Feasibility study of integrated biogas and composting plant at community scale in Malaysia

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Malaysia is in a transition state towards a more developed country which stress on sustainable development. The Malaysia government has introduced several policies related to the installation of renewable energy to secure its energy demand, which has an annual growth rate of 8.1 %. In the Iskandar region in Johor, low carbon projects have been continuously implemented under the low carbon society blueprint for Iskandar Malaysia. The selected village, Felda Taib Andak, is located within a palm oil plantation and a crude palm oil processing mill where a community-composting prototype had been successfully implemented in 2011. The environmental and economic performance of the community-composting project were analysed in our previous study. The co-composting of food waste from residential area with the empty fruit bunches from the plantation showed a reduction potential of 71.64 % on greenhouse gas emission as compared to landfill in our previous study. In this study, the financial analysis is extended based on scenario with the integration of anaerobic digestion as a mean of energy recovery. A total of three scenarios is analysed in terms of their environmental and economic performances.

Keywords: organic waste management, food waste, oil palm biomass, biogas, composting

1. Introduction:

Malaysia is currently actively pursuing its goal towards a 45 % reduction of CO_2 emissions by 2030 to address climate change and global warming. According to the Federal Department of Town and Country Planning, a satisfactory reduction of 33 % had been achieved in 2015, as compared to the CO_2 emission level in 2005 (Bernama, 2016). However, following continuous development and urbanisation, the generation of municipal solid waste (MSW) is expected to exceed 9 Mt/ yr in 2020 (Saeed et al., 2009). Landfill remains the main disposal options but it is not sustainable in the future due to the increase in waste generation, greenhouse gas (GHG) emission and the scarcity of land. Most of the landfills in Malaysia are not equipped with the recovery system for landfill gas.

Based on the Low Carbon Society (LCS) Blueprint for Iskandar Malaysia 2015 (LCS, 2013), by 2025, the total GHG emission from the waste sector will be 31.3 Mt CO_2-eq at the business-as-usual (BAU) scenario. The incorporation of renewable energy based on waste to energy, for long-term availability and sustainability, are palm oil biomass, municipal solid waste (MSW) and sewage sludge. Composting at home and decentralised composting plant are one of the measures contributing to the reduction of MSW to landfill, the former at 5 % and the later at 3 %.

The AD in Malaysia is mostly on animal manure, oil palm plantation and sludge. FELDA has been the leading company in practising green technology in Malaysia. FELDA currently have twelve biogas trapping plants, two power plants, six compost plants, two mini gasifier plants and one fuel pellet plant, all based on biomass waste as feedstocks. The Biogas Power Plant (biogas digester lagoon) by FELDA Umas in Sabah, which has started its operation since 2012, can generate 1,000 m^3 of biogas per hour, supplying electricity to 3,000 households in the mill area, which has approximately 15,000 people. This plant initially cost RM14M. It is expected that the plant can receive a FiT with a quota of 9.2 MW in 2014, 7.2 MW in 2015 and 5.6 MW in 2016. NIRAS has set up a biogas plant aiming at the biomass from the 250,000 pigs owned by farmers that include pig manure and sewage sludge from the slaughterhouse. It is expected to be able to collect around 3750 m^3 of pig manure and 250 m^3 of wastewater/ day from the slaughter house which can be provided to the biogas plant. The Subang Jaya Municipal Council (MPSJ) has initiated more biomass project in town that includes garden waste composting, anaerobic digestion biogas, vermicomposting, food waste composting and cooking oil recycling. One of the pilot projects includes the setting up of an anaerobic digestion biogas plant at Pasar Awam Seri Serdang (wet market) where the meat waste from the market is collected and processed in the biogas plant for electricity generation.

In the Iskandar region located in the Johor State, Malaysia, a series of effort has been on-going to introduce the low carbon concept to the communities within the region. The FELDA Taib Andak (FTA) is a sub-urban community where its primary economic activity is from oil palm plantation. From the previous composting project, (Bong et al., 2016), the low carbon concept, 3Rs and community composting have been introduced. The social impact was presented through the economic analysis and environmental analysis. In this study, the authors extended the economic analysis to incorporate anaerobic digestion (AD) and composting as a mean of sustainable waste management for food waste and oil palm biomass.

2. Methods

2.1 Project background

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 Kulai Jaya, Johor, Malaysia, was selected for this study. The community was continuously exposed to the low carbon society concept since the year 2011. A small-scale centralised composting was established in 2012. The composting site is currently receiving 2 t of food waste (FW) and 2 t of empty fruit bunches (EFB) from oil palm, and is capable of producing 1.5 t compost per month.

The FTA community has approximately 600 households and has a population equivalent of 3,000 people. The community is expected to produce 72 t of municipal solid waste (MSW) per year, where 30 t is of FW, based on the average MSW production rate of 0.8 kg/ppl·d in Malaysia. The nearby crude palm oil (CPO) processing plant process 10,000 t of oil palm fresh fruit bunch (FFB) and generates around 460 t EFB per month, where 5 t of FFB is reported to produce 0.23 t EFB and 0.65 t palm oil mill effluent (POME) (Yusoff, 2006).

The organic waste, including FW and EFB, offers high waste valorisation value. Through the co-implementation of anaerobic digestion and composting, renewable energy in the form of biogas and biofertiliser in the form of compost can be recovered, which contributes to a waste-to-resource oriented community. Three scenarios are depicted as in Figure 1 to conduct the feasibility study of the co-implementation of AD and composting for managing the waste sustainably.

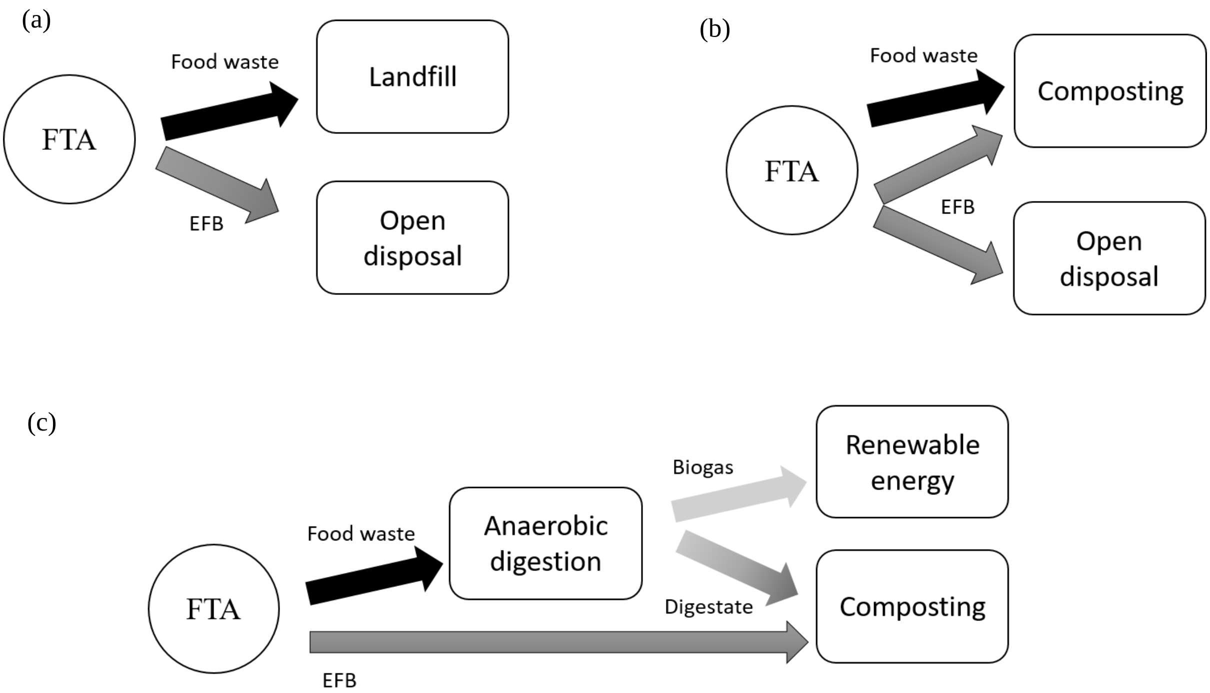

Figure 1. Three scenarios modelled for the management of solid waste at FTA.

Figure 1 (a) represents the business-as-usual (BaU) scenario where the FW is disposed to the landfill without landfill gas recovery where the EFB is open-dumped. Figure 1 (b) presents the current practice where the FW and partial EFB are sent to composting. Figure 1 (c) illustrates the proposed co-integration of AD and composting, where labile organic waste such as FW are sent for AD and the produced digestate is co-composted with EFB.

2.2 Economic analysis

The economic analysis took into the account on the assessment for all three scenarios to provide the information on the initial costing and potential revenue generation which served as the references to the local authorities or potential investors. The required information to tabulate the economic analysis is presented in Table 1.

Table 1. Input data to perform economic analysis.

Scenario	Waste category	Amount (t/mth)	Treatment	Biogas produced	Digestate produced	Compost produced
1	FW	30	Landfill	-	-	-
	EFB	30				
2	FW	30	Composting	-	-	22.5 t (Bong

	EFB	30				et al., 2016)
3	FW	30	AD	43.86 kWh	-	-
	EFB+ digestate	30	Composting	-	-	22.5 t

*The maximum receiving capacity for the composting is 30 t FW and 30 t EFB (Bong et al., 2016)

* biogas production= 98 m^3/ t (Banks et al., 2011)

1 m^3= 19 Mj

1 kWh= 1 Mj/3.6, so 3,000 m^3 biogas= ~160 Mj/ 3.6= 43.86 kWh

3. Results and Discussion

The cost and potential revenues per year from all three scenarios are tabulated in Table 2.

Input	Scenario			Remark
	1	2	3	
		FEEDSTOCK		
1) Biogas	-	-	230,528.16 kW	43.86x365x24x0.6
2) Compost	-	270	270 t	22.5 t x 12
		COST		
1) Capital cost	-	80,000.00	70,000.00	Normalised for 10 y
2) Operational cost	-	9500.00	34,000.00	
3) Feedstock cost	-	2100.00	2100.00	1 t EFB= MYR20 1 t FW= MYR50
4) Waste tipping fee	21, 600.00	0	0	Tipping fee for food waste in MSW is MYR 120/t, There is no tipping fee for EFB as it is typically left for open dumping at the mill.
		REVENUE		
1) FiT biogas to grid	0	0	0.28 x 43.86 x 365 d x 24 h = 64,800.00	MYR 0.28 for 1 kWh 60 % CH_4
2) Compost sale	0	270,000	270,000	Compost selling price = MYR1,000/t, MYR1/kg
TOTAL	+21,600	-178,400	-228,700	

AD offers another stream of revenue due to the production of biogas that can be converted into the renewable energy and fed into the national grid. The accessibility to the grid is crucial for the sale of energy to grid. In the absence of such connection, alternatives such as the direct burning of the biogas produced to prevent contribution to global warming might be practised where the compost sale will be the only revenue stream. The biogas could be channelled through pipelines where the biogas could be used as cooking gas. These aspects would require further study to perform a complete economic assessment of the feasibility of AD technology in FTA, e.g. extra cost for the further compression of biogas for storage.

The capital cost and operation cost the composting was lower as compared to AD. This was possible due to the joint-venture model among the local communities, government and university. Partial of the cost was absorbed by the different parties, including construction, machinery, the vehicles for waste transportation and labour.

4. Conclusion

In conclusion, the AD technology offers the greater advantage regarding financial perspective as it generates revenue from the sale of energy to grid and sale of compost. The limitation of the study is that the consideration of accessibility of grid and the potential alternative to using the biogas as cooking gas are not considered. There is also a need for the study on the environmental impact, especially the global warming potential, for a better comparison among the waste management practices for the management logistic in FTA. To facilitate the utilisation of the AD and the composting technologies in sub-urban communities, development of guidelines for the installation, operation, maintenance and also health and safety issues on these systems are required.

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