively exclusive. Automobile manufacturing, chemical production, foodservice distribution, pharmaceutical drugs, concrete and asphalt making, left-over water management, electronic goods and supplies, papers and steel's manufacturing, and reformatories and hospital are only a few industries that use landfill gases.

iii) *Renewable Natural Gas:*

By the methane content while decreasing CO2, nitrogen, and oxygen levels, LFG can be converted to renewable natural gases (RNG), a great Btu gases, via management procedures. In lieu of fossil natural gas, RNG can be used as pipelines eminence shale, compressed natural gas (CNG), or liquid petroleum gases. RNG is generated by around 13% of the existing LFG energy ventures. Thermal applications, power generation, and automotive fuel are also possible applications for RNG. RNG may be used on-site or inserted into natural gases diffusion or delivery pipeline to be delivered to another site[5].

LANDFILL GAS TREATMENT/USE

Anaerobic therapy is used in the vast majority of landfills. As compared to aerobic therapy, this results in high level of methane in the LFG, so new landfill therapies are ineffective and aerobic landfills are not applicable/feasible. Presently there are four types of treatments: adsorption, absorption, cryogenic therapies and permeation. After treatment, landfill gas is used for power production, as low-cost fuels for stoves and heaters, and as pipeline-grade natural gases. Since anaerobic biodegradation intermediates play a large role in the development of NMOCs (Non-Methane Organic Compounds), aerobic conditions can reduce NMOC levels. A variety of factors affect LFG processing, including waste volumes, carbon-based consistency, dampness content, and oldness. Moisture improves LFG efficiency, but too much can clog escape routes, reducing sample quality.

To regulate amount of LFG emitted, a number of mathematical models based on zero, first, and second order kinetics have been created. Because of their lack of accuracy, zero order models are rarely used. Conform to scientific evidence, the mistakes in model parameters create excessive complexity to be appropriate for estimation, second order models aren't utilized. The most commonly used models are first order, but they do not account for all of the complex processes that occur during landfill depletion. The EPA (Environmental Protection Energy) model and the IPCC (Intergovernmental panel for climate change) model are the two most widely used versions. The IPCC model can be helpful, but its parameters must be carefully chosen.

Pretreatment is relatively simple in the case of LFG power generation. Condensate reduction and filtration are the only therapies available. If there are corroding or hazardous trace elements, more thorough cleaning could be needed. The best use of LFG was discovered to be mixed temperature and energy generation with a heat engines. Until it becomes uneconomical, the LFG is utilized in heat engines. It has been shown that it offered the largest reduction in GHG emissions as compared to other options. The burning of flammable gases is known as flaring (LFG). Flaring burns the LFG's methane to produce carbon dioxide. Flaring must be performed at a temperature of 1200°C or above. Lesser temperature increases the risk of harmful complexes such as dioxins forming.

CO2 adsorbs selectively over CH4 in both carbon-based (activated carbon) and minerals (silica gel, alumina, and zeolite). CO2 and CH4 are nearly similar in proportion in anaerobic LFG. As a result, large concentrations of CH4 can be generated and used for a variety of purposes. CO2 can be removed from LFG using absorption. Commercial natural gas may be produced after pretreatment to remove harmful trace components. Permeation is used to strip CO2 from CH4 in the final stages of LFG therapy. Permeation is the isolation of gaseous components via a membrane. To cool down, the LFG must be compressed and isenthalpically stretched regularly in a cryogenic treatment, which requires a lot of energy. Methanol is pumped into the steam, allowing it to condense and impurities are separated from the condensate[6].

LITERATURE REVIEW

Barun Kumar Das et al. investigated the generations, features, administration of communal solid leftover in Rajshahi City and power production by the techniques of landfilling. In Bangladesh, bad MSW (Municipal Solid Waste) administration is becoming a rising matter in most cities and small towns. Bangladesh's Rajshahi city's waste disposal quality is low and the bulk of wastes is discarded in the exposed area. Landfill gases are produced unsurprisingly in landfills as a consequence of the bacterial activity of organic waste. Methane gas, which has a 21-fold potential relative to CO2, is a major provider of greenhouse gases (GHG) pollution and ozone layer degradation when released from uncontrolled MSW landfills. On the other hand, if MSW is properly handled, it can be a viable foundation of electricity production in region. According to the author's report, landfills produce 7549 tons of CH4 per year. The landfill gas energy capacity is projected to be around 5.3MWe [7].

Mukherjee. C et al. explained regional differences in technological implementation, special constraints of every technologies, widely utilized choice backing mechanisms, and large operator were outlined in the latest US (United States) urban waste management patterns. Just 13% of MSW in the United States is used for energy recovery, with the remaining 53% going to landfills. In the northeast (mostly in New York) and Florida, there are 86 WTE (Trash to Power generation) amenities that primarily utilize mass scorch and refuse-derived fuels technology and are located in compactly inhabited areas. For the rest of the world, the majority of MSW is disposed of in landfill fitted with gases retrieval, which is then distributed to home or utilized to generate power. The mixed existence of MSW, biomass gasification, and airs quality restrictions are the major pitfalls. The academic group and large operators in the United States use three principal design and decision support methods: techno-economic research, product lifecycle sustainability evaluation, and supply chain modelling. Since suitable land for new landfills is scarce in coastal and urban areas, the author hypothesized that acceptance of thermal WTE technologies will continue to expand, although gradually.

Charles J.R. Coccia et al. provided a study review concentrated on classification of the thermal resources of landfill municipal solid waste. Heat exchange effects on methane production rates, landfill lining hydraulic capability, and leachate collection system clogging are also considered in the report. For various landfill operational and closure scenarios, different conformations for geothermal heat exchanger in landfill are suggested based on landfills design specifications and different methods for GSHP (Ground Source Heat Pump) installation used in practice. Surface heat pump requires minimum additional drive than orthodox heating and air conditioning for households as they share warmth with the sub - surface rock and soil, which has a stable temperatures matched to the outer air. Municipal solid waste (MSW) landfill might be possible sources of heat for GSHPs because of the high temperature related with the enduring, exothermic disintegration of carbon-based resources within the leftovers. Geothermal heat exchanges in MSW landfill is projected to provides an open and long-term thermal vitality source, according to an economic analysis [8].

M. Jibran S. Zuberi explained the effect of greenhouse lessening by improving energy from left-over landfill in Pakistan. The study calculates methane emissions using the Pakistan Environmental Protection Agency's most recent data and the First Order Decay model applied to landfill sites in Pakistan. Landfilling's must be highlighted third in the waste supervision process because of the uppermost greenhouse releases as comparison to other leftover administration schemes. However, landfilling is much popular everywhere in the realm. Pakistan is in the midst of a serious economic crisis as the disparity between supply and demand for energy continues to expand. Because of frozen capacity, demand has been rising exponentially while supply has remained constant in recent years. Currently, there is a 6000 MW electricity deficit. In Pakistan, currently operating landfills can only contribute 0.1 percent to the overall deficit, which is negligible. According to the findings, Pakistani landfills emit approximately 14.18 Gg of methane per year. Combustion of methane in the form of biogas composed from landfill sites as part of a waste administration will decrease the greenhouse effects by up to 88 percent[9].

J. S. Wu et al. explained the opportunities and challenges in transforming the waste management operations to green energy. The landfill industry is facing new obstacles such as increased trouble in arrangement and authorizing landfills, increasing oil prices, and looming declines in greenhouse gas (GHG) releases. A plan for resolving these barriers and transforming landfill operations to green energy projects is presented. While both landfill and solar energy are inexpensive, bioenergy requires careful preparation of production capability and also tax credits and incentives. Without requiring direct land-use reform, returns on investment will be used to finance renewable solid wastes tipping charges, cover backing for post-closure expenditures, and decrease GHG releases. Energy policies for carbon allowances, as well as tax incentives, are important for the waste management industry to continue to fund renewable energy initiatives[10].

DISCUSSION

One of the most reliable and operative inexhaustible energy solutions for lowering methane and CO2 emissions is production of energy from waste. Waste to energy (WtE) is very attractive option for removal solid waste with energy retrieval. Landfill gas (LFG) can be used to extract electricity and mitigate methane emissions, which benefits both local residents and the atmosphere. People, nonprofit agencies, city municipalities, and industry cooperate on LFG utilization programmes to prepare for a healthy environment. Many countries around the world use solid waste as a source of energy. The WTE facilities, on the other hand, must adhere to strict guidelines in order to minimize environmental impact and adhere to the precautionary principle. For the valorization of biogas, the use of landfill disposal techniques should be encouraged. Governments all over the world are implementing improved MSW management policies, including handling residual waste with different WtE technologies as a viable alternative for MSW disposal and energy production. Waste-to-energy and solid waste valorization are two emerging topics that need to be explored further.

CONCLUSION

Landfills are considered as one of the major cause of greenhouse gas production. The adverse effects on environment can be reduced by recovering the biogas from the landfill. The existing study has explained about the negative impacts of the solid waste on the environment and the presented the most effective approach in the solid waste management as well as recovering the energy from the waste. It can be concluded from the above study that the landfill gas recycling schemes is a cost-effective way to reduce total greenhouse gas emission from landfill. Now it a very well-known fact that from its beginnings in waste reduction, the industry has come a long way. New energy-from-waste (EfW) or waste-to-energy (WtE) plants in the world wide have converted about 13% of the nation's waste at 77 operating sites, treating nearly 30 million tons of solid waste with a generation capacity of over 2,500 megawatts. The EfW industry will continue to advance through several trends like EfW facility expansions, Innovations in combustion and boiler design, and Enhancements in metal recovery systems. Additionally, government, in partnership with NGOs and private organizations, should expand an existing landfill site to collect LFG and use it to produce electricity. In future this will also help to ease the global energy shortage by reducing the reliance on fossil-fuel-based power plants.

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