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Greenhouse Gas Emission and Economic Evaluation from Municipal Solid Waste Landfill in Thailand

Tubtim Pattharathanon, Sirintornthep Towprayoon and Komsilp Wangyao [+]

The Joint Graduate School of Energy and Environment, KMUTT, Bangkok, Thailand
126 Pracha-Uthit Rd., Bangmod, Tungkru, Bangkok, Thailand

Abstract. The municipal solid waste (MSW) management in Thailand is necessary to concern greenhouse gas (GHG) emission. In this study, the landfills are interesting which are anaerobic landfill, landfill gas to energy (LFGTE) and semi-aerobic landfill. LFGTE, landfill gas is reduced by use to energy and it is flared before release to atmosphere and semi-aerobic landfill is a new landfill technology in Thailand. The advantages of semi-aerobic landfill, it can reduce more greenhouse gas emission than anaerobic landfill and the operation is easy and low cost than LFGTE. However, electricity generation from LFGTE can sale and get adder from the government therefore, economic evaluation of these landfills are considered as compare in term Net Present Value (NPV) and Internal Rate of Return (IRR).The economic implications with/without Clean Development Mechanism (CDM) project are also assessed. This study, to indicate the appropriate waste management according to quantity of waste is 100, 250, 500 and 1,000 tons/day. The result, Quantity of waste 100 tons/day and 250 tons/day should be managed in semi-aerobic landfill because have more NPV and less emission than LFGTE. About, 500 tons/day and 1,000 tons/day should be used to electricity because NPV values are more than semi-aerobic landfill and emissions are more than semi-aerobic landfill not so much. The result can be used to development and improvement municipal solid waste management in the future and it will be guideline to researcher, government or who have an interest in municipal solid waste management.

Keywords: Semi-aerobic landfill, Landfill Gas to Energy (LFGTE), Greenhouse Gas (GHG), Clean Development Mechanism (CDM), Municipal Solid Waste (MSW).

1. Introduction

Thailand is developing country, the population increased rapidly and economic development of big cities and tourist cities which lead to the major solid waste problem. The Thai Government has a solid waste management plan. As Anaerobic landfill is a low cost and easily manageable technology, it is a very popular mode of waste management but organic waste degradation under anaerobic condition produce greenhouse gas emission. Greenhouse gases generated from landfill system are methane and carbon dioxide. Methane, comparison with carbon dioxide (CO_2), methane has affecting to be 21 times more than efficient at trapping heat within the atmosphere (Wanichpongpan and Gheewala, 2007). Therefore, new solid waste management technologies are developed for reducing environmental problems which are semi-aerobic landfill and LFGTE. These landfill technologies are interesting for sustainable development technology because LFGTE, landfill gas can be collected for utilization and, semi-aerobic landfill combines anaerobic and aerobic metabolism which aerobic condition produce carbon dioxide instead methane. There are several case studies of semi-aerobic landfill in Denmark, Japan and Malaysia but in Thailand, there is rarely semi-aerobic landfill data and cannot use factors from the case studies because Thailand has a tropical climate and rainfall which is different condition then this paper, to study environmental impacts and economic system of anaerobic

[+] Corresponding author. Tel.: + 081-6405696
E-mail address: nan_pattt@hotmail.com

landfill, LFGTE and semi-aerobic landfill system and, to indicate the appropriate waste treatment technology according to the quantity of waste for decision to use suitable disposal technology.

2. Methodology

2.1. Research Objective

-Comparison of greenhouse gas emission between anaerobic landfill, landfill gas to energy and semi-aerobic landfill.

-To study economic assessment by analyzing costs and income compare as investment CDM project.

-To indicate the appropriate waste treatment technology according to the quantity of waste.

2.2. Boundary of the Assessment

The boundary of this work begins the waste is disposal in area of anaerobic landfill or semi-aerobic landfill or landfill with landfill gas to energy (LFGTE) by each landfill is concerned environmental impact and cost analysis. Environmental impact focus on global warming and these landfill systems are assumed no leakage of leachate then natural attenuation emission from uncontrolled leachate does not consider. Transportation, collection and separation of MSW do not included in the system boundary as they are common to the three waste management system and they will not influence the comparative result. Cost analysis include investment cost and operation cost by assume cost of anaerobic landfill is zero, costs of semi-aerobic landfill and LFGTE are costs which add from anaerobic landfill such as venting system and equipment of electricity plant, if waste management landfill is invested in CDM project that have to concern operation cost and income in CDM project. And then, compare of environmental impacts and economic between these three technologies.

This paper, to study the appropriate waste treatment technology according to the quantity of waste is 100, 250, 500 and 1,000 tons/day. The MSW is dumped in landfill area 15 years continually. The landfill was opened 2008 and closed 2022 and time period of the project is 21 years by beginning year 2009 to the end year 2029 because in year 2009, generated landfill gas is enough to produce electricity thereby anaerobic landfill and semi-aerobic landfill should be compared as same time period.

2.3. Methane Emission from Landfills

It is necessary to assess a landfill's potential for methane recovery before building a project. This study predicts methane production by CDM-EB adopted in most of the LFG projects. According to this methodology, the amount of methane produced in a specific year 'y' of the crediting period in a landfill and it is expressed as the CO_2 equivalent emission amount (CO_2eq). After landfill gas is collected in the collection system, LFG has passed through pre-treatment plant and boost up to flare stacks or engines to power grid. The LFG flows to flare stacks or engines depend on amount of LFG and flare and engine efficiency.

Waste composition is a one factor of amount of landfill gas produced therefore, the information of waste composition in Thailand is necessary to investigate all 16 provincial parts of Thailand. The waste composition in Thailand is investigated by Pollution Control Department (PCD) of Thailand. Food waste is the main component at about 47.81 % and the other waste composition are shown in Figure 1.

Ex-ante calculation of emission reductions

Ex-ante estimate of methane destroyed by power generation and flaring

$$MD_{project,y} = BE_{CH4,SWDS,y}/GWP_{CH4}$$

$MD_{project,y}$ will be determined ex post by metering the actual quantity of methane captured and destroyed once the project is operational. The methane would have been destroyed by flaring & fuelled to gas engine to produce electricity only. Thermal & feeding to the natural gas distribution network is not under project scenario.

$$MD_{project,y} = MD_{flared,y} + MD_{electricity,y}$$

The amount of methane generated from disposal of waste at the solid waste disposal site (SWDS) is $BE_{CH4, SWDS}$ that is based on first order decay (FOD) model. The model differentiates between the different types of waste *j* with respectively different decay rates k_j and different fractions of degradable organic carbon (DOC_j). The model calculates the methane generation based on the actual waste streams $W_{j,x}$ disposed in each year x, starting with the first year after the start of the project activity until the until the end of the year y, which baseline emissions are calculated (years x with x = 1 to x = y). The amount of methane produced in the year y ($BE_{CH4,SWDS,y}$) is calculated as follows: (CDM-EB, 2006)

$$BE_{CH4,SWDS,y} = \Phi \cdot (1\text{-}f) \cdot GWP_{CH4} \cdot (1\text{-}OX) \cdot \frac{16}{12} \cdot F \cdot DOC_f \cdot MCF \cdot \sum_{X=1}^{y} \sum_{j} Wj,x \cdot DOCj \cdot e^{-kj(y-x)} \cdot (1\text{-}e)^{kj}$$

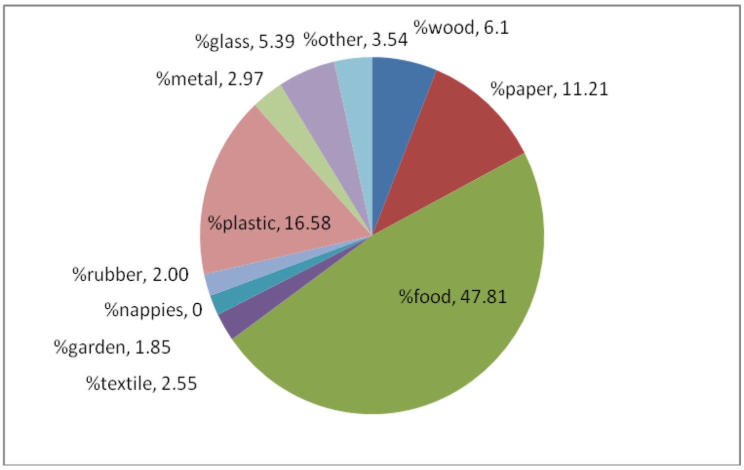

Fig. 1: Waste compositions in Thailand

Table 1: Inventory Data for the Estimation of Landfill Gas and Electricity Production

Parameter	Value	Unit
Oxidation factor, OX	0.1	-
Methane fraction, f	0.0	-
Methane Correction Factor, MCF of anaerobic managed	1.0	-
Methane Correction Factor, MCF of semi-aerobic managed	0.5	-
Methane Collection Efficiency	60	%
Heating Value of CH_4	37	MJ/m^3
Percent methane in landfill gas	50	%
Rate electrical output	1025	kW
LFG feed to 1025 kW gas engine	700	m3/hr
Rate electrical output	595	kW
LFG feed to 595 kW gas engine	390	m3/hr
Rate electrical output	260	kW
LFG feed to 260 kW gas engine	200	m3/hr
Electrical efficiency	40	%
Flare efficiency	90	%

2.4. Economic Assessment

2.4.1. Investment Cost

Semi-aerobic landfill; HDPE Pipe dia. 200 mm (PE100 - PN10), rock column 1 x 1 m. 3.2 mm. - Steel mesh (2" x 2") and HDPE Pipe dia. 500 mm (PE100 - PN10.

Landfill gas to energy (LFGTE) costs are preparation and design, pumping test, gas engine, collection system, gas pump system and flare system.

2.4.2. Operation Cost

The operation costs of landfill are operation and maintenance costs, salary and administration and depreciation**.**

2.4.3. Cost in CDM Project

The project is invested in CDM project have to pay baseline study, monitoring plan, validation, emission reduction purchase agreement(ERPA) preparation, registration and Verification.

2.4.4. Income

Incomes of the project are revenue from generated electricity and adder from government and, trade of emission reduction one that it is invested in CDM project.

2.4.5. Tool for Calculated Economic of the Landfill System

The economic analysis in this study indicates by use Net Present Value (NPV) and Internal Rate of Return (IRR).Net Present Value (NPV) is defined as the sum of the present values (PVs) of the individual cash flows of the same entity. NPV is a central tool in discounted cash flow (DCF) analysis, and is a standard method for using the time value of money to appraise long-term projects. Internal Rate of Return (IRR), are commonly used to evaluate the desirability of investments or projects. The higher a project's internal rate of return, the more desirable it is to undertake the project. Assuming all projects require the same amount of up-front investment, the project with the highest IRR would be considered the best and undertaken first.

3. Result and Discussion

3.1. Greenhouse Gas Emission

Methane generation is calculated by using CDM-EB adopted and the 60% methane is collected in the collection system. After that, landfill gas has been sent to flare or engine to power grid. This study assesses rate of waste disposal in landfill; 100, 250, 500 and 1,000 tons/day which can produce landfill gas differently that are shown in Figure 2. The rate of waste disposal 100 tons/day can generate electricity 0.26 MW, 12 years because amount of landfill gas is not enough, about rate of waste disposal 250, 500 and 1000 tons/day can generate maximum electricity 0.52, 1.785 and 3.075 MW respectively. The time periods of electricity generated of the cases study are 21 years.

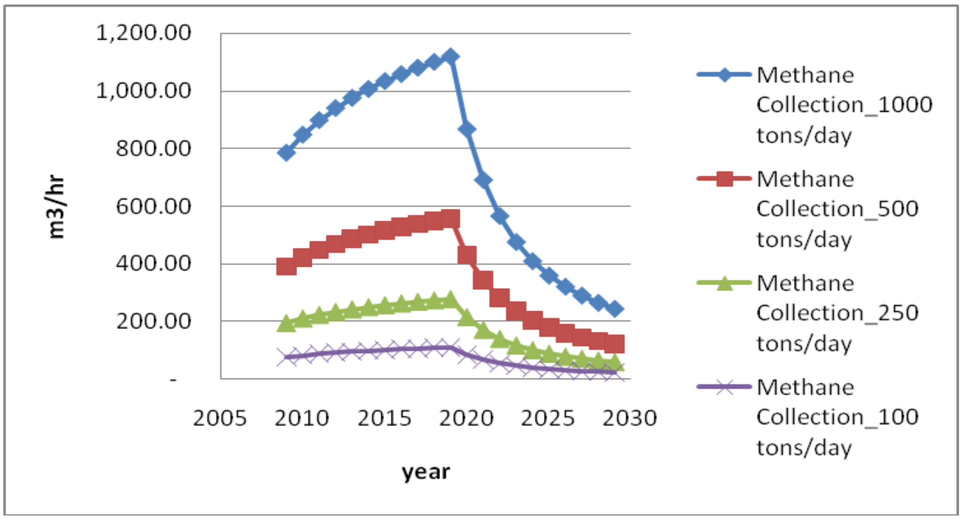

Fig. 2: Methane collection of landfill gas to energy

The amount of methane emission and emission reduction from three landfill technologies according to quantity of waste are presented in Figure 3 and 4. Landfill gas emission from LFGTE has least affecting to atmosphere and anaerobic landfill with flare release landfill gas emission less than semi-aerobic landfill.

The methane generation from anaerobic landfill is collected to electricity production and excess methane is sent to flare system for reducing landfill gas emission. Semi-aerobic landfill is one technology can reduce landfill gas emission because organic waste is degraded under aerobic condition combine anaerobic condition that is called semi-aerobic condition. When organic has been decomposed under semi-aerobic condition that produces methane less than anaerobic condition 50%. Therefore, methane correction factor (MCF) of semi-aerobic landfill is 0.5 for calculating methane generation and semi-aerobic landfill can reduce landfill gas emission less than LFGTE and anaerobic landfill with flare thereby when concern environmental impact as compare these three landfill types, the LFGTE is most appropriate landfill technology.

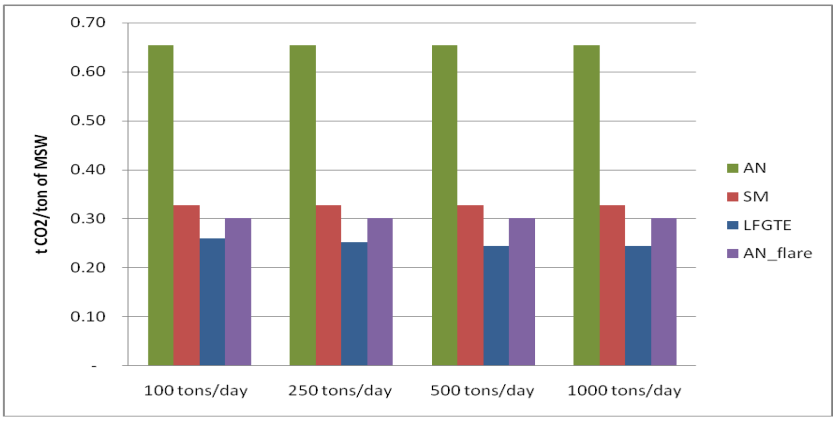

Fig. 3: Greenhouse gas emission from landfill technologies

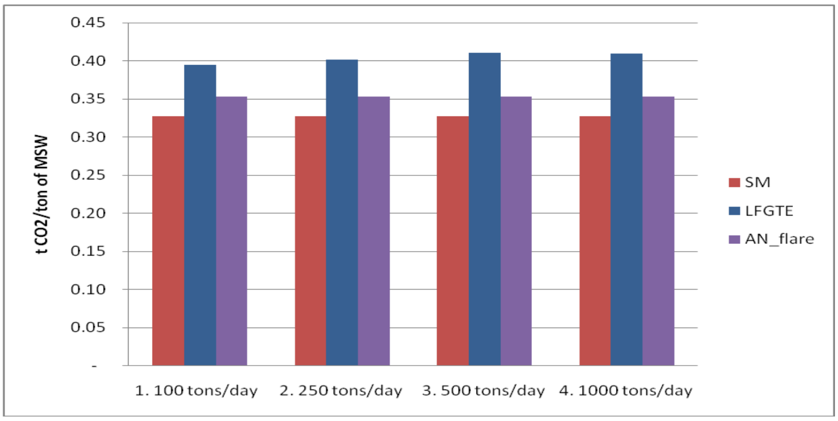

Fig. 4: Emission reduction of landfill technologies

3.2. Economic Assessment

Semi-aerobic landfill, anaerobic landfill with flare and LFGTE can invest in CDM project for sale emission reduction and LFGTE get income from sale electricity and adder value. Therefore NPV values with/without CDM project are presented in Figure 5 and 6. If three landfill are not invested in CDM project and assume anaerobic landfill cost is zero, at 100 tons/day case, semi-aerobic landfill is most NPV but LFGTE is less NPV because it is high investment cost although, it can sale electricity and get adder value 7 years from government but it is not break even while, semi-aerobic landfill is low investment cost. 250 tons/day case, all three landfills are negative NPV but LFGTE is less negative when compare as 100 tons/day, the result of LFGTE is opposite that mean a lot of MSW is appropriate to use LFGTE. 500 and 1,000 tons/day cases, NPV of LFGTE landfills are most positive. If bring anaerobic landfill with flare, semi-aerobic landfill and LFGTE to CDM project, NPV values of 100 tons/day case are negative because CDM project cost is high for small project but in this case, semi-aerobic landfill is less negative and 250, 500 and 1,000 tons/day cases NPVs of LFGTE are most. However, when concern specific economic according to quantity of waste; 100 tons/day should be managed in semi-aerobic landfill and 250 tons/day, 500 tons/day and 1,000 tons/day should be used to electricity. Both landfill technologies should be invested in CDM project.

However, decisions have to assess environmental impact and economic of project but if the alternative technologies are difficult decision that depending on government or investor because there are many factors such as investment cost, area, equipment and specialist. Some company may have those things support.

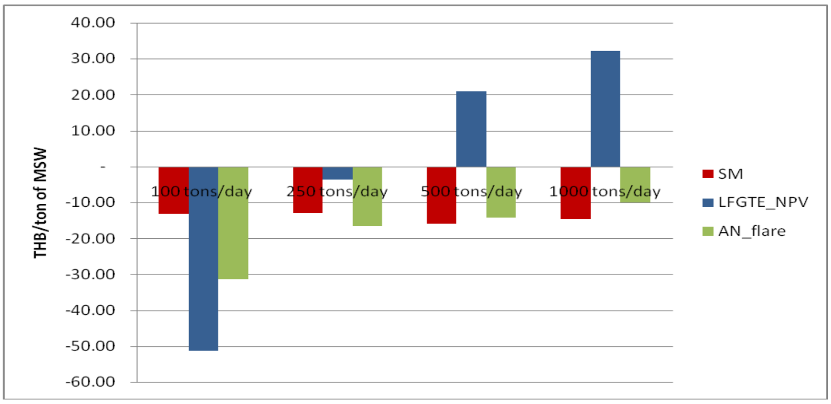

Fig. 5: Net present value (NPV) without Clean Development Mechanism (CDM) of landfill technologies

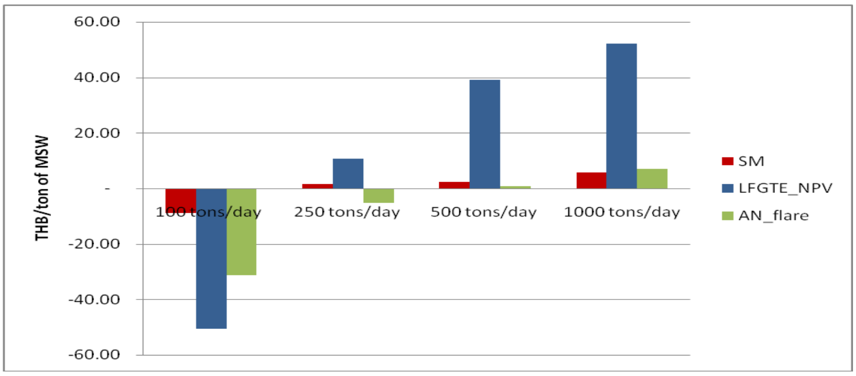

Fig. 6: Net present value (NPV) with Clean Development Mechanism (CDM) of landfill technologies

4. Conclusion

This study, to compare of greenhouse gas emission between anaerobic landfill, landfill gas to energy and semi-aerobic landfill, the result landfill gas to energy (LFGTE) is most appropriate landfill technology. When concern economic according to quantity of waste; 100 tons/day should be managed in semi-aerobic landfill and 250 tons/day, 500 tons/day and 1,000 tons/day should be used to electricity. Both landfill technologies should be invested in CDM project. The semi-aerobic landfill is suitable small project while, LFGTE is appropriate large project (a lot of municipal solid waste).

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