Assessment of the Environmental, Technical and Economic Issues Associated with Energy Recovery from Municipal Solid Waste in Malaysia

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Abstract. Malaysia is a fast emerging economy country and its outlook on sustainable energy production are at the center of debate. Although waste to energy (WtE) technologies are well established but the disconformity of the municipal solid waste (MSW) composition, the complexity of the treatment facilities, and the pollutant emissions still express considerable issues for these technologies. Hence, this study focuses on WtE technologies in Malaysia by considering the energy potentials of the landfill sites and incineration plants as the most common effective MSW in Malaysia. The major environmental, technical and economic issues associated with WtE technologies were evaluated. An annual growth rate of 3.3% has been projected for MSW production in Malaysia. The most common used WtE technologies were incineration and controlled landfill to capture Landfill Gas (LFG). Malaysia MSW contains 60% biodegradable fraction, making landfills a potential source of LFG. Although, the potential of energy recovery from waste in Malaysia is high but the current production is less than 20 MW of electricity per day.

1. Introduction
As an emerging developing country, Malaysia facing problems associated with municipal solid waste (MSW) management. Currently. Malaysian generates around 1.1kg/capita/day of MSW, while at major cities its around 1.5 kg/person/day. By 2020, the generation of MSW estimate to be around 30,000 metric tons and the mass to be increase further 9% by year 2030. The continuous increase of population and development of the country contribute to significant increase of the municipal solid waste. Around the 80% of the MSW generated end up in 171 active landfills with 12 sanitary landfills currently operated at Malaysia. Off the 171 landfills around 50% of the landfill approach is open dumping; 30% of the landfill utilize controlled tipping; 12% of the landfill-controlled landfill with daily cover; 5% sanitary landfill without leachate treatment facility; and the other 5% of the other sanitary landfill with leachate treatment. Over 80% of the open dump landfill have almost reached full capacity and are expected to shut down over the next few years. The major fractions of MSW generated in Malaysia include paper (7%), organic material (45%), plastics (24%), glass (6%), metal and others (6%) [1-2].
Closing a landfill is environmentally challenging and involves acquiring other pieces of land, which will eventually become scarce in the future. Subsequently, the MSW operator’s various challenges that will need creative solution. Alternatively, another essential sector, energy sector, is considered to be a perfect match, as MSW is classified as a valuable resource of energy. In light with the above mentioned, energy production from MSW can address two issues: (i) handling huge amounts of non-recyclable or non-reusable MSW; (ii) producing renewable low cost energy [3]. So far, Malaysia effort and strategic plan associated with energy recovery from MSW yet to achieve its target and indeed facing many challenges. Therefore, this study is needed to investigates the key environmental, economic and technical issues that must be considered while implementing the WtE technologies in Malaysia. The major challenges and opportunities associated with Energy recovery from MSW in Malaysia are deliberated.

2. MSW to Energy in Malaysia
Various technologies have been identified and utilized in small scale intended for MSW management include composting, recycling and burning. Another concern for Malaysia is the ever increasing the need for energy to sustain the industry and count’s economic development. In seeking better solution in waste management and as approach toward renewable energy need for the country, Malaysian government come out with proposal of waste-to-energy (WtE) in the form of renewable energy from MSW [4]. The aims of all WtE processes are to reduce the volume of waste and therefore lessen the total size necessitating dumping in landfill; lessen to zero the biodegradable portion of MSW; besides harvest power from non-recyclable MSW. The two main categories of WtE technology are thermal and biological. Thermal technology consists of combustion, pyrolysis and gasification associated practices in which waste will subject to high temperatures with changeable oxygen levels. However, biological process, anaerobic digestion (AD), is normally employed to harvest bioenergy from wet and biodegradable wastes. Another way of WtE is process of turning landfill gas is to energy through number of landfill technologies [5]. Waste conversion to energy absolutely can reduce the amount of existing landfill and concurrently cuts the emissions of greenhouse gas. Considering the factor pushing the solid waste management and need of clean renewable energy number of WtE technology we re established and operated. The idea of WtE in Malaysia takes big step forward through construction of incineration plant at Lanagkawi and establishment of number of biogas power plants to convert MSW to electricity [4]. Currently, Malaysia only has one WtE plant and 5 mini incinerators. In the 10th Malaysia Plan, another WtE plant is to established by 2018 in Negeri Sembilan [6]. Malaysian MSW can be processed for energy recovery using one of the three ways, thermal treatment, biological treatment and landfilling.

2.1 Incineration Plant as WTE Technology in Malaysia
The usage of incineration technology in Malaysia is still limited and in small scale. Typically, incineration can reduce volume of the MSW up to 95%. Malaysian government through the Ministry of Local Government and Housing initiated the incineration project to manage the MSW back in 2011 with expenditure of RM 187.74 million. Five small size incinerators were constructed in five tourism locations as presented in Table 1 [2]. Kajang WtE plant, is the most comprehensive incinerator operated at Malaysia, and also act as the first refused-derived-facility (RFD). Nearly 8 MW/day of electricity daily from RDF which has the capacity to process 1,100 tons of MSW per day. The energy harvested powers the plant, and the balance approximately 5 MW is sold to the national power grid [7]. Efforts are made to make the facility to operate at steady state and to increase the export of power from 5 MW to about 6 MW. Furthermore, currently only 77% of the energy stored within the MSW recovered in the form of fuel, in near time the recovery on energy target to be increased to 83% by adding the biogas produce from the recovered wet organics through anaerobic digestion [7]. Analysis of potential generation WtE in Malaysia from year 2010 to 2030 indicated that electricity generation from the incineration plant will be increased from 5000 Gwh/year energy within 2020 to 6200 Gwh/y by year 2030 [4].
Table 1. Summary of Incineration plant in Malaysia

| Location       | Pulau Pangkor | Pulau Langkawi | Pulau Tioman | Cameron Highlands | Labuan |
|----------------|---------------|----------------|--------------|-------------------|--------|
| Completion by (yr) | 2009         | 2010           | 2010         | 2010              | 2010   |
| Capacity (tones per day) | 20            | 100            | 15           | 15                | 60     |
| Status         | Active        | Active         | Closed       | Active            | Active |
| Energy Generation | Nil        | 1 MW           | Nil          | Nil               | Nil    |

2.2 Landfill Gas (LFG)
There are almost 171 active landfills currently operated at Malaysia with around same number of landfill are closed. Only twelve of the active landfill categorize as sanitary landfills. Decomposition of biodegradable components of MSW roughly produces 50% of methane gas, less than 50% of CO₂ in addition to minor quantity of non-methane organic compounds. Studies on the methane gas production at Malaysia highlighted landfills as the major source of methane emission (53%) [8]. Figure 1 shows the generation of methane gas from landfill in Malaysia (ton/year).

As a successful example, Bukit Tagar Sanitary Landfill (BTSL) developed with capacity of 120 million metric tons. At present, Bukit Tagar receives 2,500 tons of MSW daily. The BTSL facility captured 3,600 cubic meters of LFG with 60% of methane gas per hour, which translated to 6 MW electricity per day. The BTSL facility installed with 1.2MW of gas power engine to generate electricity from the produced methane gas. At present, only partially captured methane gas translated into electricity and the remaining methane gas demolished using enclosed flares. Up to date, BSTL is one of the largest WtE project with 10.5 MW gas engine to generate electricity from the LFG. In Air Hitam sanitary landfill, LFG harvested from the MSW amassed throughout the past ten yrs to generate two megawatts of electricity/month. The power harvested is sufficient to power around 2,000 households. The generated electric supply sold to TNB at cost of RM 0.40 per kilowatt. In addition, Jeram landfill with an area of 160 acres and MSW capacity of 2500 ton per day was established with a capacity to hold 6 million tons of waste. Currently 2000 tons of waste is disposed of at the landfill every day, and to-date 4.1 million tons of waste has been added to the landfill. To date the gas power plants from Air Hitam sanitary landfill and Jeram landfill produces combined power generation of 6 MW which can utilize to power up 6,000 homes of surrounding populations. According to Tan et al., [4], energy production by year 2010 was around 3000 GWh/year while by year 2020 the generation increase to 3300 GWh/year and by year 2030 the potential energy can
be harvest from LFG estimated as 5000 GWh/ year. The combination of anaerobic digestion with land fill
gas collection system can be utilizing to increase the output of the methane gas.

3. Technical, Economic, and Environmental Issues.

Technical issues: Various types of wastes can be utilized as a potential renewable energy source to attain
sustainability and for switch over to WtE [10]. A study on MSW collected from the municipal waste
indicate the high average amount of heating value of the MSW is approximately 23,000 kJ/kg, its clearly
indicate the MSW present in Malaysia as have potential to be use in waste to energy plan. Moisture
content is the most important problem related to the Malaysian MSW as it will diminish the calorific value
and thus energy potential. Because of the unfortunate repairs servicing and the high operational budget
enforced via the high water content of MSW, the practice of small incinerators working in the vacationer
islands were discontinued. Most of the landfills in Malaysia were in small capacity, hence the MSW
capacity received by such landfill is not enough to make sufficient bulk of LFG feasible for production
and utilization. Moreover, majority of the Malaysian’s landfills in Malaysia are just open dump site that
rely generally on clay lining and have no set-up for the collection of leachate and LFG. These dump site
were not designed with the purpose to make resources such as methane. Thus, most of the landfill gas
generated will be runaway naturally from crevices and cracks [11].

Economic issues: In Malaysia, the requirements for energy increase by factor about four times by year
2050. Increasing of Malaysian population make the ratio of energy available to energy required become
imbalance. For each of 1% growth on Malaysian GDP there is 1.2 -1.5 % in the energy demand [8]. Thus,
it should be wise to develop technology to produce alternative energy source from MSW. The economic
benefit of incineration plant operates using MSW estimated through electrical production and carbon
credit. Incinerator using MSW is predicted to generate RM 1500 M/y from the sales of electricity by year
2010, RM 1800 M/y by 2020 and further increase to RM 2,500 M/y by year 2030. The revenue to be
generate from the carbon credit by year 2030 estimated around RM 120 million / year (Table 2). Cost
analysis study of incineration technology in Malaysia found that the net profit was about RM 73 M/ton
MSW while the incineration plant combines with LFG gas recovery system have potential to generate
revenue of RM 135 M/ton MSW [4]. The high costs linked with incineration project are mainly accredited
to the air greenhouse gasses control devices. In Europe, about 2/3 of the capital budget of a modern
incinerator is paid on air pollution control devices. Regarding the operational cost, more fuels usage and
additional professional employments requisite are the main issues. The operational cost for incineration is
within the range of USD 40-100/ ton of MSW [12]. The capital expenditure of incinerator facility with
capacity of 800-1000 ton of MSW estimated around RM 500 million to RM 800 million, the capital
expenditure to build an incinerator is estimated around 10 times of sanitary landfill while the operational
expenditure 3 times more compare to sanitary operation costing. The capital cost for gasification is higher
compare to incineration by 1.5 times but the overall efficiency of gasification in term of WtE technology
is 30% more than incineration [13].

Methane emissions from dumpsites and sanitary landfills in Malaysia were equal to 55.6% and 44.4%,
respectively. The usage of LFG expertise brings the possibilities of low cost energy production combined
with the opportunity of gas emissions lessening. By year 2020 the revenue can be generating from the
methane gas collection and transfer into energy around RM 998 Million from both carbon credit and
electricity generation [9]. The total revenue from the landfill gas through carbon credit and electricity
generation are summarized in Fig.2.
The economic analysis of the energy recovery from LFG indicated an anticipate increase of electricity sales and carbon credits from year 2010 to 2030. Sales of electricity generated from LFG by year 2010 estimated at RM 1,600 M/ year, the value to increase to RM 2000 M / year by 2020 and the revenue to be at RM 2,140 M/ year by 2030. Approximately the revenue from the carbon credit estimate to be at RM 200 M/ year by 2030 from around RM 160 M/ year. The study also performs cost analysis of the LFG recovery system to energy production, it shows the operator of such LFG gas power plant may achieve net profit of RM 120 M / tone of MSW from generation of electricity within the next ten years (by year 2030). Even though biogas sectors especially using LFG can mitigate some environmental problems and resolve energy resource shortages, the technology requires high capital investment. Also, due to lack of financial assistance for landfill management only few larger operators able to develop and operate sanitary landfill with adequate landfill gas recovery system and WtE technology from gas collection.

**Environmental issues:** The process incineration plays major role in the reduction of the volume of MSW and efficient in recovery of energy. Whereby, the solid mass waste could be reduced up to 85% while the total volume of solid waste could be reduced up to 95%. Although, after the incineration process the retrieve ash need to be handle, most of the incinerator technology produces only 10% of ash which later disposed into the landfill. Emission standard for incinerator in Malaysia was started under Environmental Quality (Dioxin and Furan) Regulation 2004. However, the requirement of the regulation established basically based on the United States Environmental Protection Agency (USEPA) Method 23 which required very stringent dioxin and furan emission requirement. To achieve such stringent requirement,
there were need for development and installation of various control measure which often up to one half of the project cost. As the rules related to air pollution controls need to be updated, this could result in higher budgets. Compared to incinerator, the drawbacks of incinerators are normally the environmental issues such as higher carbon emission, higher land contamination, and lesser energy recovery. Nevertheless, the incineration operation in Malaysia face challenges include opposition from the public and non-governmental organization; and high capital expenditure required; unsuitability of available technology for incineration of local MSW. Other challenges face by current incinerator operators were failure to comply EIA criteria; higher cost for incinerator parts and maintenance; insufficient local expertise; and incompetent local operators.

4. Conclusion
There were number of improvements can be take into consideration to make WtE as effective and profitable in term of support the renewable energy production in Malaysia. In Malaysia there were still lacking in the WtE from MSW. The stakeholders should provide adequate knowledge on the strategies in such policies and government should play great role in translates policies in the paper into actual changes in behaviors. There is a need for good and effective cooperation in between the Federal and Local authority in the implementation of the SWM policies. Using an alternative approach such as pyrolysis and gasification rather than incineration would be useful as both pyrolysis and gasification technologies produce energy from MSW with cleaner than incineration and not possess any public health threat. Although the capital cost for gasification is higher than incineration by 1.5 times but the total efficiency of gasification is higher by 30%.

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