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Kirkuk municipal waste to electrical energy

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ABSTRACT

Municipal solid waste (MSW) in Kirkuk city in the north of Iraq poses a serious problem having adverse effects on environment and health of the citizens. Both quantity and volume of MSW have continued to increase with the rapid growth of city population. The population of Kirkuk city, on average, has increased by 3% per annum over the past two decades. The population of Kirkuk city is predicted to increase from 1,050,000 in 2008 to 1,445,556 in 2020. The generation of waste is expected to grow in the future with the rise of city population. The daily waste generation is projected to 1000 tone in 2011. By 2021, the daily waste will amount to 1200 tones. The waste to electricity suggested project in Kirkuk and the choice of electricity generation technology, would lead to improved electricity supply and efficient waste management in the city, and is expected to contribute to technology transfer in this new area. Landfill or Biodigestor technology seems to be the most preferred technology for Kirkuk city to start with. Potential power for a plant sourcing from the MSW mass to be fed into the national grid was estimated at 5 MW.

Equivalent CO_2 emission in the absence of waste to electrical energy project and the emission by proposed project were calculated. The reduction in CO_2 emission is 87.4%.

1. Introduction

Proper management of solid waste is critical to the health and well-being of urban residents. Landfilling is a threat to all basic needs for humans, e.g. clean air to breathe, clean water to drink and non-toxic and healthy food to eat as well as shelter for those living close to the landfill. For instance, Landfilling pollutes the air with methane and CO_2 and other gases depending on the chemical and biological activities of the material in the landfill. Leachate and storm water from the landfill contaminate ground and surface waters, transporting the pollutants into the food chain. Waste dumping can also affect the shelter of people living near the landfill. For instance, avalanches and waste slides can occur during rainy periods if the waste is not properly compacted [1,2].

The term MSW describes the stream of solid waste (“trash” or “garbage”) generated by households and apartments, commercial establishments, industries and institutions. MSW consists of everyday items such as product packaging, grass clippings, furniture, clothing, bottles, food scraps, newspapers, appliances, paint and batteries. It does not include medical, commercial and industrial hazardous or radioactive wastes, which must be treated separately [3].

Daily, there are millions of tons of municipal solid waste deposited into thousands of landfills and other dumping sites, worldwide. The decomposition of organic material in these places—typically food and paper products—results in the production of methane and other greenhouse gases. Landfill gas (LFG) typically is made up of 50% methane (CH_4) and 50% carbon dioxide (CO_2), with small amounts of non-methane organic compounds often present. Methane is the second largest of the five categories of anthropogenic, or human-related, greenhouse gas emissions, subsequent only to carbon dioxide emanating from fossil fuels, comprising about 9% of all anthropogenic greenhouse gas emissions. Methane concentrations in the atmosphere have more than doubled over the last two centuries, particularly since the advent of the industrial revolution, indicating an increase in methane emissions from anthropogenic sources. Various factors determine the level of methane emissions in each country or region. Waste management practices, the types and sizes of agricultural and manufacturing industries, the types of energy sources and the ways they are used, as well as the climate of a region, all affect methane emissions. About 20% of the total methane emissions from global anthropogenic sources are from landfills.

Methane is a far more puissant greenhouse gas than carbon dioxide. Due to methane’s ability to trap heat, it warms the earth 23 times more than carbon dioxide and has an atmospheric lifespan of about 12 years, one much shorter than that of other greenhouse gases. The level of methane currently in the atmosphere can drastically be reduced or eliminated within a short period of time, if proper action is taken. Short lifespan, along with its high heat-trapping potential, make methane elimination from the atmosphere a particularly effective method of combating global

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Table 1
Comparison of properties for landfill gas, biogas and natural gas.

Property	Unit	Landfill gas	Biogas	Natural gas
Calorific value, lower	MJ/Nm^3	16	23	40
	$kW\ h/Nm^3$	4.4	6.5	11
	MJ/kg	12.3	20.2	48
Density	kg/Nm^3	1.3	1.2	0.83
Wobbe index, upper	MJ/Nm^3	18	27	55
Methane number		>130	>135	72
Methane	vol-%	45	65	89
Methane, range	vol-%	35–65	60–70	–
Long-chain hydrocarbons	vol-%	0	0	10
Hydrogen	vol-%	0–3	0	0
Carbon monoxide	vol-%	0	0	0
Carbon dioxide	vol-%	40	33	0.9
Carbon dioxide, range	vol-%	15–50	30–40	–
Nitrogen	vol-%	15	0.2	0.3
Nitrogen, range	vol-%	5–40	–	–
Oxygen	vol-%	1	0	0
Oxygen, range	vol-%	0–5	–	–
Hydrogen sulphide	ppm	<100	<500	3
Hydrogen sulphide, range	ppm	0–100	0–4000	1–8
Ammonia	ppm	5	100	0
Total chlorine as Cl^-	mg/Nm^3	20–200	0–5	0

warming. Many experts contend that LFG recovery projects that use methane for fuel have become effective tools for combating the effects of global climate change. LFG recovery projects have existed since the late 1970s [4–6].

2. Literature review

2.1. The processes of methane capture and use

The method by which methane is recovered from landfills involves the use of a series of wells and vacuums that collect the gas. The methane is then sent to a processing and treatment facility, which typically operates on-site at the landfill but can be located between the landfill and the end user, at a separate location, or at the site of the end-user. Several functions exist for gas that has been collected, processed and treated. The most common use is by utility companies that require natural gas or some other fuel to produce electricity through the operation of engines, turbines or microturbines. Since LFG is emitted during the bacterial decomposition of organic material found in landfills, there are various factors that affect the quality of the gas that is produced. The types of waste stored in a landfill can affect the rate of decomposition and, therefore, the potency of the emitted gas. The age of the waste contributes to the quality of gas that is emitted from the landfill. Therefore, older landfills that lack collection systems are prime candidates for LFG projects. The surrounding climate—moisture levels and air temperature—can affect the quality of the gas. Finally, the amount of methane created in these landfills depends on the quantity of waste in the landfill and the moisture content of the waste. (Methane is generated only in anaerobic conditions.) Also, methane can be produced in landfills for years after the site is closed, due to continued decay of waste. These factors must be taken into consideration when calculating the potential output of a given landfill [2,7,8].

2.2. General comparison of natural gas, biogas and landfill gas

The composition of biogas depends on a number of factors such as the process design and the nature of the substrate that is digested. A special feature of gas produced at landfills is that it includes nitrogen. Table 1 below lists the typical properties of biogas from landfills, digesters and a comparison with average values for natural gas [9].

Table 2
Energy required in the production of various materials [19].

Materials	Energy required (MJ/kg)	
	New	Recycled
Glass	25	25
Steel	50	26
Aluminum	250	8
Copper	60	7
Paper	24	15

Table 3
Kirkuk annual population growth 2008–2020 [10].

Year	Population	Waste quantity (t/y)
2008	1,050,000	306,600
2009	1,078,350	314,878
2010	1,107,465	323,379
2011	1,137,367	332,111
2012	1,168,076	341,078
2013	1,199,614	350,287
2014	1,232,004	359,745
2015	1,265,268	369,458
2016	1,299,430	379,433
2017	1,334,515	389,678
2018	1,370,547	400,199
2019	1,407,552	411,005
2020	1,445,556	422,102

2.3. Recycling

One of the best ways to handle solid waste is to reuse as much of it as possible. Recycling is the process by which the materials in consumer goods are returned to the production facility and remade into new products. There are two basic types of recycling: post-consumer and pre-consumer.

Recycling has several environmental benefits. It removes some solid waste materials from the waste stream and prevents them from ending up in a landfill or being incinerated. It also conserves precious natural resources which would be needed to produce virgin materials. The energy saved through recycling is considerable. In Brazil, the selective collection of solid waste was implemented in Campinas, in 1991. The analysis showed that about 10,900 l of diesel oil are used to collect 329 ton/month of recyclables. The resulting energy economy is about 32 times the fuel energy used by the collecting trucks in the same period. This amount of recyclables led to an energy economy of 12,552 GJ/month, enough for a monthly equivalent electric consumption of 4000 residences [10]. Lino and Ismail show that the rate of CH_4 production from the Brazilian waste landfills can avail for Brazil about 41.7 MW and the reuse of recyclables can avail to the energy system an additional quantity of 286 GJ/month enough for the consumption of 318,000 families [11]. In Table 2 aluminum can be made from recycled aluminum with 95% less energy. The lower energy requirements also mean less fossil fuel resources are needed for power production. By lessening the need for producing virgin, recycling also indirectly aids the battle against air pollution.

Many communities should have curbside recycled material collection programs or drop-off collection facilities. One way to encourage recycling is to require deposits on the purchases of recyclable containers and using materials recovery facilities (MRFs) in addition to or instead of curbside programs. Trash containing both recyclable and non-recyclable materials is sorted in recyclable materials at the MRF. MRFs make it easier for everyone to