

Using Life Cycle Assessment in Investigating Electricity Generation Potential: (By Harnessing Garbage)

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Abstract:
Solid waste is a waste that is predominantly domestic garbage. These wastes can be solid or semisolid form, but does not include industrial or hazardous wastes. Energy Recovery from garbage is not a new idea globally but the method of determining the energy content of the waste stream has developed over the period. Life Cycle Assessment (LCA) is a tool used to determine the environmental impact, of any product from its raw material (cradle) stage to finally being discarded (grave) as a waste deposit. LCA can also be useful in identification of effective waste management system and in determining the energy content of a waste stream. For a complete LCA, scenarios have to be created which will aid the studies by comparing results of activities with the base case scenario. For this study, two scenarios were created, the base case scenario and energy recovery scenario. In the Base Case Scenario all the waste generated is taken to landfill. While in the Energy Recovery Scenario energy and material recovery is involved. From the result of the LCA, about 12MW of electricity can be recovered by harnessing the Garbage in UTM. With associated high decrease in environmental emissions from 5 tons of CO_2 and 390Kg of deposited goods at the landfills to -0.97 tons of Co_2 and no deposited goods because materials can be recovered from the waste that can be recycled. Gabi Software was used for the LCA assessment.
Keywords: Scenario, LCA, Landfill, Gabi Software, University Technology Malaysia, energy recovery

1. INTRODUCTION:

Solid waste is a waste that is predominantly house-hold or domestic garbage. These wastes can be solid form or semisolid form, Solid waste normally does not include industrial or hazardous wastes. Energy Recovery from garbage is not a new idea globally. With the current increase in waste generation globally from 0.68 billion tonnes per year reported by the UN in a global review of waste management report with an annual estimated increase of about 1.3 billion tones of MSW per year. In 2050, the report forecasted an increase of about 2.2 billion tons of MSW per year Hoornweg, D. and Bhada-Tata, P. (2012).

A life-cycle assessment (LCA, also known as life-cycle analysis, ecobalance, or cradle-to-grave analysis) US Environmental Protection Agency (2010) defines LCA as a technique to assess environmental impacts associated with all the stages of a product's life from-cradle-to-grave (i.e., from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling).

Life cycle analysis takes a systematic approach to evaluate the environmental impact of a particular product, process, or activity from cradle to grave or gate to gate US Environmental Protection Agency (2010), by taking a snapshot of the developing process (life cycle) of a product. Apart from LCA there are other tools that are used in impact assessment for example statutory impact assessment but LCA unlike other tools gives comprehensive assessment, accommodates more data, performs faster analysis and has a variety of tools to choose from for analysis Özeler, D., Yetis, Ü., & Demirer, G.N. (2006). LCA was used in many studies as an environmental tool for comparative assessments of waste disposal options or waste management scenarios. LCA tools have a wide range of application as a decision-making tool, benchmarking tool, product management and in new product development.

In a study by Beigl P. & S. Salhofer (2004) performed an LCA using IWM software to compare the effects of the waste on ecology with economical impact, based on global warming potential, acidification potential, and the net energy used. Three (3) scenarios were derived when carrying out the study 1. Recycling by collection in the bring system 2. Recycling by kerbside collection method. 3. No recycling involved. It was concluded that Kerbside collection is ecologically better than collection in the bring system because the specific fuel consumption is lower for collective transports since the route is always shorter than that for individual transports which have to take longer route. Iriarte, A., et-al (2009) and Rives J. et-al (2010) applied LCA to compare the overall environmental impacts of solid waste management; both used SimaPro software to perform the LCA. Where in Iriarte, A., et-al (2009) it was concluded that that the collection system with the least impact is multi-container collection. While Rives J. et-al (2010) concluded that choice of waste container is based mostly on economic or aesthetic criteria. LCA can be used as a decision making tool as discussed in a study by

Miliūtė J., & Staniškis, J. K. (2010) and Cherubini, F. et-al (2009) using WAMPS and SimaPro LCA software respectively. Both studies concluded that Landfill present the worst environmental burden from waste.

Using an LCA as a decision making tool was also demonstrated by Dodbiba, G. et-al (2008), an LCA of two scenarios of recycling and incineration of electronic waste from TV sets in Japan. In conclusion, from the LCA, mechanical recycling of the plastics from the disposed TV sets shows less environmental pollution than Incineration of same waste.

University Technology Malaysia main campus is located in Skudai Johor, the campus is made up of 17 residential hostels, 100 units of guest houses, 12 faculties, administration block, student union building, Sultanah Zanariah Library building, cafeterias, health centre e.t.c., which generates up to 3520.4 tons of waste in 2011 as shown in table1. All these facilities are sources of waste therefore; it has become necessary to identify the environmental effects of such huge amount of waste generated and useful products that can be recovered.

University Technology Malaysia has seen an increase in waste generated particularly between 2009 and 2010 as shown in table 1 despite the green and eco related initiatives by the university community. From table1 about 10% waste increases in 2010, 3% in 2011 and an overall 13% increase for the three years that is from 2009 to 2011. This translates to a huge amount of money spent in managing these wastes. Table one (1) shows a corresponding increase of 7% increase in terms of money spent in 2010, 1.3% for 2011 and an overall three (3) years increase of 8%.

2. MATERIALS AND METHODS:

This paper is intended to perform a grave-to-grave life-cycle assessment of solid (household) waste to determine the viability or otherwise of electrical energy from the waste generated by UTM community and investigates its suitability as an option in waste management policy for the University. The LCA, was based on the general principles of ISO 14000 ISO 14040 (2006) and ISO 14044 (2006) standards and adapting them to suit the presented case. Data used for this work are of two categories; the first is the amount of waste generated and disposed off to landfills by the university community. This data was obtained from the Office in-charge of waste management issues for the university, that includes records of waste disposed to Landfills and its related cost. Second is the data for waste composition or characterization, obtained mainly from literatures reviewed.

In a study conducted Malkahmad et-al (2010) at UTP campus to determine the waste distribution pattern and composition, the result of the studies is as shown in table2. It shows paper and food/organic waste has the highest percentage in the waste stream.

In all similar studies, food and other organic waste constitute the highest percentages for waste generated. Basri et-al, Saeed, Isa Ahmed et-al all reported a total of 74% and 61.7% of biomass/biodegradable waste in a typical Malaysian setting. Similarly, it applies to the University as seen from the work of Malkahmad et-al (2010).

2.1 LCA Methodology:

The approaches in performing LCA can be many among which the popular ones are cradle to grave and grave-to-grave. It is cradle to grave if all the inputs to the flows are from the environment without any changes due to human activities and the outputs are disposed to the environment without human intervention too Jiménez-González, C. (200). The grave-to-grave approach is when all the inputs to the flows are from the result of human activities and the outputs are disposed to the environment with or without human intervention Sundqvist, J.-O. (1999). An LCA study on waste management is of the grave-to-grave or gate-to-gate approach as the system starts from waste generation and ends with waste disposal. The upstream process involving raw materials extraction and processing not considered part of the LCA process FInnveden, G. Et-al (200) and Lundie et al. (2001, unpublished). Figure 3gives an overview of the gate-to-gate LCA process. From the figure, the input is the respective tonnages of the waste components as given in table3. While the output, is made of emissions such as green house gases and useful products if available. The system/boundary is university Technology Malaysia and the functional unit is the total waste generated for the year 2011 (3025.42 tons).

In order to perform this study, two LCA scenarios were formulated the base scenario and the WTE scenario. In the former, all generated waste was taken to landfill with no energy recovery considered while in the later an energy recovery was included to see the amount of useful electrical power that can be recovered from the waste stream.

Figure two (2) shows that all collected waste is taken to landfill in the case of base scenario. At the landfill two types of emission is involved, emission due GHG emission from chemical decomposition of the waste and water from the moisture content of the waste Lundie et al. (2001, unpublished). From figure 2 still shows that before the landfill a resource recovery facility can be included to obtain useful products from the waste, in this case electrical energy. The product of the WTE facility is an inert compound called a slag, emissions from the facility itself and useful products in terms of electrical energy as shown in fig 2.

3. SIMULATION AND MODELLING:

The simulation and modelling is based on models developed for each scenario in the LCA using GaBi^{TM} software version 4. To get a potential environmental impact from an LCA, a good definition of the input and output flows is required for each process GaBi^{TM}, Handbook (2011). For a complete modelling processes (household waste, transport, landfill, and the WTE) have to be modelled as shown by GaBi^{TM}, Handbook (2011) and Jenkins, S.D., 2007. There are inbuilt databases that are used in evaluating the impacts depending on the parameters to be monitored. For this study, emissions to air, industrial soil, fresh water, seawater, deposited goods and useful products are the parameters under study.

A. *Functional Unit:*

The functional unit is the quantified definition of the function of a product GaBi^{TM}, Handbook (2011). The functional unit for both cases is the yearly-generated waste. The FU consists of 3520.42 tonnes of waste per annum based on the 2011 data. This includes garbage and recyclables (since recycling is not in practise).

B. Boundary:

The system boundary defines the processes to be or not to be part of the LCA process GaBi^{TM}, Handbook (2011). In this studies the boundary considered is the waste collection, transportation, resource recovery and landfilling as shown in figure2.

C. Outputs:

The output of the LCA or this study is in terms of emissions (emissions to air, emission to fresh water, and emission to industrial soil) and avoided products (electricity) as in this case. As shown in figure2.
Assumptions made during the modelling stage are as follows;

- The technology used for the energy conversion is the gasification method.
- That 90% of the waste will be reduced by using the chosen technology.
- The by-products are inert and economical, example the glassy slag recovered from high-temperature gasification can be used in roofing tiles (Jenkins, S.D. 2007).
- The plant is sited near the source and hence, less emission from transportation since the amount of waste to be taken to landfill is greatly reduced.
- The landfill period is 100years.

4. RESULTS AND DISCUSSION

A. Technical and Environmental analysis

Models formed for each scenario were based on the data gathered at the life cycle inventory stage. The inputs to the models were similar for each of the scenarios developed (3520.42 tonnes/year). The components of the waste stream as shown in Table 3.

In scenario 1 all the waste generated is assumed to be taken to landfill, that is land filling is the only disposal method for the waste, except for some few waste from plastic bottles and papers which was picked by scavengers before reaching the landfills. While in the second scenario, the syngas is generated from the waste based on the gasification conversion technology. The syngas is then used in electricity generation and this will reduce the environmental effect drastically because the remaining materials to be land filled are mostly inert materials with a reduced volume too.

The amount of emissions resulting from the simulation of scenario 1, where all the waste is taken to a landfill as in table 4, shows that there is a massive emission to air from the landfills. The major sources of emission are; carbon dioxide (45%) and methane (55%) Morris, M. (1998). While there is still an amount of goods that are deposited at the landfill if assuming the landfill is allowed to degrade until, it reaches its lifetime (100 years) in this case. There are also traces of emission to industrial soil, fresh water and seawater.

For scenario 2 where it is assumed in the simulation that all plastics, organics, papers and another biodegradable material can be used in aerobic decomposition in-order to generate electricity from table5 the results obtained from the simulation shows a drastic reduction for emissions as compared to scenario 1. In terms of valuable substances as in table5 below illustrates that there can be an estimated amount of 12 MW of electricity that can be generated from the conversion of the waste generated through the process of gasification with a negative impact to the environment. The emission to air has reduced from 5 tons to -10Kg of CO_2 equivalent (53700%). While the emission to fresh water reduced from 4Kg to -2Kg of CO_2 equivalent (300%). the observation from the result is that, there is no emission to industrial soil and emission to seawater. This is because gasification technology helps in the reduction of total land required to landfill and the amount that is taken to landfills. The inert wastes taken to landfills have effect to surface water Morris, M. (1998) and Niessen, W. et al. (1996). Reduction from these emissions can be attributed to the residues after the decomposition process are inert and will result to less or no impact to environment.

5. CONCLUSIONS

This study was conducted to determine the viability of electrical energy generation from the household waste in

UTM. Two scenarios were developed to investigate this process by using life cycle assessment (LCA) tool. The models generated for this study does not include the type of technology used in the conversion process but was based on simple basis of using generated gas from the waste to produce electricity. To the best of the authors' knowledge, no LCA study has been conducted in-order to investigate the viability of electricity generation from solid waste in an institution of learning.

General conclusion from the study is summarized as follows:

• Scenario 1 gives a significant amount of emission deposits to air, water and industrial soil with the air emission been the highest.

• the least amount of emission was obtained from Scenario 2 was best, in terms of all types of emissions compared to scenario 1.

• Distance of the landfill also contributed to the high amount of emissions because in scenario 1 all the waste are taken to landfill more waste more distance to be travelled and more fuel consumption but Scenario 2 has less waste since it is the residue after decomposition that will be taken to landfill hence less distance of travel. The results of scenario two which is the main focuss of the study shows an electrical energy recovery of the about 2.2 MW can be generated from the total waste accrued from the university community. Also it can be seen that LCA can be successfully used to evaluate electrical energy potential cum environmental impact of waste.

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Table 2 Tonnage and Cost of UTM Waste (3 yrs period) Harta Bina (2011).

Year	Tonnage	% Change	Cost '000 (RM)	% Change
2009	3116.08	-	393	-
2010	3425.28	10	420	7
2011	3520.42	13 (09), 3 (10)	425.8	8 (09), 1.3 (10)

Table 3 Waste Composition at UTP campus Malkahmad et-al (2010) .

Component	Percentage
Paper	40
Food/Organic	30
Plastic	15
Cardboard	10
Tin/Aluminum	4
Glass	1
Metal	<1

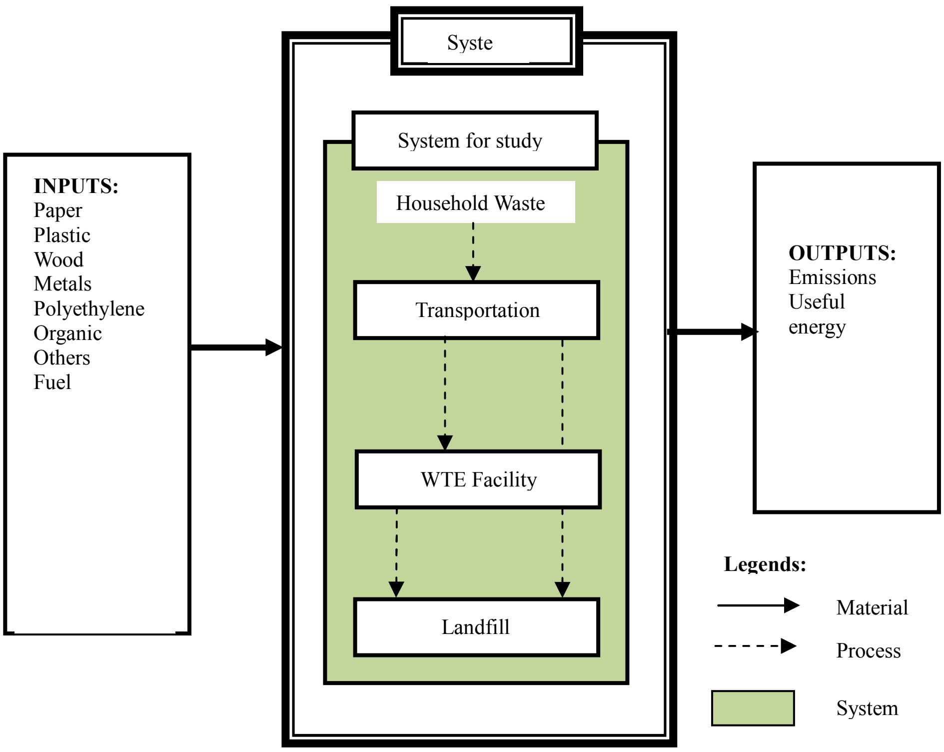

Figure 2; General LCA Process Overview.

Table 4; Waste Components in Percentages 2011

Components	Percentage	Tonnage/year
Paper	18.4	647.8
Plastics	17.62	619.6
Wood	2.6	91.5
Metal	<1	30.3
Polyethylene	19.7	697.0
Organic/Food	34.9	1228.6
Others	4.6	161.9

Table 5; Simulation Results of Scenario 1.

Monitoring Parameter	Value (Kg)
Emission to industrial soil	31.3
Emission to Sea Water	0.9
Emission to Fresh Water	4.1
Emission to Air	5,364
Deposited Goods	390.7
Valuable substance	-

Table 6; Emission Result Scenario 2.

Monitoring Parameters	Value
Electric Power	12MW
Emission to air	-10Kg
Emission to fresh water	-2Kg