A STRATEGIC PARTNERSHIP IN IMPLEMENTING WASTE-TO-ENERGY (WTE) TECHNOLOGY IN PENANG, MALAYSIA

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ABSTRACT

Penang municipal solid waste generation is increasing as population and urbanization increased. The current landfill to accommodate Penang municipal solid waste is expected to reach its maximum capacity. Due to limited land available, Penang should consider implementing an alternative method in managing municipal solid waste. Therefore, this paper aims to study the applicability of Waste-to-Energy technology implemented by Japan in Penang context. Waste-to-Energy technology has proved its capability in reducing waste disposal into landfill and at the same time able to recover energy for various purposes. Current Waste-to-Energy technology also is able to mitigate the emission of greenhouse gases and other environmental impacts. The proposed Waste-to-Energy technology can guide Penang local authorities to consider for next municipal solid waste disposal method.

Keywords: Energy Recovery, Environmental Impact, Energy from Waste, Greenhouse Gases, Municipal Solid Waste.

INTRODUCTION

Worldometers.info (2017) estimated that the world population is expected to increase from 7.5 billion in 2017 to 9.7 billion in 2050, where Asian countries contributed almost 60 percent of the current world population. This immense figure gives a stress situation to every country across the world especially in managing Municipal Solid Waste (MSW) generation. According to EPA (2016), MSW also can be called trash or garbage consisting of everyday items that generated from domestic, industrial and commercial, and services institutions such as hospitals and schools.

The amount of MSW generation across the world is caused by the growth of population and urbanization together with the improvement of the individual living quality of life. On average, the developed countries typically generated 521.95-759.2 kg per person per year and 109.5-525.6 kg per person per year typically generated by the developing countries (Karak et al., 2012). A recent study by Karak et al. (2012) estimated that the world MSW generation exceeds 2 billion tons per year, which will rise to approximately 27 billion tons in the year 2050. This significant number will surely give environmental impacts if the waste is not treated properly.

Current waste disposal and treatment have been proved that generated waste can be extracted into unconventional energy as well as can reduce the emission of greenhouse gases and

environmental impacts. It also saves land usage for waste disposal since waste is treated in one big container. Waste-To-Energy (WTE) technology is widely implemented especially in developed nations where treated waste is converted into electricity or heat (Conserve Energy Future, 2016). By using this developing technology, waste can be disposed and compressed, as well as attempting the energy generated from them and reduce environmental impacts.

Penang is one of the most urbanized states in Malaysia. Its strategic situation at the Northern part of Peninsular Malaysia together with many industrial and commercial activities has attracted people to migrate into Penang. It is also connected with good road, highway, and railway, together with airport and seaport facilities has even escalated connection between Penang and the neighbouring states. Penang also has many business and trading activities which offer many employment opportunities and has become a preferable place to work and live.

The exponential growth of Penang population has also increased the amount of MSW generation in Penang. To date, Penang waste generation rate is 1.5 to 1.8 kg per person per day which is expected to rise to 1.1 million metric tons in 2020 (PPCC, 2016). This number increased by 15 percent of the amount MSW generated in 2011. Even though the amount of recycling waste able to recover is also increased, but there is still a huge amount of waste disposal being dump into landfill (PGC, 2011).

Currently, Penang has one operating transfer station, one Construction and Demolition (C&D), Green, and Bulky Waste landfill, and one sanitary landfill to accommodate MSW disposal. This sanitary landfill has used 33 acres (0.134 km^2) and can be used up to the year 2028 to operate before reaching its maximum capacity of 66 acres (0.267 km^2) (Kamaruddin et al., 2016). The increasing amount of MSW in Penang will shorten the lifespan of the current landfill which will force local authorities to locate new MSW landfill. However, limited land available in Penang would give difficulties to local authorities to develop new landfill site for Penang. Thus, this paper aims to explore available WtE technology and discussed a strategic approach to implement feasible WtE technology for Penang state in handling MSW.

PENANG MUNICIPAL SOLID WASTE

MSW Characteristics

Table 1
MSW CHARACTERISTICS FOR PENANG STATE

Item	Penang	
	Metric Tons	Percentage
Food	812.07	44.62
Garden & Yard	208.85	11.48
Paper	230.27	12.65
Plastics	297.99	16.37
Textile/Rubber	57.50	3.16
Metal	72.45	3.98
Hazardous	4.61	0.25
Others	136.16	7.48
Total	**1819.90**	**100.00**

Based on the Satang Report in 2003, MSW generation consists of more than 50 percent of organic waste per day as shown in Table 1 (Gok, 2007). There are four major types of organic waste generated from Penang state; food and kitchen waste, green waste (garden & yard

trimmings), animal waste (manure), and bulky waste (organic portion of furniture and household hold fittings) (Omran et al., 2009). Due to Penang MSW characteristics, Penang state government has implemented '*Organic Waste Segregation*' because they want to reduce the amount of waste generation by diverting it from disposed of in the landfill (Teik, 2016a).

MSW Management

Penang state authority has implemented several campaigns, acts and policies to encourage people to participate with them in reducing and controlling MSW generation. "*No Free Plastic Bag*" and "*No Styrofoam*" policies are successful examples of efforts from Penang State government in avoiding harm and bad emission to the environment. "*Waste Segregation at Sources*" and "*Organic Waste Separation*" is also becoming successful campaign which is very important in diverting organic waste and recyclable waste into the landfill.

The current practice of MSW Management in Penang is all unseparated garbage will be collected and sent to Ampang Jajar Transfer Station except for C&D, Green and Bulky Waste that will be sent to Jelutong Landfill (Teik, 2016b). From here, the unseparated garbage will undergo Ampang Jajar Transfer Station processes before sending it to Pulau Burung Landfill. Pulau Burung Landfill will receive the compact solid waste in a silo. Solid waste in the silo will undergo Material Recovery Facility (MRF) to recover recyclable waste manually (Noor et al., 2013).

Green Waste collected from Penang state will be processed using Groundswell Process to cover on top of Jelutong Landfill and Pulau Burung Landfill (Teik, 2016b). Green Waste process facilities are currently at Ampang Jajar Transfer Station and Jelutong Landfill. Food and kitchen waste segregated from a residential area, institutions, wet markets and etc. will be either compost or process using a Bio-regen machine that installed at 12 separated collection station in Penang.

Composting and producing bio-liquid is a good and cheap way to process food and organic waste but how far it is marketable is a question need to rise up. Even though there is no study showing on how far compost and bio-liquid product from food and organic waste will be favourable to farmers, once the people started to segregate food and organic waste, will the existing facilities enough to support and process all the collected food and organic waste product? Thus, it is time for Penang state to implement medium or large scale Waste-to-Energy technology that is suitable with current MSW management and waste characteristics.

METHODOLOGY

This study adopted a qualitative approach, where primary data collected through in-depth interview, and secondary data through reports and published data. In-depth interview is performed using purposive sampling, where four academicians from Yokohama City University (YCU), and two experts from Institute for Global Environmental Strategies (IGES) have been interviewed based on their specialization in sustainable environmental management and experiences in advising municipal solid waste management. The interview has been done in October to December 2017 during the Yokohama Urban Solution Study (YUSS) program in Yokohama, Japan. The interview question of the study includes: 1) type of WtE implemented in Japan, 2) cost and preparations of implementing WtE in Japan, and 3) role of government and society in participating WtE implementation. The interview data were transcribed for analysis considering cost, preparations and type of technology in order to identify the suitable WtE for Penang state. Role and participation of government, local authority, and society in WtE were

transcribed for an appropriate approach in implementing WtE technology for Penang State. Secondary data based from reputable data sources, such as published papers, data, reports, thesis, journal papers, and official government websites are also used to gather MSW management, current practices and policies made by Penang State to support the study. Japan's experience in integrating WtE technology will be explored and analyzed to propose feasible WtE technology for Penang state (Figure 1).

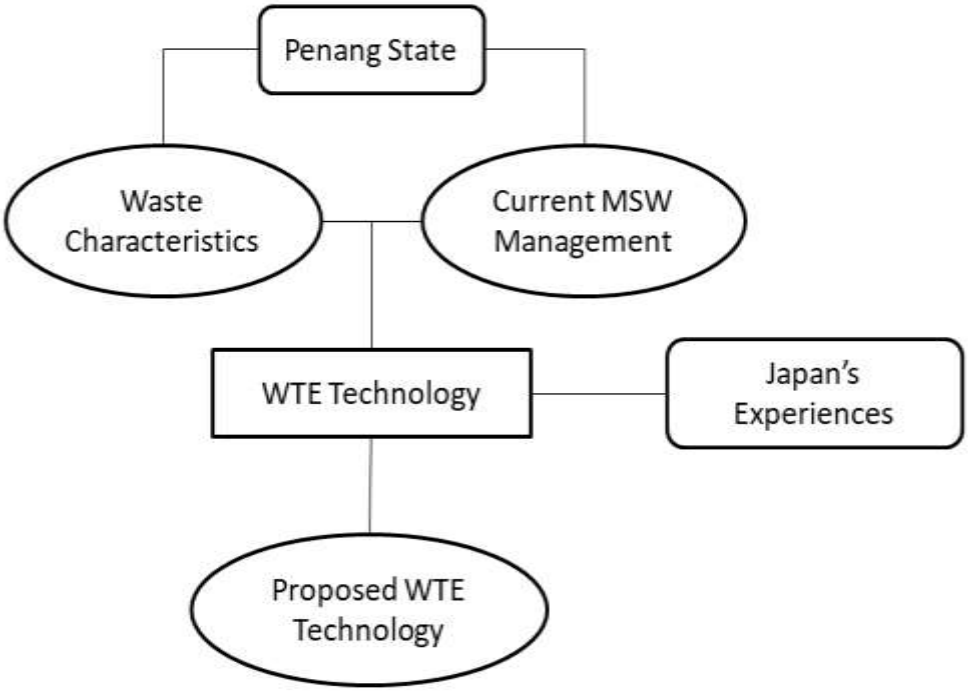

FIGURE 1
ANALYTICAL FRAMEWORK

RESULTS AND DISCUSSION

Incineration becomes a major waste treatment method in Japan because of its high population density and limited land availability for landfill area. In the year 2009, there were 1243 incineration facilities in Japan, which makes Japan possesses the world's leading MSW incineration facilities (Japan Products, 2017; Wada, 2011). Even though incinerator has become the best option for Japan to dispose of MSW, organic waste is not appropriate disposal to go into incinerator plant because organic waste contains high moisture content. Due to that reason, Japan has implemented a very successful 3R (Reduce, Reuse, and Recycle) and "*Waste Segregation at Sources*" policy to ensure only unrecyclable and non-organic waste are disposed into incinerator plant.

Academicians from YCU suggested that Anaerobic Digestion (AD) would be appropriate WtE technology for tropical season country with most of MSW generation are the organic waste. Table 2 summarizes findings from the interview with YCU's academicians. Some of the cities in Japan have actively segregated organic waste and implemented a good example of WtE technology used for organic waste disposals such as Hita City and Oki Town. One of the academicians introduced two experts from IGES to be interviewed as they actively involved in

biomass-related technology in Japan and have advised many Asian countries in implementing WtE technology.

Penang State Government has done necessary action to reduce waste generation at the landfill by implementing "*Waste Segregation at Sources*" and "*Organic Waste Segregation*" Policy, and also installing leachate treatment at Ampang Jajar Transfer Station and Pulau Burung Landfill. By segregating waste, Penang state able to recover recyclable and organic waste into the landfill. Considering current MSW Management practices of "*Segregating Waste at Sources"* and "*Organic Waste Segregation*" Policy, together with the high moisture content of solid waste, AD technology can be explored more in integrating WTE Technology in MSW Management (Sharp & Sang-Arun, 2012). This technology not only capable on avoiding 99 percent of GHG emission from treated organic waste, but it also capable to generate electricity from the methane gas produced during organic waste disposal (Sharp & Sang-Arun, 2012; Zhao et al., 2016). This technology also not requires massive land area which makes it available to install within the city area (Tan & Mikkelsen, 2016).

Table 2
COMPARISON OF WTE TECHNOLOGY

WtE Technology	Combustion	Gasification/Pyrolysis	Anaerobic Digestion	Sanitary Landfill with Gas Recovery
Feedstock Type	Unsorted Waste (dry and low calorific)	Unsorted Waste (dry and low calorific)	Sorted Organic waste	Unsorted Waste
Output	Heat	Syngas, Char and Tar	Biogas and Compost	Biogas
Energy Recovery	Electricity	Electricity, Ammonia, Methanol, Gasoline	Electricity and Compost	Electricity
Climate Change Mitigation	99% of waste avoid GHG emission	99% of waste avoid GHG emission	99% of waste avoid GHG emission	Up to 50 %of waste avoid GHG emission
Estimation Investment	High	High	High	Medium
Estimation Operational Cost	High	High	Medium-High	Medium
Estimation Area	Low-Medium	Low-Medium	Low	High

Investment (MYR/ton) = Low (100,000-300,000) Medium (350,000-700,000) High (800,000-1.5 mil)
Note: Operational cost (MYR/ton) = Low (30-50), Medium (50-80), High (80-130);
Area (m^2/ton) = Low (60-100), Medium (200-500), High (650-1000).

Public-Private Partnership

Based on the experiences learnt from Oki's Town and Hita's City (MAFF, 2017; Japan Products, 2017), a good public-private partnership is very important in implementing WtE Technology. According to experts from IGES, there are five mains stakeholders involved when implementing WtE technology. These five stakeholders have successfully been applied in WtE technology in Japan. The experts added that instead of selling excesses electricity for costing operational purposes, Oki's Town has distributed high-quality fertilizer from biomass technology to its residents for free so that they are encouraged to continue segregating waste from sources.

Figure 2 showed proposed Public-Private Partnership adapted from the interview with IGES experts. As the beginning, Malaysia Government can subsidize Penang State for their initiative to implement WtE Technology for future benefit. Providing loan with zero interest and flexible repayment will be a great assistance to Penang State. On the other hands, Penang State is fully responsible to provide services and operational management in handling WtE Technology. Penang State Government can earn income from tipping fee charges and excessive electrical sale to the Tenaga Nasional Berhad.

Penang State can take advantage on the Fit-in-Tariff system where KeTTHA has approved Advanced Renewable Tariff which makes municipal waste disposal WtE technology qualifies under biomass category with RM0.31 per kWh with a bonus RM0.10 per kWh for 16 years (KeTTHA, 2012). Penang State also can earn extra capital or operational expenditure from investment through private companies such as Fertilizer Companies, and also Joint-Credit Mechanism where developed countries like Japan will pay every avoid GHGs emission done by a state or country.

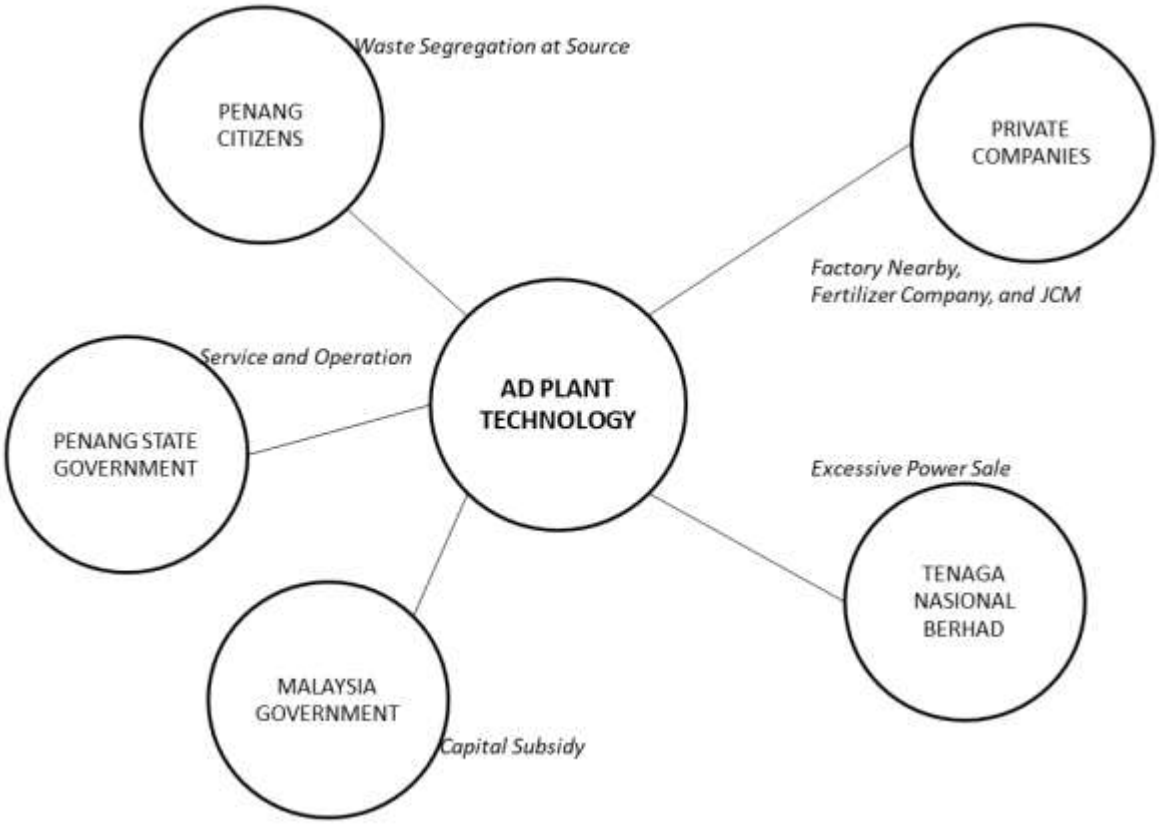

FIGURE 2
PUBLIC-PRIVATE PARTNERSHIP (3P)

Citizen participation in segregating waste at source especially segregating organic waste is the key importance of successful Public-Private Partnership. Incentivizing communities or residential management who successfully provide good quality of segregate organic waste with money incentive will be a great encouragement to the Penang citizens. Many things can be included into Public-Private Partnership from time to time if there is an improvement in

segregating waste at source and if there are many investments coming from private companies since this kind of WtE Technology is the first to be implemented in Malaysia.

CONCLUSION

Anaerobic Digestion technology can be the first large-scale of WtE Technology to Penang state and Malaysia. Batu Maung Transfer Station is currently undergo upgrading process and also designed so that WtE technology can be implemented after the right waste to energy technology has been sourced. At the same time, all actions and policies done by Penang State Government are good enough to utilize this waste disposal biomass technology. Food and other organic waste is the main contribution to overall MSW generation; diverting it from landfill through good "*Organic Waste Segregation*" and "*Waste Segregation at Sources*" policies will definitely give a good result in reducing MSW. Subsequently, the operational cost in maintaining sanitary landfill will be reduced and thus avoiding GHG emission to the environment.

This operational cost saving and properly documenting on how much avoidance of GHG emission to the environment can be a great start to implement WtE Technology as developed countries like Japan gives money incentive to developing countries who manage to reduce GHGs emission. One major thing to concern when implementing WtE Technology is that how to have a good flow of capital expenditure and operational expenditure since the overall cost is exceptionally high for a developing country. Also, labor expertise in handling advanced WtE Technology will be a hinder for local and federal authorities to consider in implementing WtE Technology. Japan has provided many good examples and guidelines in sustaining WtE Technologies. A good Public-Private Partnership is one of the major keys in having a sustainable in term of operational and society. This concept should be further explored as every stakeholder will be benefitted in this implementation of WtE Technology.

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