Journal of Petroleum & Environmental Biotechnology
ISSN: 2157-7463
OPEN ACCESS Freely available online
Research Article

Environmental and Economic Evaluation for Biogas Generation in Jordan as a Greenhouse Gas Mitigation Option

Zaid AL-Husban*

University of Glasgow, United Kingdom

ABSTRACT

Reduction of Landfill Gases (LFG) positively affects the environment because they contain greenhouse gas emissions like CO_2, CH_4 and other trace gases. Therefore, one of the solutions to mitigate the climate change impacts is using landfill recovery system. Al Ghabawi Landfill was chosen as a case study and the model used to predict the amount of landfill gases generated from the landfill is based on the IPCC (Intergovernmental Panel on Climate Change) default method. The estimation was based on quantification of waste quantities and components. Preliminary economic study was made to evaluate the feasibility of constructing power generation plants over the lifetime of the proposed project by assuming a case of using landfill gas recovery and a case without integrating any landfill gas. This study found that the Landfill gases utilization in landfills is considered satisfactorily enough both in electric energy production and in mitigating greenhouse gases.

Keywords: Renewable energy; Power; Science; Engineering

Abbrevations: $BECH_4$,$SWD_{S,Y}$=Amount of CH_4 generated from decomposable material (Gg); BE_y=Baseline emissions in year y (t CO_2e/yr); CDM=Clean Development Mechanism ; $CEF_{elec,}BL,_y$ =CO_2Emission of the baseline source of electricity displaced with applied value of 0.5228 (t co_2e/kWh); CER=Carbon emission reductions; DOC_f =The fraction of degradable organic carbon (DOC) that can decompose which assumed as 0.5; DOC_j =The fraction of degradable organic carbon (by weight) in the waste type j; $ECS_{J,J,Y}$ =Quantity of electricity consumed by the system electricity consumption source j in year y (MWh/yr); $EFE_{L,J,Y}$=Emission Coefficient of power displaced in the grid instead of heavy fuel oil with applied Value of 0.5228 (t co2e/kWh); $ELLFG,_y$=Net quantity of electricity produced using LFG, which would be produced in the absence of the system activity during year y, in megawatt hours (MWh); ER_y=Emission reductions in year y (t CO_2e/yr); EBRD=European Bank for Reconstruction and Development; F=It is the volume fraction of methane in the Landfill gas and assumed to be 0.5; f=Fraction of methane Captured without project assumed 0 as there is no methane captured and destroyed previously; GAM=Greater Amman Municipality; GDP=Gross domestic product; GHG=Greenhouse Gases; $GWPCH_4$=Global Warming Potential value for CH_4 which is tCO_2e/tCH_4; IPCC=Intergovernmental panel on climate change; IRR=Internal rate of return; JOD=Jordanian Dinar; K_j=It is the decay rate for the waste type j; LFG=Landfill Gas; MCF=the methane correction factor assumed 1 as it is a well-managed landfill; $MDB_{L,Y}$=The amount of CH_4 that would have been combusted during the year in the absence of the project which is equal to 0; $MD_{system,y}$=The amount of CH_4 that would have been combusted during the year, in tons of methane (tCH_4); MSW=Municipal Solid Waste; NPV=Net Present Value; OX=Oxidation Factor which reflects the amount of methane from landfill gas that is oxidized in the soil or other material covering the waste and assumed to be 0; SE_y=System emissions in year y (t CO_2/yr); $TDL_{j,y}$=Average technical transmission and distribution losses for providing electricity to source j in year y with applied value of 20%; VOC_s=Volatile organic compound; wjx=Mass of waste deposited at landfill at that year (Gg); x=Year number at which the methane gas emission is calculated; y=Year number at which waste is deposited in the landfill.

INTRODUCTION

The changes of concentrations of different greenhouse gases in the atmosphere like water vapor, carbon dioxide, methane), nitrous oxide (N_2O), and ozone (O_3) and other gases which change the earth's absorption of radiation can alter the balance of energy

Correspondence to: Zaid AL-Husban, PhD Researcher, University of Glasgow, United Kingdom, Tel: + +4407387603461; E-mail: hosban90@hotmail.com

Received: June 12, 2019, **Accepted:** June 22, 2019, **Published:** June 29, 2019

Citation: AL-Husban Z (2019) Environmental and Economic Evaluation for Biogas Generation in Jordan as a Greenhouse Gas Mitigation Option. J Pet Environ Biotechnol 10: 392. J Pet Environ Biotechnol. 10:392. doi: 10.4172/2157-7463.1000392

transfers between the atmospheres, space, land and the oceans; as a result there will be long- term fluctuations in precipitation, temperature, relative humidity, wind and other elements that are known as climate change [1].

An increase in the earth's global average surface temperature by 0.6 ± 0.2°C was observed over the 20th century by the emissions of these greenhouse gases (GHGs) [2].It is clear that human activities play an important role in affecting concentrations, life cycles and distributions of these gases [3].

A lot of climate change mitigation actions can be used to limit the magnitude or rate of long-term climate change. They generally involve reductions in the emissions of GHGs that are made by humanity [4].

One of the methods to reduce the emissions of GHGs is capturing landfill gas which has a large component of greenhouse gases [5,6]. The utilization of their recovered LFG in the landfill sites is considered as a useful process to provide a significant amount of electric power as well as treating organic wastes at the same time [7]. Solid waste can be considered as a renewable source of energy as wastes are continuously produced.

Landfill gas usage as an energy resource can reduce methane emissions and dependence on fossil fuel as sources of energy and it is now a near-commercial technology, as it can cover a good percentage of energy demand [8]. It yields a good amount of energy as well as it reduces associated emissions of VOCs, odors, and other local air pollutants. Landfill gas is an independent source of energy because it generates energy 24 hours per day, and 7 days per week [9].

Jordan is country which does not produce oil. The energy requirements are covered by imported oil and natural gas. The cost of importing energy places a financial burden on the national economy as Jordan spends more than 25% of its GDP on the consumption of energy [10,11]. The wastes affecting the environment of the country is big a challenge. Therefore, LFG plant can turn the waste disposal problem into a profit solution by producing electricity, connecting it to the national electricity grid, as well as generating profits from selling electricity and carbon emission reduction certificates in certified carbon development mechanisms enterprises [12]. The primary benefits of the projects are increasing environmental benefits and generating new revenue.

The purpose of this paper is to make an environmental and economic evaluation of climate change mitigation [13, 14]. Option of a selected landfill in Jordan which is the Al Ghabawi landfill with two alternatives (the first one is no gas treatment system for LFG and the second is with implementing the biogas collection system) (Figure 1). ∅=Model Correction Factor for model uncertainties which is assumed to be 0.9.

MATERIALS AND METHODS

Selection of the landfill

Al Ghabawi Waste Landfill was selected among other landfills as reported in Greater Amman report [5] because:

a) It has most of the solid waste quantities generated in the country with significant environmental impacts in its location.

b) It has the greatest methane generation potential and huge waste design capacity and thus, a good potential to generate electricity.

c) Good engineering design of cells.

d) There is enough information about characteristics of landfill site such as its waste quantity and waste composition while there is lack of information about other landfills.

e) Its location is near Amman and Zarqa which are the biggest cities in Jordan.

Waste amount in Al Ghabawi landfill and characteristics

Al Ghabawi landfill is a developed landfill without CH4 recovery and operated throughout the whole year; it started receiving waste in 2003 with expected closing year in 2031 [15]. The design of the landfill is to include a total of 9 cells with a full capacity of 40.92 million tons of waste by 2031[16]. Cell 1, 2 and 3 reached its full capacity while cell 4 is still receiving the wastes (GAM). The other cells from 5 to 9 are planned to be established and filled with time over the lifetime of the landfill (GAM).

The quantities of solid wastes disposed in landfills for the next years based on yearly increase in solid waste generation rates were forecasted [17]. The quantities disposed in landfill are highly increased due to the high percentage of population increase, and the large number of refugees who came from Iraq and Syria [18]. It is expected that the quantities of waste disposed will be highly increased in the upcoming years. The average increasing percentage from the previous year for the period between 2004 and 2015 is about 4.85% based on the (Figure 2). The expected increasing values from 2016 to 2031 are assumed to be about 5% which is very near to 4.85%. However, there are several uncertainties that can change the data, so it is difficult to know what the right estimate (Figure 3). Total expected waste disposal at the landfill closure = 40,582,200 tons (Tables 1-5).

IPCC default method

CH_4 is formed through the anaerobic conditions in the landfill and emitted to the atmosphere [19].

The method used to for CH_4 estimation from solid waste disposal was the IPCC default method which is based on the theoretical gas yield (a mass balance equation) and gives a much accurate estimate. Landfill gas is supposed by this model to consist of approximately CH_4: CO_2=50:50, as well as relatively low concentrations of other air contaminants [20].

The default IPCC method is simple which requires data only for the inventory years, the calculations for CH_4 estimation require the following:

- The quantity of waste disposed in the landfill
- Opening year, closing year of the landfill
- Age of the waste
- Composition of waste
- Conditions at the landfill for the whole term of operation

The equation used to evaluate the CH_4 possible generation throughout the years as [21].

$$BE_{CH4,SWDS,Y} = \phi.(1-\mathrm{f}).\mathrm{GWP}_{\mathrm{CH4}}.(1-\mathrm{OX}).\frac{16}{12}.F.DOC_f.MCF.\Sigma\frac{y}{x=1}\Sigma_j W_{jX}.DOC_j.e^{-Kj(\mathrm{y}-\mathrm{x})}.(1-\mathrm{e}^{-\mathrm{k}_\mathrm{j}})$$

The density of Methane is 0.7168 kg/m^3 while the density of CO_2

Figure 1: Graphical abstract.

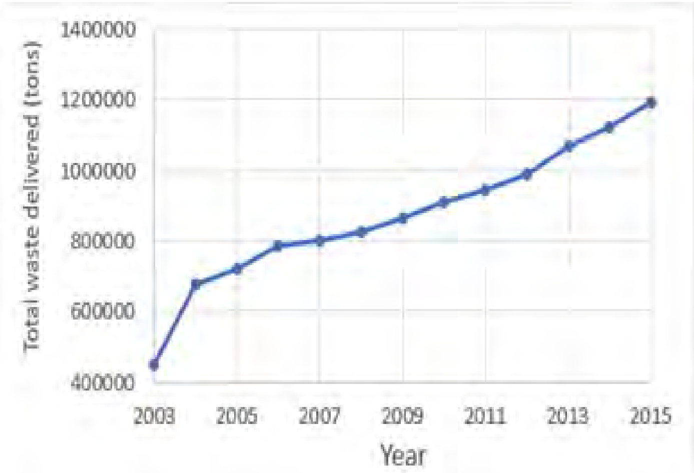

Figure 2: Total amount delivered to Al Ghabawi landfill from 2004 to 2015 (GAM, open access reports).

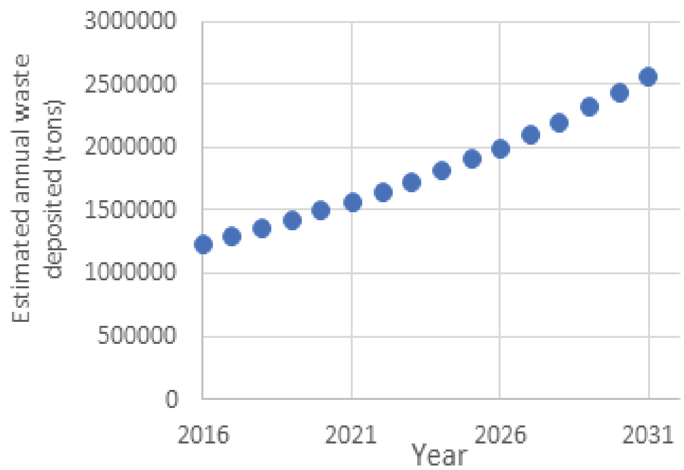

Figure 3: Estimated annual waste deposited at Al Ghabawi landfill from 2016 to 2031 with a fixed increasing percentage of 5%.

is 1.977 kg/ m^3

Estimation of landfill gas emission

It is suggested to start the landfill gas recovery system in 2018 based on an economical point of view. The generated methane that we can utilize for different years is calculated based on the quantity generated after the starting year of operating the recovery system in the cells. (Table 6) shows the expected time for cells operation based on economical point of view. A projection of the LFG generation up to 2056 was done for the landfill. The graph shows that the amount of landfill gas would keep on increasing until it reached a maximum in 2032 where 1,031,898 CO_2 equivalent (tons/year) would be produced and 137.1 Mm^3 LFG gas would be generated. After 2031, no more waste would be placed in the landfill, nevertheless, the landfill gas would continue to produce but at lower rate (Figure 4).

Electricity production calculation

In order to calculate the electricity produced the following are suggested [22].

$$CH_4Generated\ (t) = \frac{CH_4Generated(tCO_2e)}{21} \quad (1)$$

$$CH_4Generated(m^3CH_4) = \frac{CH_4Generated(m^3CH_4)}{density\ of\ methane} \quad (2)$$

$$Electricity\ generated = \frac{LGF\ Captured}{operation\ hours * LFG\ consumed\ per\ engine} \quad (3)$$

$$Potential\ LFG = \frac{Electricity\ generated * LFG\ consumed\ per\ engine}{\frac{1}{operations\ hours}} \quad (4)$$

$$\begin{aligned} &If\ the\ LFG\ captured < Potential\ LFG\ used\ by\ installed\ capacity: \\ &Electricity\ produced = \frac{LFG\ captured}{LFG\ consumed\ per\ engine} \end{aligned} \quad (5)$$

$$\begin{aligned} &IftheLFGcaptured > potentialLFGusedbyinstalledcapacity: \\ &Electricityproduced = generatorsinstalled * operationhours \end{aligned} \quad (6)$$

The basic conservative value for the LFG collection efficiency has been estimated to be 50% [2].

The selected period for engine installation and electricity generation should be chosen with the best economic revenues based on the highest methane generation and taking into consideration the investment and annual costs. Methane emissions are converted into CO_2 equivalent to be more familiar with their effects [24].

- Total electricity produced from 2019 to 2046=2.116 TWh.
- Over the landfill lifetime, the maximum electricity capacity is expected to be 14 MW (by extraction LFG from the 9 cells) (Tables 7 and 8).

Cell number	Area (1000 m^2)	Waste quantity capacity (million ton)	Duration of landfilling
1	138	4.6	3/2003- 12/2007
2	143	3.1	12/2007-6/2011
3	120	3.22	6/2011-8/2014
4	200	5	8/2014-9/2018

Table 1: Quantities of Waste disposed at Al Ghabawi Landfill (GAM).

Cell number	Area	Waste quantity capacity	Duration of landfilling
	(1000 m²)	(million ton)	
5	200	5	9/2018-1/2022
6	200	5	1/2022-1/2025
7	200	5	1/2025-7/2027
8	200	5	7/2027-12/2029
9	200	5	12/2029-12/2031

Table 2: Expected quantities of Waste disposed at Al Ghabawi Landfill for the upcoming years (GAM).

Waste Composition	% of Moist MSW
Pulp, paper, Cardboard (other than Sludge)	15.0%
Textiles	3.0%
Food and Food Waste, beverages and tobacco (other than sludge)	48.0%
Garden, Yard and Park Waste	2%
Glass, Plastic, metals, other inert waste	32.0%
Wood & Wood Products	0.0%

Table 3: Waste composition at Al Ghabawi landfill (GIZ, 2014).

Waste Type	Waste Degradability (DOC_j)
Pulp, paper, Cardboard (other than Sludge)	40%
Textiles	24%
Food and Food Waste, beverages and tobacco (other than sludge)	15%
Garden, Yard and Park Waste	20%
Glass, Plastic, metals, other inert waste	0%
Wood & Wood Products	43%

Table 4: Waste degradability at Al Ghabawi landfill (DOC-j) based on (IPCC, 2006) Guidelines for National Greenhouse Gas Inventories.

Waste Decay Rates k_j per year for boreal, temperate and dry	
Pulp, paper, Cardboard (other than Sludge)	0.04
Textiles	0.04
Food and Food Waste, beverages and tobacco (other than sludge)	0.06
Garden, Yard and Park Waste	0.05
Glass, Plastic, metals, other inert waste	0
Wood & Wood Products	0.02

Table 5: Waste decay rates at Al Ghabawi landfill based on (IPCC, 2006) Guidelines for National Greenhouse Gas Inventories.

- LFG capture must start on 01/01/2018 and electricity generation is expected to start after registration and implementation on 01/01/2019.
- Each engine has a typical capacity of 1 MW.
- Engine overhaul is required typically after 60,000 hours of operation.
- The typical overall lifetime of engine is expected to be 21 years.
- Flare efficiency considered to be 90%. Over the landfill lifetime, the maximum numbers of flares are 8 with a total capacity of 8000 m³/hour (Figure 5).

Overall emission reductions (tco2 e) calculations

The estimation of overall emission reductions are (tco_2 e) based on the following equations:

$$ER_Y = BE_Y - SE_Y \quad (7)$$

$$BE_Y = (MD_{system,y} - MD_{BL,Y}) \quad (8)$$

$$BE_Y = (MD_{system,y} - MD_{BL,Y}) * GWP_{CH4} + EL_{LGF} * CEF_{elec,BL,y} \quad (9)$$

$$SE_y = \sum_j EC_{S,J,Y} * (1 + TDL_{j,y}) \quad (10)$$

Cell number	Starting year of operation
1	2018
2	2019
3	2019
4	2020
5	2023
6	2026
7	2028
8	2031
9	2032

Table 6: Expected timetable for the operation of cells.

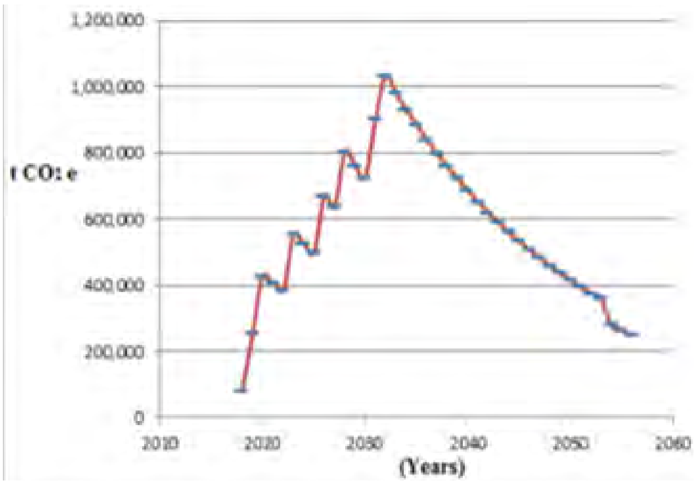

Figure 4: Expected methane generated from cells (CO_2 quivalent (tons/year)) with different year.

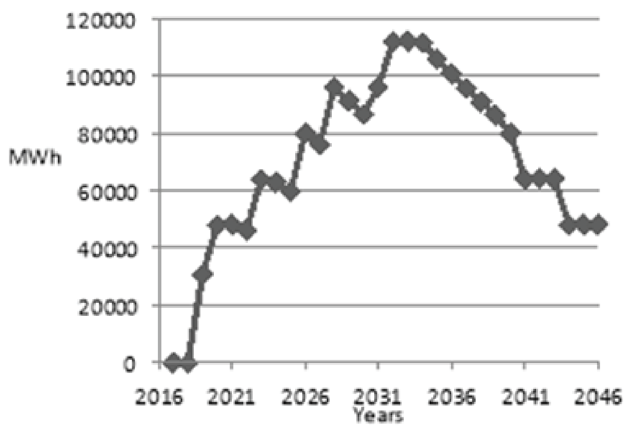

Figure 5: Electricity produced (MWh) with different years.

The estimations of emissions reduction will result in an overall reduction of 10, 282,740 (tco_2 e).

Description of the project activity

- The proposed system will be under Private contractors, who will have the full responsibility to build a start-up company and operate the LFG plants and power plants.
- The proposed system lifetime is 30 Years from 2017 to 2046.

-A typical system for the collection and management of LFG would comprise of the following: 1) LFG collecting system

2) LFG pre-treatment system 3) enclosed flaring system 4) electricity generation system 5) grid connection system (Table 9).

-The landfill will be capped to prevent the biogas to come out through the landfill surface. Therefore, the basic conservative value for the LFG collection efficiency has been estimated to be 50% [2].

Cost Benefit Analysis of Landfill Gas Recovery Plant

The study is carried over 30 years (2017 until 2046) covering LFG plants at cells 1-9. A 28-year period for producing electricity is conservatively selected since the LFG generation will enter in a declining phase in 2046, while engines will reach the end of their technical lifetime after 21 years and additional investment will be needed to replace engines, which is not considered for simplifications. LFG will be extracted from about 40.528 million tons of waste deposited from 2003 to 2031 [25].

Parameter	Value
Total amount of waste at the landfill closure in 2031	40582200 ton
Density of CH_4	0.7168 kg/m^3
CH_4 content in LFG	0.5
Typical yearly operation hours	8000 typically.
Flare efficiency for CH_4 incineration	(0.9) Based on typical on-site measurements from flow meter and CH4 content.
LFG consumption per engine	(555Nm^3/MWh). Based on interview with project manager of Helector S.A. company for construction and power generation of recovered LFG at Al Ghabawi landfill.
Plant load factor	(91%) Based on operating hours of 8,000 hours per year. Therefore 8000/8760 =0.91

Table 7: Data are used for power generation.

Year of installation	Cell number at which the engine will be installed	Installed Electrical capacity
2018	2 and 3	4 MW
2019	4	2 MW
2022	5	2 MW
2025	6	2 MW
2027	7	2 MW
2031	8	2 MW

Table 8: The implementation plan for the LFG Plant with different years by economical point of view.

Year	Timetable with major step for the landfill and the LFG plant
2016	The expected Pre-qualification for the design and implementation, and operate contracts covering landfill gas recovery and energy system.
2017	The expected Construction of LFG Plant on Cell (1)
2018	The expected Construction of LFG Plant on Cell (2)
2018	The expected Construction of LFG Plant on Cell (3), Beginning of system operation on Cell (1)
2019	The expected Construction of LFG Plant on Cell (4), Beginning of system operation on Cell (2) and cell (3)
2020	Beginning of system operation on Cell (4)
2022	The expected Construction of LFG Plant on Cell (5)
2023	Beginning of system operation on Cell (5)
2025	The expected Construction of LFG Plant on Cell (6)
2026	Beginning of system operation on Cell (6)
2027	The expected Construction of LFG Plant on Cell (7)
2028	Beginning of system operation on Cell (7)
2030	The expected Construction of LFG Plant on Cell (8)
2031	Beginning of system operation on Cell (8) The expected Construction of LFG Plant on Cell (9)
2032	Beginning of system operation on Cell (9)

Table 9: Expected timetable for the LFG plant construction and operation based on economical point of view.

The preliminary economic study was made to evaluate the feasibility of constructing power generation plants at Al Ghabawi landfill by comparing the overall costs and expected benefits on a year-by-year basis for the life of the system covering LFG plants at cells 1-9. An economic analysis for the two alternatives (no gas treatment system for LFG scenario vs. implementing the Biogas collection system Scenario) in the Al Ghabawi landfill will be carried out (26,27)

The overall costs include investment costs, annual salaries, operation and maintenance costs. While the expected benefits are sales of electrical energy and of carbon credits according to Clean Development Mechanism [28]. The economic viability of landfill gas in the study is based on profitability parameters of Net Present Value (NPV) and Internal Rate of Return (IRR).

Total investment costs

It involves the cost of Purchase and installation of equipment for extraction, collecting, flaring, generating and transmission of electricity (Table 10).

Annual costs include staff salaries, operation and maintenance costs.

The overall cost for staff salaries, Operation and Maintenance =24,452,600 Euro. The following are used in the analysis:

- Unit price for sold electrical power is 0.073 Euro/kWh.
- There is no governmental tax for environmental systems.
- The proposed interest rate is 9% (8% for loan based on the EBRD bank and 1% for risk sensitivity).
- Price of CER is 0.4 Euro/ton of CO_2 equivalent
- There must be a crediting period for 7 years with 2 renewed periods to reach a total period of 21 years. The author suggested the following from an economical point of view:
- CDM project registration will set at January 2022.
- First crediting period starts after registration of CDM project from January 2023 to December 2029.
- Second crediting period from January 2030 to December 2036.
- Third crediting period from January 2037 to December 2043.
- Over the three-crediting period, the average gas recovered will be about 8,584,447 tons of CO_2e.
- Exchange rate used in the investment analysis is 1.24635 Euro/JOD (April18, 2016).
- Fair value of the engines is calculated using 4.76% of depreciation per year (based on typical engine Overhaul of engines =3.47 Million JOD (every 1 MW typically needs of 12% from the initial cost after regular working period of 7 years).
- The results of the economic analysis of landfill gas recovery plant with income from sales of CER's and electricity production are:

a) The net present value of the system is expected to be 3.74 million JOD.

b) Internal rate of return of about 11%.

Externalities costs

An overview of the environmental externalities that should to be taken into account when evaluating economics benefits of the scenario of implementing landfill recovery system and reducing the air pollution effects [29]. The externalities include health impacts externalities from air pollutants and odour reductions externalities.

Health impacts externalities from air pollutants: Local air pollutants impact such as SO_2, NO_X, particulates and VOCs are determined by distance to human populations, topography, and prevailing meteorological conditions, e.g. wind directions) [30].

Air pollutants externalities in Al Ghabawi will be calculated by the comparison with other studies like BDA group study in Australia based on distance to human populations, per capita income for population, and organic waste fraction of municipal solid waste [31].

Based on the study of BDA group (2009), the external benefits of local air pollutants reduction effects on the health from landfills in rural areas in Australia can be estimated by using LFG capturing system, and calculating the difference in costs between two scenarios of using LFG capture system and not using it based on the following:

Item	Quantity	Unit	Total Cost (Euro)
Preliminaries (Mobilization,Insurance,Bonds,requirements,Temporaryworks,etc)	1	each	400000
capping +cell configurations, site plans, site design criteria, final contour and grading	9	each	22410000
Vertical extraction wells (170 wells,160mm average 30 m deep)	2058	unit	4695000
Gas wellhead	2058	each	514500
Horizontal pipes from 90 to 560mm		m	3441000
Manifold	99	unit	297000
Condensate trap	270	unit	81000
Gas treatment	1	unit	750000
Flare and pump station for 1,000 m^3/h	8	unit	3200000
1,000 kW Gas engine/generator unit in containers	14	unit	14000000
transformer for power connection	17.5	MVA	437500
Cabling	15	Km	1500000
Running-in, tests, safety monitoring, and protection system	9	Each	180000
Total			51,906,000

Table 10: Estimated total investment cost for cell 1 to 9.

Item	Baseline scenario without landfill gas utilization	Landfill gas utilization scenario
Expected CH_4 generated (CO_2 equivalent (tons/year))	18,729,463	8,446,723
Total investment cost for the recovery of cells	0.0	41.65 Million JOD
Total annual, operation and maintenance costs	0.0 (Base)	19.62 Million JOD
Electricity produced	0.0	2116315 MWh
Net Present Value of system	0.0	3.74 Million JOD
Health externalities costs from local pollution	1,476,722 JOD	632,885 JOD
Price of adjacent lands to the landfill (0-3) km	650,317 JOD	1,350,905 JOD

Table 11: Summary of feasibility study results.

1) The cost per ton of waste for local air polltants at rural area (in Australian dollar, 2008) when there is no LFG capture is about 0.21.
2) The cost per ton of waste for local air polltants at rural area (in Australian dollars, 2008) when there is LFG capture is about 0.09.

Australian rural landfills and Al Ghabawi landfill are the same in surrounding human population densities, landfill design, and operation standards. In Australia, the organic waste fraction of municipal solid waste is approximately 47% by mass [32] which is very near to Al Ghabawi organic composition [33,34].

Both of them are considered to be in arid dry weather with no big difference in biodegradation.

By converting from Australian dollars to Jordanian Dinars with expected 2.66168 million tons of waste disposed from 2018 to 2031:

- Local air pollutant effects without LFG capture=1436500 JOD
- Local air pollutant effects with LFG capture=615647 JOD

The local air pollutants effects with and without LFG capture and the benefits from capturing LFG at the closure year of Al Ghabawi landfill are equalized to their equalizing value in 2008 based on the BDA group study (2009).

- With an inflation rate of 2.8% in Jordan between 2008 and 2016:
- Local air pollutant effects without capturing LFG=1476722 JOD in 2016.
- Local air pollutant effects with capturing LFG=632885 JOD in 2016.
- The expected benefits equal 843839 JOD in 2016.
- The effects on adjacent lands prices

Hydrogen sulfide and ammonia which result from anaerobic degradation cause a bad odor in the vicinity of the landfills. The energy recovery system will lead to prevent the odor to the adjacent land, which will increase its costs [35].

Based on several interviews with employees in the Department of Lands and Survey and Real Estate offices in Zarqa Governorate, where the author met experts in evaluating land prices before and after using the energy recovery system. The adjacent lands around the landfill are divided into 3 areas and the increase in the price of the adjacent lands with the landfill gas utilization system is expected to be as the following:

1) The increase in the price of the lands from 0-1 km around the landfill site will be about 56,556 JOD.
2) The increase in the price of the lands from 1-2 km around the landfill site will be about 212,062 JOD.
3) The increase in the price of the lands from 2-3 km around the landfill site will be about 431,970 JOD.
4) The total increase in land price from 0-3 km is expected to be 700,588 JOD if there is energy recovery system.

RESULT AND DISCUSION

The results of the feasibility study show financial benefits of about 5,723,790 JOD in different aspects such as system feasibility income, externalities of health and adjacent lands (Table 11).

CONCLUSION

Based on the results of this study the following conclusions can be drawn:

1. Methane emissions from Al Ghabawi landfill is estimated by the IPCC default method with reaching maximum value in 2032 of about 1 million tons of CO_2 equivalent.
2. 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 energy produced for the whole project is about 2,116,315MWh with a reduction of about 10283 thousand tons of CO_2 equivalent. As a result, LFG is a good source for power generation, and it can be used to displace fossil fuel.
3. The results of the feasibility study show positive financial benefits of about 5,723,790 JOD in different aspects such as system feasibility income, externalities of health and adjacent lands.
4. This research is important because it gives needed information on the feasibility of LFG projects and may stimulate future research and development in this area, resulting in an increase in the number of LFG systems and potentially improved economics at landfill site.

RECOMMENDATIONS

1. Future landfills should have an appropriate design and methane recovery systems.
2. The default IPCC model is very simple method and it is suitable when there is low knowledge about decay process in landfills .It is recommended to apply more developed modeling techniques with better efficiencies toward calculating LFG and methane emissions like Landgem software that gives better estimates

with needs of more accurate data about wastes deposited and degradation conditions.

3. Using more developed studies to calculate environmental externalities since there were limited number of studies.
4. Governmental institutions should cooperate more with researches especially by giving information and allowing interviews with experts to get accurate results.
5. The method of economic and environmental comparison between baseline and mitigation scenarios can be implemented to measure feasibility of other renewable energy projects.
6. There are uncertainties in the estimates of CH_4 emissions as there is a lack in data of quantities of waste disposed, waste composition and disposal conditions. Therefore, the statistics and data should be improved so the future emissions will be based on more reliable data and the recovery of energy from landfills is improved.
7. Characteristics of wastes such as the percentages of organic substances should be collected to get better results in the future

ACKNOWLEDGEMENTS

I wish to specially than my research assistant, Mr. Chimezie Brown and my project student Chinedu Obanye of class 2012 set of the Department of Animal and Environmental Biology, University of Port Harcourt.

REFERENCES

1. Du Preez M, Lottering T. Negative Effects on House Values that are Near to a Landfill Site. SAJEMS NS 2009;12:256-262
2. Houghton J, Ding Y, Griggs D, Noguer M, van der, et al. Climate Change 2001: The Scientific Basis Intergovernmental Panel on Climate Change IPCC cambridge university press New York,USA.
3. Intercontinental Exchange, Inc. (ICE) (2003) Available from https://www.theice.com/marketdata/reports/icefutureseurope/ECXCERIndex.shtml.
4. Cheremisinoff N. Handbook of Solid Waste Management and Waste Minimization Technologies 2003.1st edn. Elsevier Publisher, Amsterdam, Netherlands.
5. Themelis NJ, Ulloa PA. Methane generation in landfills. Renew Energ. 2007;32:1243-1257.
6. Virginia AM, Lerner SL, Maclean DL. Electricity, Methane and Liquid carbon dioxide Production from Landfill Gas. Gas Sep Purif. 1987;1:77-83.
7. Sasao T (2002) Analysis of the Socioeconomic Impact of Landfill Siting Considering Regional Factors. Environ Econ Policy Stud 6: 147-175.
8. Abdulla FA, Al-Ghazzawi ZD. Methane Emissions from Domestic Waste Management Facilities in Jordan Applicability of IPCC Methodology. J Air Waste Manag Assoc. 2000;50: 234-239.
9. Amini HR, Reinhart DR. Regional Prediction of Long-term Landfill Gas to Energy Potential. Waste Manag. 2011;31:2020-2026.
10. Jaramillo P, Matthews HM. Landfill-Gas-to-Energy Projects:Analysis of Net Private and Social Benefits. Jordan meteorological department. Env Sci Tech. 2005;39:7365-7375.
11. NEPCO National Electric Power Company, Electricity Regulatory Commission of Jordan.
12. Rajaram V, Siddiqui FZ, Khan ME. From landfill gas to energy, Technologies and challenges. CRC Press Florida, United States 2012.
13. United Nations Framework convention on climate change UNFCCC (2013) FOCUS: Mitigation - NAMAs, Nationally Appropriate Mitigation Actions.
14. World Meteorological Organization (2011) Climatological information for Australia landfills. Available from https://www.wtenergy.org
15. Greater Amman municipality GAM Pre - Feasibility Report: Amman Ghabawi Landfill Gas to Energy Project Greater Amman Municipality, Jordan in 2007.
16. Shen FW, Guo HC, Xin CL. The Environmental Assessment of Landfill Based on Stakeholder Analysis. Procedia Environ Sci. 2012;13:1872-1881.
17. Dijkgraaf E, Herman RJ, Vollebergh . "Burn or Bury? A Social Cost Comparison of Final Waste Disposal Methods," Working Papers 46, Fondazione Eni Enrico Mattei in 2003.
18. GIZ Country report on the solid waste management in Jordan in 2014.
19. Fei X, Zekkos D, Raskin L. Quantification of Parameters Influencing Methane Generation due to Biodegradation of Municipal Solid Waste in Landfills and Laboratory Experiments. Waste Manag. 2015;55:276-87.
20. Kumar S, Gaikwad SA, Shekdar AV, Kshirsagar PS, Singh RN. Estimation Method for National Methane Emission from Solid Waste Landfills. Atmos Environ. 2004;38:3481-3487.
21. Intergovernmental Panel on Climate Change IPCC Guideline for National Greenhouse Gas Inventories in 2006.
22. El-Fadel M, Findikakis A, Leckie J. Environmental Impacts of Solid Waste Landfilling. J Environ Manage. 1997;50:1-25.
23. Helector SA (joint venture Construction Company) interviews with project manager.
24. EMCON Association. Methane Generation and Recovery from Landfills, Ann Arbor Science Publisher. Washington, DC in 1980.
25. Aye L, Widjaya E. Environmental and Economic Analyses of Waste Disposal Options for Traditional Markets in Indonesia. Waste Management. 2006;26:1180-1191.
26. Karapidakis ES, Tsave AA, KatsigiannisYA, Moschakis MN. Energy Efficiency and Environmental Impact of Biogas Utilization in Landfills. Int J Environ Sci Tech. 2009;7: 599-608.
27. Yedla S Parikh JK. Economic Evaluation of a Landfill System with Gas Recovery for Municipal Solidwaste Management Int J Environ Pollut. 2001;15:94-115.
28. European Commission A Study on the Economic Valuation of Environmental Externalities from Landfill Disposal and Incineration of Waste in 2005.
29. Eshet T, Ayalon O, Shechter M. A Critical Review of Economic Valuation Studies of Externalities from Incineration and Landfilling. Waste Manag Res. 2005;23:487-504.
30. BDA Group report, The Full Cost of Landfill Disposal in Australia, BDA Group, Canberra, Australia in 2009.
31. Ministry of Environment in Australia Composition of municipal solid waste in 2009.
32. Murphy JD, Mckeogh E. Technical, Economic and Environmental Analysis of Energy Production from Municipal Solid Waste. Renew Energ. 2003;29:1043-1057.
33. Reinhart DR, Cooper DC, Walker BL. Flux Chamber Design and Operation for the Measuremen of Municipal Solid Waste Landfill Gas Emission Rates. J Air Waste Manag Assoc. 1992;42: 1067-1070.
34. Nahman A. Pricing Landfill Externalities: Emissions and Disamenity Costs in Cape Town, South Africa.Waste Manag. 2011;31: 2046-2056.