Towards Low Carbon Society in Iskandar Malaysia: Implementation and Feasibility of Community Food Waste Composting

Rebecca Kar Yee GOH[1], , *Jeng-Shiun LIM*[1,6], *Wai Shin HO*[2,6]**,** *Chew-Tin LEE**[1,6] , *Haslenda HASHIM*[1,6], *Nur Naha ABU MANSOR*[3], *Chin Siong HO*[4,6], *Abdul Rahim RAMLI*[4], *Fatin Aliah PHANG*[5,6], *Zainura ZAINON NOOR*[1,6], *Fujiwara TAKESHI*[7]

[1]Faculty of Chemical Engineering, Universiti Teknologi Malaysia 81310 Johor Bahru, Johor. Malaysia.

[2]Faculty of Petroluem and Renewable Energy Engineering, Universiti Teknologi Malaysia 81310 Johor Bahru, Johor. Malaysia.

[3]Faculty of Management, Universiti Teknologi Malaysia 81310 Johor Bahru, Johor. Malaysia.

[4]Faculty of Built Environment, Universiti Teknologi Malaysia 81310 Johor Bahru, Johor. Malaysia.

[5]Faculty of Education, Universiti Teknologi Malaysia 81310 Johor Bahru, Johor. Malaysia.

[6]UTM Low Carbon Asia Research Centre, Universiti Teknologi Malaysia 81310 Johor Bahru, Johor. Malaysia.

[7]Solid Waste Management Research Center, Graduate School of Environmental Science, Okayama University, Okayama, Japan.

*Email for Corresponding author: ctlee@utm.my

Rapid population growth and urbanisation have generated large amount of municipal solid waste (MSW) in many cities. Up to 40-60% of Malaysia's MSW is reported as organic or food waste where such waste is highly putrescible and can cause bad odour and public health issue if its disposal is delayed. In this study, the implementation of community food waste composting in a village within Iskandar Malaysia is presented as a case study to showcase effective MSW management and mitigation of GHG emission. The selected village, Felda Taib Andak (FTA), is located within a palm oil plantation and a crude palm oil (CPO) processing plant. This project showcases a community-composting prototype to compost food and palm wastes into valuable high quality compost. The objective of this article is to highlight the impact of community based composting project to the economic and environment of key stakeholders in community, i.e., residents, oil palm plantation and palm oil mill by comparing two different scenarios. First scenario is the baseline case, where all the domestic waste is sent to landfill site. In the second scenario, composting project is implemented. The results show that the annual production cost for a small scale community composting project (1.5 t/mth of compost) is around RM 73,259. This project can reduce 54% of the residents' waste tipping fees and 50% of oil palm plantations' chemical fertiliser cost. On the environmental aspect, it could potentially reduce the greenhouse gases up to 65%. The results indicate the positive impacts of community based small scale composting project. Despite the encouraging result, further assessment needs to be done for larger scale composting project.

Keywords: Low Carbon Society, community project, composting, GHG emission reduction, sustainability, cost-benefit analysis

1. Introduction

Municipal solid waste (MSW), commonly known as refuse or rubbish is discarded from residential, commercial, and institutional areas (Fodor and Klemeš, 2012). As the global population increases dramatically, changes are seen in the aspects of consumption patterns, economic development, rapid urbanisation and industrialisation. In early times, the removal of solid waste was not a significant issue as the population was small and there was vast amount of land available for the assimilation for solid waste (Tchobanoglous et al., 1993). With the rapid growing population rate and urbanization progress, it is indispensable that the availability of land is getting less even to serve the purpose of providing space for solid waste disposed from the increased population alone. With the world population at six billion in 2001, 46% of this population resides in urban areas (HMGN, 2003). Global MSW generated in 1997 was about 0.49 billion tons with an estimated annual growth rate of 3.2–4.5 % in developed nations and 2–3 % in developing nations (Suocheng et al., 2001). Characteristics of solid waste generated differ with time due to rapid urbanization and industrialization. As a result, the solid waste management system (SWMS) needs to be updated with the waste quality, quantity and composition.

A typical solid waste management system in the developing countries faces various problems, including small collection coverage and infrequent collection services, crude open dumping and burning without air and water pollution control, the breeding of flies and vermin, and the handling and control of informal waste picking (Ogawa, 2000). As urbanization develops, the management of solid waste is becoming a serious environmental and public health issue in the developed areas. These complications are contributed by technical, financial, institutional, economic, and social factors which is the bane to the improvement of effective solid waste management systems (Ogawa, 2000). MSW is being generated at a rate that outstrips the ability of the natural environment to assimilate it and municipal authorities to manage it.

MSW has become a major issue in the development plans worldwide, especially in rapidly developing cities. Malaysia is one of the most successful countries in transition. Rising economic growth and low unemployment rates due to steady political conditions and abundance in natural resources makes the country on par with other developed countries (Hamatschek, 2010). Malaysia is undergoing rapid industrialisation and urbanisation consequently causing detrimental effects on the environment from the increase of waste generation (Abdullah, 1995). The daily waste generation has shown an upward trend. Waste generation was 16,200t/d in year 2001. This amount increased to 19,100t/d in 2005, 17,000t/d in 2007 and 21,000t/d in 2009 (Ahmad, 2011). Due to the increased population growth rate, the daily solid waste generated is estimated to rise to 31,000t/d by 2020 (Johari, 2012). Landfill is considered the easiest and cheapest technique to handle the waste in large quantities. On the other hand, there is public opposition and a shortage of available land for disposal purposes. The over dependency on landfilling and inappropriate waste disposal have been continuously pressing the environmental, health and safety issues for the citizens. It is also amplifying the share of total global anthropogenic greenhouse gases (GHGs) emission, which is caused by the production of methane gas (CH4) through the anaerobic decomposition of solid waste in landfills. GHGs emission in the waste sector increased 54% from 1990 to 2008 (Haslenda et al., 2015). Meanwhile, comparing the sub-sectors within the waste sector, the main release of GHGs come from waste landfill sites, which contributed up to 90% of the total emission from the waste sector in Malaysia (Johari, 2012). The present practice for MSW management is still depending on landfilling in many developing countries including for Malaysia. The operating cost for MSW management in Malaysia was reported approximately at USD 300 M in the year 2014 alone. To date, Malaysia is at the stage of transition towards sustainable and effective MSW management. Many cities including Putrajaya and the Iskandar Malaysia region have launched their Low Carbon Society Blueprint where effective MSW management is one of the key pillars to sustain efficient cities for living.

The aim of this study is to implement a community composting prototype in a sub-urban community in Malaysia by evaluating the socio-economic and environmental impacts. This is a joint project conducted among the researchers from Universiti Teknoloti Malaysia Low Carbon Asia Research Center (UTM-LCS) and the LCS committee of the community. Food waste composting is showcased as an effective MSW management for creation of value-added product from waste and also for mitigation of GHGs emission, as described in Section 2. Section 2 also highlights the methodology to perform the economic and environmental performance emission Section 3 discussed about the key findings of this community project. Section 4 then concludes the key impacts of this project.

2. Methodology

A community composting project in a community is evaluated based on the economic and environmental performance. At first, the selection of community and composting site are presented followed by the description of two scenarios. The data and calculations to evaluate the economic and environmental impacts for both Scenario 1 and 2 are presented.

2.1 Selection of community and composting site

A sub-urban community, Felda Taib Andak (FTA), located within the vicinity of a palm oil plantation and a crude palm oil (CPO) factory in Kulaijaya, Johor State, Malaysia, was selected for this community composting project. This community is also located within the southern economic corridor of Iskandar Malaysia. The community was exposed to the concept of Low Carbon Society (LCS) since year 2011 where researchers from Universiti Teknologi Malaysia (UTM) Low Carbon Asia Research Centre (UTM-LCS) proposed several actions to develop this village as a LCS model in Iskandar Malaysia (Ibrahim and Anis, 2013; UTM LCS Blueprint, 2012). Composting represents one of the Dozen LCS actions as means of efficient solid waste management and mitigation of GHGs emission.

The composting site was selected within a palm plantation owned by one of the key LCS committee member in FTA as supported by the committee. The composting site of about 1000 ft^2, located 7km away from the FTA community, was provided by the FTA LCS committee. Any benefits generated from the program would be co-shared among the LCS committee of FTA. The land owner also offered partial co-sharing of costs for waste collection and manpower for the composting work, as both resources (transportation vehicles and labour) were readily exist to transport the oil palm fresh fruit bunch (FFB) from the plantation to the CPO factory located within the residential area of FTA.

2.2 Scenario analysis

The community comprises of approximately 600 households. It currently pays about RM4,000/month (RM1≈USD0.27) for the waste tipping cost of RM120/t to the nearby sanitary landfill site, hence the total waste produced is approximately 33.3t/month. Typically waste collection is two times per week and about 4t per trip of collection by the appointed waste collection company. Scenario 1 serves as the baseline case representing the current municipal waste management practice, where all the waste is collected by the existing contractor and sent to the nearby landfill site. Whereas for Scenario 2, a community composting is implemented in FTA based on a collaborative model where part of the project cost is co-shared by the community in addition to the grants secured by the researchers from UTM-LCS as technology and knowledge provider.

Fig.1 depicts the schematic diagram for Scenario 1 where the food waste in MSW generated is sent to the landfill site. FTA is also abundant in agricultural waste produced from the CPO factory. The agricultural waste, mainly the shredded EFB can be selected as a low cost bulking material for the composting process. The CPO factory has the process capacity of 30t/hr (138kt/yr) for FFB in the year of 2013 (RSPO Report, 2013), about 22% will be the EFB (30kt/yr). Part of the EFB waste is sold at low cost (~RM10-25/t) to other industries or used as mulching materials on the plantation. In the oil palm plantation, chemical fertilisers are applied to increase the production yield of fresh FFB.

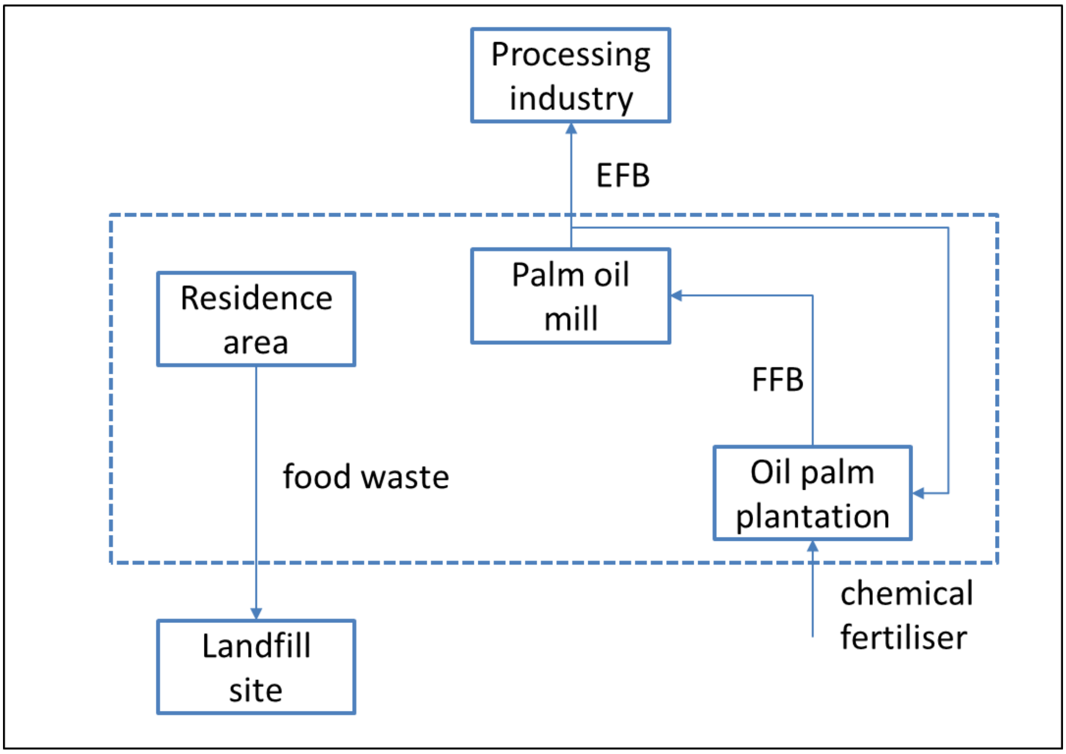

Fig.1. Scenario 1 representing the current organic waste management in FTA

Scenario 2 as depicted in Fig. 2 showcases a LCS model by incorporating composting in the community. With the inception of composting site, the organic waste can be collected for composting among the key stakeholders in an integrated way, i.e. the residents, palm oil mill and oil palm plantation. The food waste and EFB can now be channelled to the composting site to produce compost for application in the oil palm plantation to improve the yield of FFB. Although compost is not likely to replace the use of chemical fertiliser completely, it can complement the nutrient demand of the soil and hence has a potential to replace a portion of cost for chemical fertiliser.

In this case study, only 30 (5%) households were included and trained for food waste segregation at source via workshop session, hence total elimination of the MSW tipping cost to the landfill site is still not possible. As a results, the potential saving of waste tipping cost was calculated on pro-rata basis against the total tipping cost (RM4,000/mth) for comparison of potential economic impact between Scenario 1 and 2.

It is envisaged that the implementation of composting project under Scenario 2 can improve the economic and environmental performance of the community; notably this effort reduce the portion of organic waste to the landfill hence mitigating methane gas and GHGs emission.

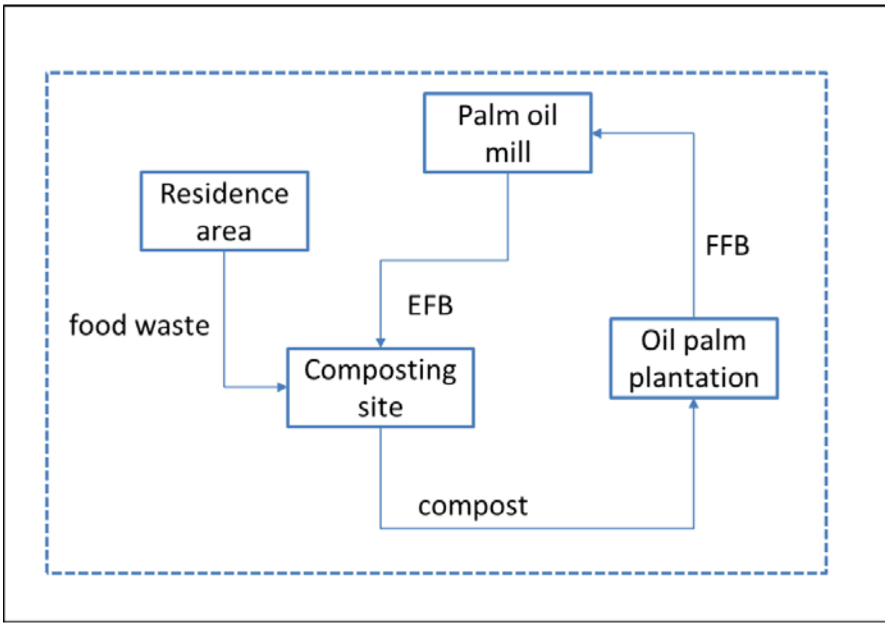

Fig.2. Scenario 2: Incorporating community composting project as an innovative model to promote socio-economic and environmental impacts for FTA

2.3 Community engagement and workshop sessions

A serial of community engagement sessions were conducted during the first three months. It mainly involved discussion with the LCS committee to build consensus on establishing the composting site as joint project with some cost co-sharing, responsibility identification, drafting of memorandum of understanding, compost site selection and overall implementation from 3R practices, food waste segregation, waste collection till the completion of composting process. Initially a few education workshops were conducted to explain to the community on the concept of low carbon society, the need of 3R (reduce, reuse and recycling) and how food waste composting can reduce GHGs emission at the landfill site. A serial of 3R workshops were conducted, up to 126 households were trained on waste segregation for the recyclable (paper, plastic and metal). A 3R competition was jointly organised with Iskandar Region Development Agency (IRDA), a government agency with a role to catalyse the development in Iskandar Malaysia. The buyback process of the recyclable items was facilitated by an existing local informal recycler where the revenue of selling was given to each household. The residential block with top three highest amounts (in kg) of recyclable items were awarded with prizes and certificates.

Prior to the composting process, a workshop on food waste segregation together with the educational session on LCS was conducted in Seelong Block where 30 households have participated. Seelong Block was selected for the training to facilitate waste collection within the households of close proximity. In addition, the residents in this block have been most active for LCS activities. To ensure the commitment of supplying the segregated food waste for scheduled collection (on every Monday, Wednesday and Saturday), the participants filled in the free registration forms to become volunteers for the food waste segregation where the co-benefits enjoyed by them were explained (eg. free provision of 10kg compost/month to each participating household). In addition, there were also engagement sessions with the manager for FTA to ensure smooth project execution; with the manager of CPO factory to secure EFB for composting; and with the manager of Felda palm plantation to discuss on potential application of compost on the plantation. The total cost involved in all engagement sessions was approximately RM14,000 mainly for materials and event organisation which excluded the cost of man power.

2.4 Data collection

A typical routine of the composting process is followed by collecting the food waste segregated by 30 residents in Block Seelong (10/8) and shredded EFB waste (up to 2t/mth) was kindly supplied by the CPO factory at FTA as depicted in Fig.3.

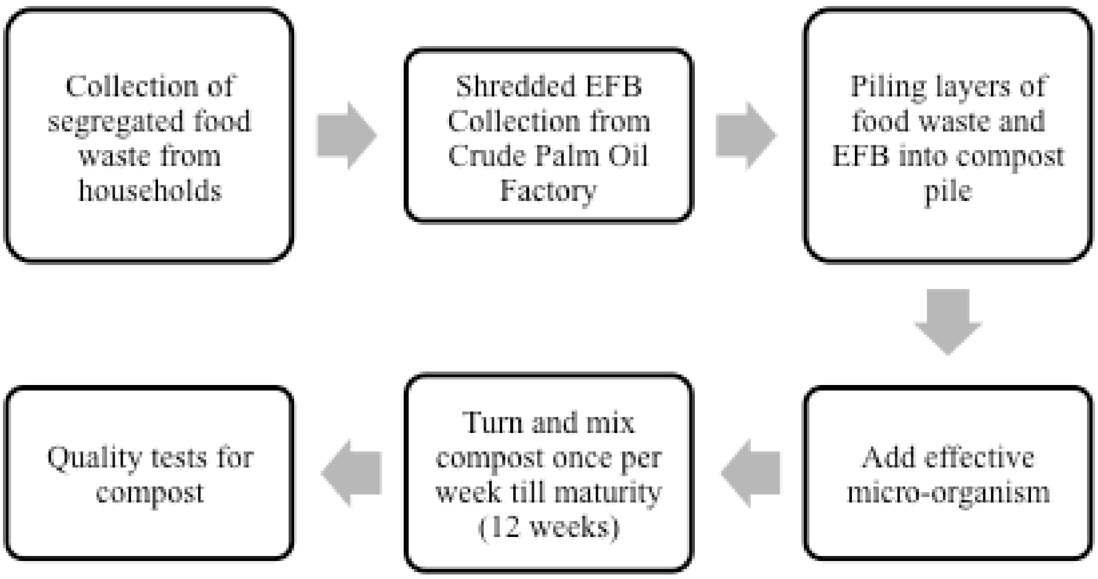

Fig.3. The methodology of community composting in FTA

The cost for the entire composting process, started from waste collection till the completion of composting and compost testing, is calculated based on the fixed and variable cost as depicted in Fig.4. In addition, the GHGs emission in terms of carbon dioxide equivalent (CO2e) is calculated for both scenarios (1 & 2) to evaluate the environmental impacts. The GHGs emission for a typical composting project can be computed from various sources, this includes the usage of fuel due to the transportation of waste to composting site, operation of machinery equipment and the fugitive emissions due to the composting process itself. However, there is no fuel consumption for machinery equipment, as the composting process relied mainly on labour operation. Hence the emission is limited to the fuel consumption of transportation and fugitive emission.

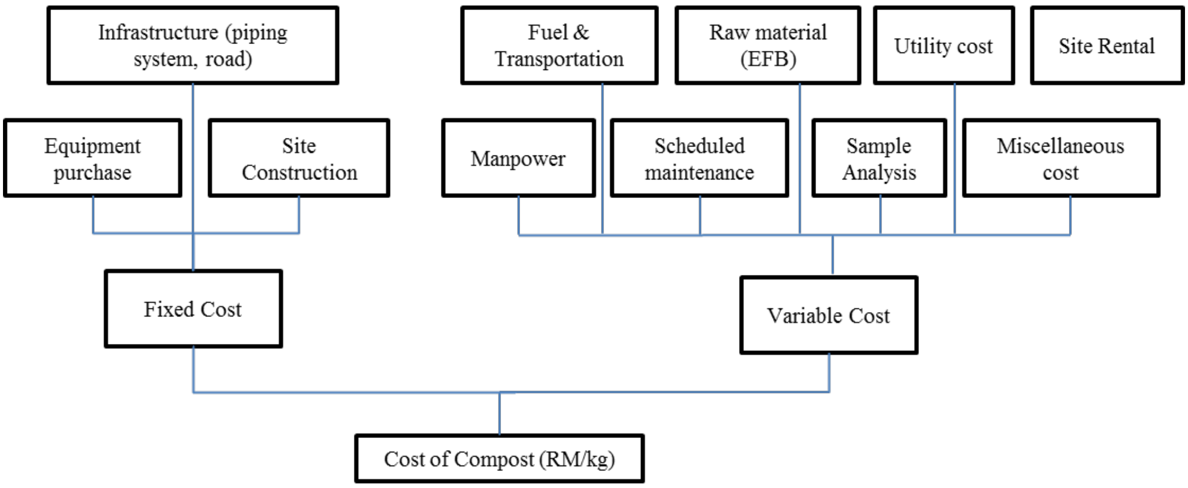

Fig.4. Key data to compute the cost of community composting.

2. 5 Evaluation of economic and environmental performance

The cost of the compost in Ringgit Malaysia (RM) per kg can be calculated based on Eq.1:

(1)

Eq.2 shows the general equation to calculate the GHGs emission per kg of compost produced, *E* (kg CO_2/kg compost), where is the fuel consumption for transportation, and is the emission factor of GHGs for specific fuel.

(2)

Eq.3 shows the equation to calculate the methane generation potential from landfill (IPCC, 2006),

$$L_o = MCF \times DOC \times DOC_f \times F \times SF \quad (3)$$

where L_o is the methane generation potential (t CH_4/t waste), MCF is the methane correction factor (fraction), DOC is the fraction of degradable organic carbon in the waste (weight fraction), F is the fraction of methane in landfill gas, SF is the stoichiometric factor.

3. Findings and Results

3.1 Financial impact assessment

Based on the collected data, the economic aspects of both scenarios are evaluated. Table 1 shows the detailed cost breakdown from both scenarios, whereas Table 2 highlights the key impacts of implementing the composting project to FTA community.

Based on the scenario analysis, it is evident that Scenario 2 reveals great benefits in terms of economic impacts. Table 1 shows that the typical cost of a pilot scale composting plant is about RM 75,161 for a year with the production scale of 1.5 t compost per month on average. Table 2 predicts the potential economic benefits from the compost product if applied to the palm oil plantations to replace a portion of chemical fertiliser, assuming that such replacement would not affect the yield of the FFB of the palm tree. This economic impact translates to the potential saving of fertiliser of RM 18,000, which is 50% saving from its initial cost. Also, the potential saving of waste tipping fee of RM 1,300 for 30 household per year (refer Table 2) as food waste was segregated for the composting process.

Table 1 Cost breakdown for Scenario 1 and Scenario 2

Cost items	**Annual Cost (RM/yr)**	**Remarks**
Scenario 1		
Residents: Waste tipping fees	2,400	RM80/household/yr; tipping fee for 30 households were considered
Oil palm plantation: Chemical Fertiliser cost	18,000	RM 1000/t of chemical fertiliser; assume the basis of 3t/month is needed (RM36,000/month), assume 50% of compost replacement
Scenario 2		
Capital Expenses		
Site Construction	952	RM 19,032 for 20 years
Infrastructure	150	RM 3,000 for 20 years
Engagement and Workshop sessions	700	RM14,000 was spent during the 1-yr project with intensive activities
Total Capital Expenses for Senario 2	**1,802**	Capital cost was normalised for 20 years
Operating Expenses		
Maintenance	1,000	For transportation vehicles, site, miscellaneous.
Utility	0	No electricity is required. Rain water harvesting to collect the water.
Manpower	36,000	1 site manager and 2 workers
Raw material	240	RM10/t of EFB; 2t/mth
Miscellaneous	5,148	Canvas, EM, and garden tools
Compost Analysis	18,871	For compost quality testing for C/N ratio, pathogen test, proximate analyses and germination tests
Transportation cost & fuel	12,000	Actual cost is estimated as RM2000/month, although in this study RM6,000 was spent as the cost was co-shared with the community
Total Operating Expenses	**73,259**	
Total Expenses for Scenario 2 (RM)	**75,161**	
Total compost produced (t/yr)	**18**	Production rate: 1.5t/mth
Cost of compost (RM/t)	**4,175**	
Cost of compost (RM/kg)	**4.18**	

Table 2

Financial impact analysis of implementing a community based composting project (30 households basis in FTA)

	Scenario 1	**Scenario 2**	**Saving (RM/yr)**	**Saving (%)**
Residents				
Amount of domestic waste (t/yr)	24	24		
Organic waste (%)	60	60		
Organic waste segregated for composting (%)	0	90		
Total waste to landfill (t/yr)*	24	11		
Waste tipping fees (RM/yr)	2,400	1,100	1,300	54
Oil palm plantation				
Amount of purchased chemical fertiliser (t/mth)	3	1.5		
Amount of purchased chemical fertiliser (t/yr)	36	18		
Application of compost (t/mth)	0	1.5		
Application of compost (t/yr)	0	18		
Purchase of chemical fertiliser (RM/yr)	36,000	18,000	18,000	50

*The total segregated food waste for composting under Scenario 2 is about 13 t/y (1.08 t/mth)

3.2 Environmental impact assessment

Based on the collected data, the environmental aspects of both scenarios are evaluated based on the GHGs emissions, as presented in Table 3 and 4. Table 3 shows the overall GHGs emission potential for Scenario 1 (waste to landfill) is 1,474 kg CO_2e/t, due to the emission from the transportation and at the landfill site. Whereas Table 4 shows the overall GHGs emissions potential for Scenario 2 (food waste to composting) is 510 kg CO_2e/t waste. This result reveals composting as a promising strategy to significantly reduce the GHGs emission by about 65 % for solid waste management. However, the GHGs emission from the composting process is mainly based on the data obtained from the literature. Detailed environmental impact need to be further evaluated by collecting on-site emissions data over longer period of time.

Table 3

GHGs emission potential for Scenario 1 (landfill)

Items	**Value**	**Remarks**
Methane correction factor, MCF (fraction)	0.6	(IPCC, 2006)
Fraction of degradable organic carbon in the waste, DOC (weight fraction)	0.15	Food waste, (IPCC, 2006)
Fraction of DOC that decomposes, DOC_f (weight fraction)	0.5	(IPCC, 2006)
Fraction of methane in landfill gas, F	0.5	Uncategorised landfill site, (IPCC, 2006)
Stoichiometric factor, SF	16/12	(IPCC, 2006)
Methane generation potential, Lo (t CH_4/t waste)	0.03	Eq 3
Methane generation potential, Lo (kg CH_4/t waste)	30	
CO_2 generation potential from landfill site (kg CO_2e/t waste)	630	GWP methane for 100 year is 21 t CO_2e/t CH4 (EPA, 2010; U.S. Department of State, 2007)
CO_2 generation potential from transportation (kg CO_2e/t waste)	844	Based on transportation emission factor from Table 3, assuming the distance between FTA and

		composting site is half the distance between FTA and the landfill site.
Total GHG emissions potential (kg CO_2e/t waste)	1,474	

Table 4

GHGs emission potential for Scenario 2 (composting)

Items	Value	Remarks
Diesel consumption due to transportation (l)	150	
CO_2 emissions due to diesel consumption (kg CO_2)	402	F for diesel is 2.68 kg CO_2/l diesel (Saunders et al, 2007)
Petrol consumption due to transportation (l)	100	
CO_2 emissions due to fuel consumption (kg CO_2)	231	EF for petrol is 2.31 kg CO_2/l petrol (Saunders et al, 2007)
Total emission due to transportation (kg CO_2e)	633	
CO_2 generation potential for transportation (kg CO2e/t waste)	422	1.5 t compost/mth
CO_2 generation potential for composting process (kg CO_2e/t compost)	88	Methane and nitrous oxide emissions during composting is 88 kg CO2e/ton (Luske, 2010)
Total GHG emissions potential (kg CO_2e/t compost)	510	

4. Conclusion

In a nutshell, this study showcased a community composting project as a viable way to reduce the amount of organic waste to the landfill while mitigating up to 65 % of GHG emission. The project successfully transfer the technology and knowledge to the community where the good practice of 3R (reduce, reuse and recycling) was also introduced. Ideally, the model could be sustained in long run by the co-benefits generated via the reduction of waste tipping fee and cost saving of fertiliser (reduced use of chemical fertiliser) in the palm plantation. The challenges remain for enhancing the cost efficiency by process scale-up and to sustaining the 3R good practices by the community notably in terms of food waste segregation at source and recycling of the recyclable material.

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