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ENERGY, ECONOMIC AND ENVIRONMENTAL IMPACT OF WASTE-TO-ENERGY IN MALAYSIA

M. Faizal[1, 2*], Y. H. Wardah[2], M. A. Husna[2], A. Amirah[3], Y. H. Tan[2]

[1]Mechanical Engineering Program, School of Engineering, Taylor's University Lakeside Campus, 47500 Selangor, Malaysia
[2]Department of Engineering, School of Liberal Arts and Sciences, Taylor's University Lakeside Campus, 47500 Selangor, Malaysia
[3]Department of Park and Ecotourism, Faculty of Forestry, Universiti Putra Malaysia, 43400 Serdang, Malaysia
**Corresponding Author email: mohdfaizal.fauzan@taylors.edu.my, drfaizalfauzan@gmail.com (M. Faizal)*

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ABSTRACT

National human population, economy development and advancement of technologies have led to a high demand of energy. Despite this, depletion of conventional fuels and global warming crisis are hindering the government to fulfil the citizens' needs. One of the options to solve the problems is by implementing Waste-To-Energy (WTE) systems which in general, can convert or process any type of wastes into energy. Apart from being an alternative energy resource, WTE is also able to relieve the conflict of disposal of wastes in the country. Therefore, this paper aims to review the energy, economic and environmental impacts of WTE in the country. As organic wastes are dominating the overall wastes in the country by 57.39%, this paper focuses on biomass and organic wastes such as sewage sludge, crop yield, animal wastes and municipal solid wastes (MSW) as potential source of energy.

KEYWORDS

Energy, Economic, Environment, Waste-To-Energy, Electricity Production.

1. INTRODUCTION

Currently, the world's main concern is on solving the global warming phenomenon and to find replacement of non-renewable sources for energy production. The energy production from non-renewable sources have been damaging the environment in various ways. In addition, it causes public health problems which related to harmful gaseous emissions like heavy metals, sulfur and nitrogen compounds. Apart from that, these non-renewable sources such as fossil fuels (coal, oil, natural gas) will eventually depleted [1]. The International Energy Agency (IEA) estimated that the release of carbon dioxide from burning of fuel in transportation will increase by 92% between 1990 and 2020. Additionally, 8.6 billion metric tons carbon dioxide will be released to the air from 2020 to 2035. About half of carbon dioxide released stays in the atmosphere as it is not absorbed by the plants or dissolved in the oceans [2]. Since 2010, 80 - 90% of the domestic's installed generation capacity and output is made up of gas and coal [3].

Based on these facts, it is unsurprising that the conventional fuels are found to be the main factor of the greenhouse effect which leads to global warming and climate change [2]. Moreover, it is expected that there will be a demand growth of 9.7% annually between 2002 and 2030, therefore Malaysia will need all the support that it can get to satisfy the needs of energy production while at the same time, reduce the harmful effect of pollution [3]. Malaysia is blessed with ample of renewable resources which are able to produce clean and eco-friendly energy. For instance, wind energy, wave energy, solar energy, biomass energy, hydropower and hydrogen fuel cells [4-8]. Hence, in order to resolve problems regarding the global warming and the depletion of conventional fuel, more effort and investment are needed for development.

According to World Bank, level of economic development, cultural norms, geographical location, energy sources, and climate influence the composition and quantity of the solid wastes from a municipality [9]. In Malaysia, the amount of waste generated in rural areas is about 0.5-0.8 kg per person per day, while in the urban areas, it doubled to 1.7 kg per person per day [10]. Besides, it has been forecasted that the municipal solid waste (MSW) in Malaysia will reach 31,000 tonnes/day in 2020 and 51,655 tonnes/day in 2025 [10-12]. The reasons behind the increment are related to the population growth, the rising of the economic productions, urbanization process [13]. Additionally, it is also affected by the multiracial society of Malaysia [10]. With all these figures, it is proven that wastes are inevitable to be reduced but instead they are rising in number. Figure 1 depicts several waste treatments which are categorized into two types; biological treatment (aerobic composting and anaerobic digestion) and thermal treatment (incineration, gasification and pyrolysis) [14]. The aim of these approaches is not only to manage the overcrowding wastes, but also for energy generation and reduction of pollution.

Organic wastes that are worth utilizing like food, paper and wood dominate the collected waste by 57.39% in Malaysia [15]. These valuable wastes are not supposed to end up in landfills since they have the potential to replace the conventional fuels and stand out as one of the important alternative energy resources in the near future. Through anaerobic decomposition, organic wastes can be converted into methane gas, CH_4 (50%-54%) which can be utilised as a fuel [11]. Therefore, we should take advantage of the biogas produced from the constantly increasing waste for energy recovery.

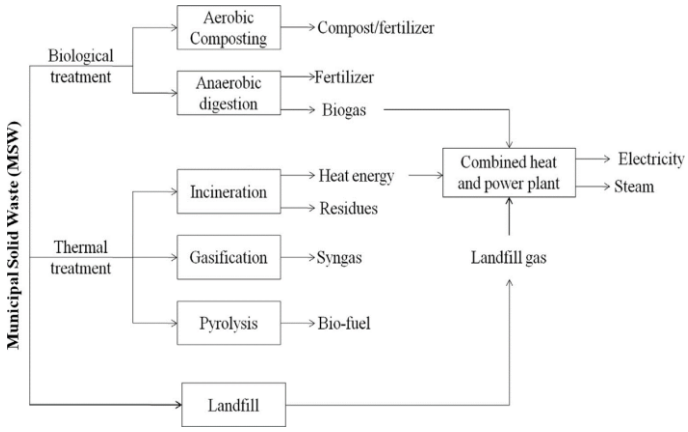

Figure 1: Waste treatment technologies and their products [16]

The objective of this paper is to highlight the energy, economic and environmental impacts of WTE in this country. Since organic wastes are reportedly dominating the overall wastes in the country by 57.39%. Hence, the focus of this paper is on biomass and organic wastes. Biomass contains in any organic matter that can be derive from plants obtained forestry and agricultural residues, organic waste, energy crops, sewage sludge and woody plants, creating a favourable renewable energy source that can be utilized in the fuels productions and electric energy [1]. If the process is efficient, biomass will recycle to its original compounds and making carbon dioxide readily use to produce new plants. This could contribute to reducing greenhouse gas emissions. Therefore, biomass is potentially a carbon-neutral fuel that reduces carbon dioxide emissions and landfill methane emissions [17].

2. ENERGY IMPACT

Due to the economic growth and the advancement of technologies, it is forecasted that in 2030, the heat energy and electricity demand will reach 4.85×10^{12} MJ and 2.34×10^{5} GWh respectively in Malaysia [8]. According to the 10th Malaysia Plan, renewable energy (RE) is targeted to contribute 5.5% of the generation mix in 2010 and by 2050, the figure is estimated to arrive at 34% from the total power generated in the country to encourage the development of RE sources and to minimize the dependence on fossil fuels [14]. Thus, due to the abundance of wastes in Malaysia, WTE would be a propitious choice to be implemented, after hydropower and solar.

2.1 Current energy production by various WTE initiatives

In Ukraine, a biogas plant produces 3300 m^3 of methane gas (CH_4) which then can generate electricity for a capacity of 180 kWh whereas an electricity-generating incinerator in UK generates 519 kWh per tonne of MSW [8,18]. Presently, UK has installed 25 MSW incinerators with energy recovery while Malaysia has only one incineration plant operating in Langkawi, which is able to produce 1 MW of electricity from 100 t/d of MSW [14,16,18]. On the other hand, there are 24 biomass power plants installed in Malaysia which altogether generate about 729 MW of electricity in 2014 and 392 MW are from Peninsular Malaysia. These biomass power plants harvest energy from agricultural wastes like POME (palm oil mill effluent), empty fruit bunch, wood waste and rice husk. In 2010, landfills located in Selangor and Kuala Lumpur produced electricity of 2.20×10^{9} kWh which is 1.5% of the total energy demand in Malaysia [19]. Beside incinerators, landfills and biomass power plants, Malaysia also installed the first Refuse-Derived Fuel (RDF) pilot plant which is situated in Semenyih in 2008. Although its maximum potential is to process 1000t of MSW and produce 8.9 MW per day, the plant currently generates 8 MW of electricity from 700t of MSW. On top of that, this RDF pilot plant has a specialty in incorporating visual, mechanical and magnetic sorting of the waste so that it combusts only the high calorific value matter [19].

2.2 Potential energy production of WTE in Malaysia

Many researches had predicted the energy generated from several types of WTE initiatives such as the incineration, anaerobic digestion system, landfill with gas recovery system (LFGRS) and others. Based on Tan et al., the results showed that waste incineration is capable of generating 639 kWh/t MSW followed by AD with 387.59 kWh/t MSW. Meanwhile, waste dumping in sanitary landfills equipped with gas recovery system produced the least amount of energy which is 296.79 kWh/t MSW. Apart from that, the study by Abdeshahian et al. shows the potential methane gas production from farm wastes (animal manure, blood and rumen) in Peninsular Malaysia, Sabah and Sarawak. The total potential electricity generated from the production of methane gas in each region is 7×10^{9} kWH/year, 4.5×10^{8} kWh/year and 8.37×10^{8} kWh/year respectively. It emphasized the potential energy produced in Malaysia is estimated to cover 7.12% of the total energy expended by Malaysians in 2012 which is 1.02×10^{11} kWh. Instead of comparing the electricity production between regions, Kumaran et al. focused their results on electricity generation from different types of wastes which include POME, sewage sludge, chicken manure, swine manure, dairy manure and food waste. The electricity generated by the wastes is expected to be 4.38 TWh/year, 1.58 TWh/year, 5.34 TWh/year, 764.06 GWh/year, 875 GWh/year and 0.49 TWh/year respectively. Based on these figures, it has been proven that WTE has a high potential to generate a great deal of energy to serve the citizen's need especially at this time of fuel depletion.

3. ECONOMIC IMPACT

Malaysia is now in the 11th Malaysia Plan (11MP) and focused to rapidly deliver high impact result to both the capital's economy and people's economy at affordable price. As a country develops in a rapid pace, the energy consumption increases which as well is synonymous to the country's economic growth. Therefore, economy plays an important role to the development of a country. The 11th Malaysia Plan predicts greater volatility and uncertainty in the future global economy as a result of the decline in oil prices [3]. Hence, it is a plausible and reasonable choice to further develop other utilization of renewable sources like WTE to improve the financial stability of Malaysia in the present and in the future.

3.1 The ever-expanding recognition of WTE

There are reports of the potential of MSW to create new financial advantages. Many party had recognized the possibility of WTE as the growth of venture capital and private business investment in WTE and biomass experienced an increase of 186% which is equal to a total investment of USD 1 billion. WTE is also considered attractive due to the fact that the source is always available and almost free. However, these technologies have been halted from developing quickly because of the increasing rate of environmental awareness, financial and technical limitation in this present time [13].

3.2 Financial potential of WTE

WTE for MSW has potential to bring profits from sales and carbon credits. However, pre-treatment is needed to produce better economic benefits of WTE. A research was conducted with the objective to find the economic potential of WTE. The economic assessment in this research considers both the profit (selling of energy, carbon credit through carbon avoidance, and additional profit from selling the by-products), and the cost (operation cost, capital cost, and transportation cost). The baseline of this study is the landfill without any energy recovery system and it leads to a negative cost impact of 222,000 USD/d because of the tipping fee, costs of transportation, operation and maintenance [16].

It has been proven that compared to a plain landfill, implementation of WTE technologies is more commercially successful. Among all WTE plans, incinerator could generate the highest amount of heat energy and electricity which comes with a high profit. Hence, it is considered the most cost-effective with a net profit of 563083.40 USD/d, followed by AD, gasification, and LFGRS. With the low net profit (less than half of incineration and AD), installing gasification system would be unreasonable despite its high potential of reducing the carbon footprints. An incinerator can generate higher amount of heat energy, thus produce more profit from the sale of heat energy when compared to AD. However, AD can also generate source income other than energy generation which is fertilizer. The production of fertilizer can be commercialized and sold to

the public [16]. Another research wrote about the potential of forest residues and oil palm biomass which have the highest energy values respectively by 11,883 and 6291 million Malaysian Ringgits (RM) per year. It is approximated that oil palm agriculture covers 85.5% of the available biomass in the country which implies that biomass is viable for large-scale power generation and at the same time can overcome environmental issues regarding the disposal of the overcrowding waste [13].

Furthermore, results were obtained from a research where it is forecasted that in 2020, RM690 million can be derived from 2.3 billion kWh/year of electricity which is approximated to be generated from 9,820,000 tonnes MSW (expectation was based on average MSW increase rate from 1998 to 2000). Moreover, the emitted methane gas with an amount of 370,000 tonnes (equivalent to 7,770,000 CO_2) , if captured and utilized, can bring about a profit of RM307,692,000 resultant from the carbon credit [11].

3.3 Plans to use WTE to boost Malaysia's economy

The government had contributed efforts towards the biomass utilization by the launch of National Biomass Strategy 2020 (NBS2020) in November 2011. NBS2020 summarizes opportunities and action plans in the biomass worth with a projected RM30 billion (USD6.98 billion) additional gross national income, new opportunities of 66,000 high-value jobs, RM 25 billion (USD5.81 billion) in new investments and a 12% possible reduction in carbon emissions to the surrounding environment which will increase the carbon credit. Initially, the strategy only focused on the palm oil industry but has extended to other biomass sources such as rice husk, rubber and wood. To further bolster the implementation of NBS2020, the former Prime Minister, Najib Razak launched 1Malaysia Biomass Strategy (1MBAS) delivery unit led by the Central Government Agency in March 2012, with the attention to encourage and advertise the benefits and utilization of biomass across all sectors. At the same time, 1MBAS also aims to encourage prospective domestic and international industry players to consider potential sustainable biomass industries locally in the entire biomass value chain [3].

Additionally, a 1500t incinerator project was also proposed to be built in Broga, Semenyih. This incinerator will become one of the biggest incinerators in Asia if it is successfully built. The location proposed was near a university, water catchment area, vegetable farms, fruit plantations and palm oil. However, the project was abolished due to massive public objection and high capital expenditure (approximately USD 400 million) and maintenance costs. Following the cancellation of this project, there have been many more proposals to establish incinerator plants in Kuala Lumpur, Penang, Selangor, Cameron Highlands and other major towns in Malaysia [19].

3.4 Disadvantages of WTE in respect to economy

Previous research paper reported that MSW utilization is not financially rewarding due to the demanding cost of technologies for incineration, gasification and pyrolysis [16]. Based on the result, gasification is not a favourable choice due to its high capacity and operational cost (250,400 USD/d). Incinerator (147,900 USD/day) shows lesser cost followed by LFGRS (95,200 USD/day) and the lowest cost among them, the AD (93,575 USD/day). The government and other parties might face difficulties when dealing with the cost of WTE like the cost of the building, technology, pre-treatment, transportation, tipping fee, maintenance and pollution control system [16].

4. ENVIRONMENTAL IMPACT

As mentioned earlier, the amount of waste in the country had increased annually due to human population and economic development growing rapidly. The wastes are taking a lot of spaces in the landfills and leaving a multitude of bad environmental impacts such as nauseous odours, leachate formation and greenhouse gas emission resulting from the MSW decomposition. Instead of leaving the wastes to rot and to emit pollutant gas, we ought to take advantage of the by-products and avail them to generate electricity and heat.

4.1 Scaling down the volume of wastes

Malaysia is rich in culture and food. Not to mention the tropical climate that encourages the production of myriad plants and fruits. One of Malaysia's largest contributor in agricultural economy is the palm oil industry. In 2015, Malaysia has about 5.64 million hectares of area of planted palm trees and as a result, ample of POME were generated from the wet process of CPO extraction [20]. POME is considered as the most concerning waste as it contains high percentage of organic compound. Also, the chicken production in Malaysia had increased 42.50% from 2004 to 2013 due to Malaysia's aim which is to be appointed as the World's Halal Food Hub. Thus, about 77,209 t/day of chicken manure are produced in the year of 2014 [15]. In the same year, swine manure, dairy manure, food waste and sewage sludge also show a high amount of production in Malaysia. Each shows a total mass of 14,720 tonnes/day, 30,400 tonnes/day, 908.33 tonnes/day and 7.53 million m^3/day respectively [15]. These wastes, if left unmanaged, will cause a massive pile-up of wastes in the landfills and farms. By using incinerator to manage the wastes, it would reduce the volume by 95% whereas if anaerobic digesters are implemented, the digestate would not be tossed of but instead, it can be used as fertilizers [8,19].

4.2 Reduction of Carbon footprint

All of the wastes which are mentioned above are the biogas resources. Biogas is produced from anaerobic decomposition of organic matter. Biogas is one of the alternative energy resources which is primarily composed of methane (CH_4) (60%) and carbon dioxide (CO_2) (35-40%) as well as other traces like ammonia(NH_3), hydrogen sulphide(H_2S), hydrogen(H_2), oxygen(O_2), nitrogen(N_2) and carbon monoxide(CO) [8, 20]. According to a data, in 2014, the potential production of methane gas from POME, sewage sludge, chicken manure, swine manure, dairy manure and food waste is 1,044,760,500 m^3/day, 1,132,512.5 m^3/day, 3,860,458 m^3/day, 552,000 m^3/day, 632,320 m^3/day, 355 950.32 m^3/day respectively [15]. Altogether, the amount of methane gas emitted can reach up to 1,051 million m^3 per day with POME as the highest methane gas supplier.

Methane gas is precious yet problematic as it plays an important role to generate energy but also contribute to the global warming phenomenon. It is expected that the emission of CO_2 in 2020 will gain up to 68.86% from 2000 [8]. Based on Figure 2, the potential carbon avoidance from anaerobic digestion is about 2487.8t CO_2/day which is considered the highest compared to incineration (2251.2t CO_2/day) and LFGRS (632t CO_2/day) [21]. One existing landfill equipped with methane recovery system which is located in Bukit Tagar, the methane recovery in 2013 is recorded to be the highest among other facilities (219,625t eq CO_2) followed by Seelong facility (108,335t eq CO_2) [10]. By capturing and utilizing the methane gas that is produced via anaerobic digestion, not only it can lower the risk of greenhouse effect, but also reduce the dependence on the soon-depleting conventional fuels.

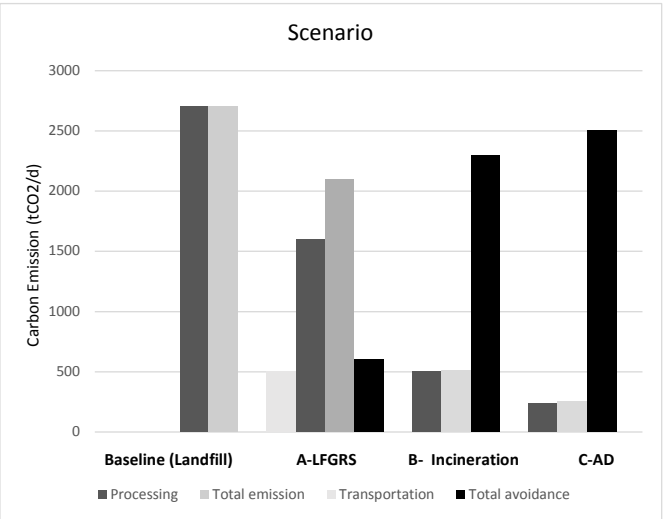

Figure 2: Carbon emission analysis for different scenarios in Taman Beringin Landfill [14]

4.3 Preserving the quality of groundwater resources

Water waste facilities which are not managed properly can pollute the groundwater as the water that comes out from the landfills, oil palm mills, farms and sewers filled with a lot of harmful and filthy contents [15,22]. Same goes when leachate is formed in landfills which are left unsupervised [10,22]. Consequently, the quality of the groundwater deteriorates which leads to disturbance of the aquatic creatures habitat and increase of human health risk [22]. The water waste and leachate can be prevented from invading the groundwater resource through a well-organized WTE system and the evaporation of the leachate by the heat produced [11].

4.4 Lower the risk of spreading diseases

The accumulated wastes in the landfills, sewers and farms attract not only pests but also it carries diseases [15, 22]. Although landfills and sewers are isolated from residential areas, the water waste and leachate can still invade the groundwater and spread diseases across the region [8]. Other than the infestation of pests, the animal manure itself infect the environment as it consists of harmful bacteria and viruses, heavy metals, growth hormone and antibiotics [8]. However, WTE systems could inhibit the spawning of the pests and prevent them from spreading any viruses to the community [8]. On top of that, not only WTE systems can reduce chances of spreading of diseases, but also the digestate (AD by-product) which is used as fertilizers are good to improve the growth of the agricultural yields [8].

4.5 Gas emission contains toxic compounds

One of the reasons incinerations is publicly objected is because the gas emitted are polluting the atmosphere [19]. Incineration leads to producing gas which has a high content of toxic compounds such as nitrous oxide (N_2O), hydrochloric acid (HCl), and heavy metals [18]. The list of the toxic compound emitted from incineration are shown in table 5. However, the related authority claimed that the amount of toxic content produced by incinerators are not as high as those produced from other systems, therefore it is recognized as safe to implement. Hence, even a developed country like Japan has been implementing incinerators for a long time [19]. Nonetheless, the solution in this matter is found in the air pollution control on incinerators [18,23].

5. CONCLUSION

Waste-To-Energy has great potential to act as an alternative source. The source of fuel from WTE is renewable, free and always available for energy generation. In terms of energy production, WTE can generate energy that will be able to satisfy the country's increasingly demanding needs. It has been projected that the potential energy produced from farm waste in Malaysia is estimated to cover 7.12% of the total energy consumed in 2012. Furthermore, WTE can continuously provide profits from sales and carbon credits despite the costly expenditure. Besides, there are many efforts from various organization to relieve the financial concerns that will be faced by stakeholders. For instance, the payback time can be relieved by feed in tariff mechanism. Looking from the environmental aspect, implementation of WTE can reduce the carbon footprint which is mostly originated from usage of fossil fuels and also from the biodegradation of wastes in landfills. Other than that, the spreading of diseases can be prevented and the quality of the water resources can be maintained. The WTE supply chain offers a method that concurrently addresses the increasing energy demand, waste management and GHG emissions to attain a circular economy system (CES). This could create a positive economy growth and healthy environment that is especially crucial in developing countries.

Results from previous studies have shown that incineration is the best choice for the highest energy production compared to other choices. However, a lot of the energy productions by incineration is in the form of heat energy, which is not desirable in a hot and humid country like Malaysia. Therefore, the favourable choice for Malaysia is AD as it is more advantageous for electricity production compared to heat production. Other than generating electricity, AD can also produce fertilizer (for agriculture use) and purified biogas (fuel for vehicles and cooking) which increase its commercialization potential. Regardless of which is opted, we must not turn a blind eye to the environmental effect and improve any flaw to create a well-balanced system. As a whole, WTE serves as a viable option for alternative energy sources due to its high potential of energy production, economic profits and environmental benefits.

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