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The Engineering of Zero Waste: Between Sustainability and Waste Production

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A B S T R A C T

A zero-waste concept does not necessarily mean that someone should not produce waste at all, which is impossible, rather the waste dumped to disposal site is minimized or zero. On the other hand, in many developing cities in Asia, the municipal solid waste is predominantly biodegradable waste, which accounted for 60-80 percent. Therefore, the zero-waste thinking is largely depending on the way handling the biodegradable waste. biodegradable waste treatments are straightforward towards zero landfill through composting and waste-to-energy program that produces biogas and electricity. This study attempts to understand the process towards zero-waste at the landfill site, through conventional engineering and technology of waste recycling, composting and producing energy from the waste, amid the dilemma between sustainable life and ever-increasing waste production.

Keywords: zero-waste, energy from waste, landfill, waste composting, waste recycling.

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1 Introduction

Zero waste has been the utopian goal of municipal solid waste management in many cities and became a keyword in urban development during the 2000-2010 period, see, for example, the studies by Mason et al. (2003), Erkelens (2003), and Lehmann (2010). The term zero-waste itself was commenced in the 1990s when environmental activists in Europe have introduced the zero elimination of waste. During this period, the advocacies were focused on environmental sustainability with sustainable consumption and production (Geels, 2015; Lorek & Spangenberg 2014). At this point, the term zero waste could not completely eliminate the waste from the source, rather minimizing waste production by minimizing consumption. Zero waste was inspired by the fact that land resources are limited particularly in urban areas to cater to the growing need for a landfill site, and nobody voluntarily wants to live next to the landfill site, known as NIMBYism, known for Not In My Back Yard (Sebastien, 2017; Simsek et al. 2014; Gallo, 2019). From this thought, people began to explore minimizing waste disposal to the landfill site to zero and therefore eliminating the persistent needs of landfill sites along with the possible social and environmental effects of the landfill site. Despite its triviality, the landfill site might generate income for the scavengers and recyclables collectors. However, it seems that the negative effects generated by the activity are much higher than the benefits gained by the scavengers (Periathamby, 2009; Ferronato & Torretta, 2019; Besiou et al., 2012; Asim et al., 2012).

The main object of this study itself could be defined as discarded solid materials such as garbage (no longer needed), refuse (no one wants it), trash (no longer appreciated), and other solid materials as a result of industrial or commercial or other business operations, and from the community activities. Municipal waste could also be any kind of domestic waste or household waste produced by households or citizens or any activities within the city. Normally municipal waste does not include the very heavy toxic and hazardous waste that requires special treatment, which not many municipalities will be able to do appropriately (Pichtel, 2014). By this condition, the specific hazardous waste such as radioactive waste could not be categorized as normal municipal waste. It is safe to argue that focusing on biodegradable waste towards zero waste or zero disposal at the landfill site is plausible.

The conventional journey of the municipal waste from the sources to the landfill sites can be schematically depicted as shown in Figure 1. Based on Zhou et al., 2019; Srinilta, C., & Kanharattanachai, 2019; Dixon & Langer, 2006), municipal waste could basically be grouped according to its characteristics, which are (1) biodegradable waste, the waste that could be broken down by the environment in a relatively short period through an abundant assimilative capacity of the environment (2) recyclable waste, the waste that can be regenerated into a new form of useful objects (3) reusable waste, the actually-still-usable objects but considered otherwise by others (4) hazardous waste, the waste that needs special treatment because of its properties (5) others or non-toxic but non-biodegradable and non-recyclable wastes.

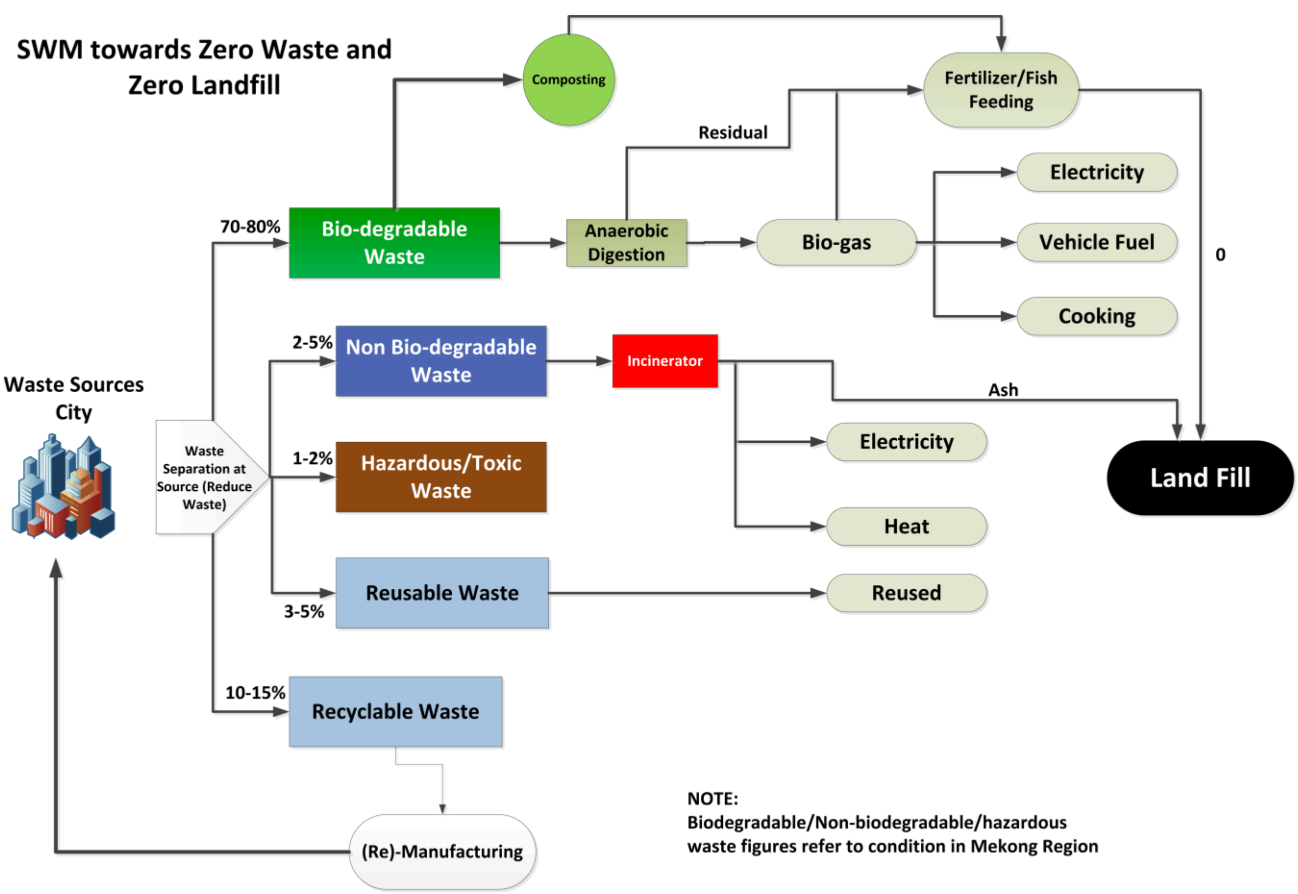

Figure 1 The Waste Journey from Source to Landfill Site

Figure 1 shows the journey of the various types of municipal waste from the sources to the landfill sites in the cities of the Mekong Region countries, namely Bangkok, Nakhon Ratchasima, Detudom, Pitsanulok (Thailand), Vientiane (Lao PDR), Phnom Penh (Cambodia) and Ho Chi Minh City (Vietnam). It shows that biodegradable wastes were the predominant type of municipal waste production. There is no direct linear correlation between waste resources and waste disposal in landfill sites within the framework of zero disposal t landfill sites. The waste should undergo the three main processes to accomplish zero-waste disposal, which is popularly known as waste reduction, waste reusing, and waste recycling (Memon, 2010; Visvanathan et al., 2007; Liu et al., 2017). Waste reduction is associated largely with lifestyle and consumption (Parizeau et al., 2015; Shove, 2004). If the waste reduction is directly associated with sustainability, on contrary, sustainability is inversed in consumption and lifestyle. Our study attempts to clarify these linear associations between sustainability and waste production due to high consumption within the framework of zero waste. This association can be illustrated in Figure 2.

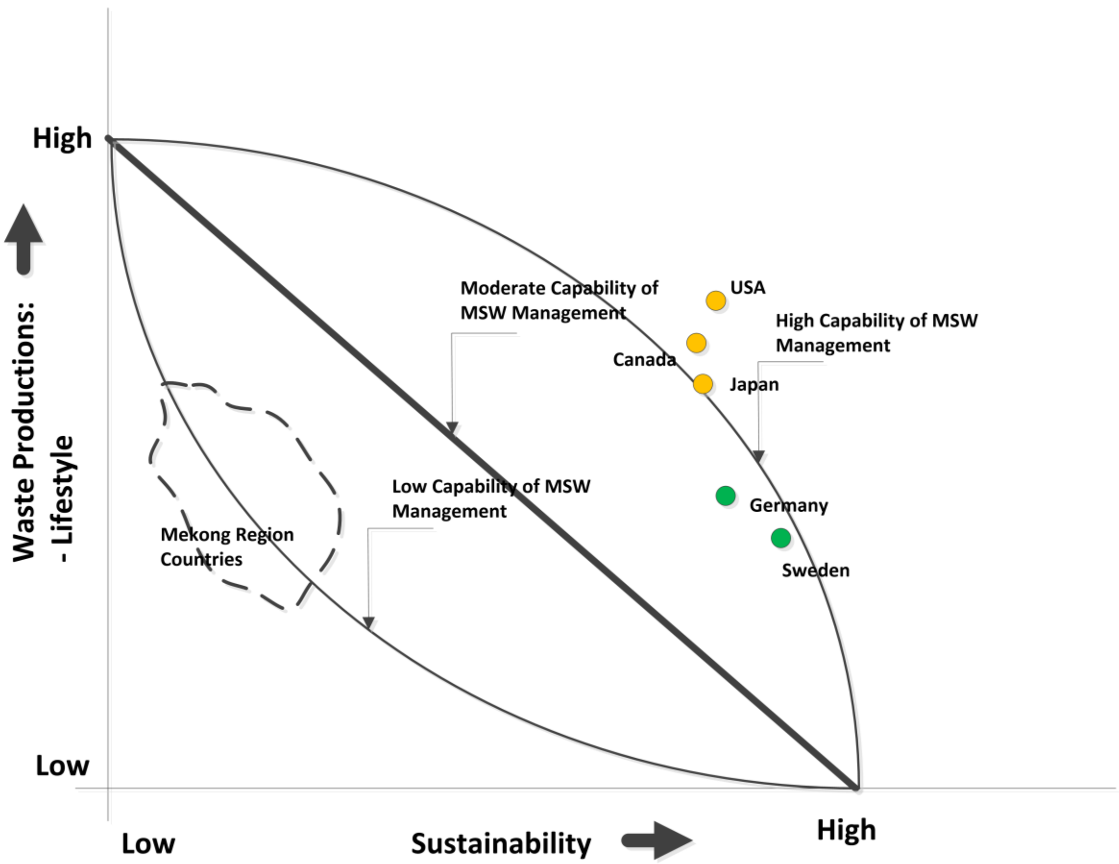

Figure 2 Sustainability vis-à-vis Waste Production

Figure 2 illustrates the three typical capacities of the municipal solid waste management authority. The high capability shows the most organized and beyond conventional waste management authority. The diversified yet cohesive waste management programs lead to higher sustainability for the same level of waste products in comparison to the other two waste management authorities. While the developing countries are mostly found in the lower part of the diagram i.e. high waste production with low sustainability, the developed countries are commonly lie in the upper part, which is signified by high waste production but also high sustainability level. Sweden shows high sustainability with lower waste production, and practically zero waste disposed of at the landfill site. The Mekong Region countries are found in the lower part of the diagram with high production of municipal waste with low sustainability levels. A significant difference between the upper and lower part of the diagram concerning the type of waste. In the lower part region, biodegradable waste i.e. food, kitchen, and wet wastes are predominant.

2. The Objectives and Methodology

There is an inversed linear association between sustainability and waste production, as illustrated in Figure 2. It could simply say the higher waste production the less sustainability of the communities or cities or countries, at any domain level. Similarly, waste production is directly associated with lifestyle. This study aims at clarifying this association and therefore the intervention to accomplish zero-waste to landfill sites could be addressed appropriately. The study was undertaken by collecting primary data in some cities in Cambodia, Lao PDR, Thailand, and Vietnam on their paths toward zero waste to landfill sites, and reviewing the relevant studies on municipal waste management and zero waste.

3. The Engineering of Zero Waste

3.1 Overview

As figure 1 reflected, in the study area i.e. Mekong Region, biodegradable waste is the predominant municipal waste. It was accounted for 70-80 percent. The existing drives toward zero disposal to a landfill site in the region were by employing the composting system and anaerobic digestion of waste to generate biogas. While the biogas system was implemented and in operation in some cities of Bangkok and Nakhon Ratchasima for the electric generation, Detudom for Cooking gas supply, in Phnom Penh Cambodia, and Vientiane Lao PDR, the progress was still at the feasibility study level. Reviewing the currently available technologies to cope with biodegradable waste, it seems that the viable technologies to be applied in the cities of Southeast Asian countries are composting and anaerobic digestion systems to generate biogas (Zurbrugg, 2002; Komakech et al., 2015). In addition to these already implemented technologies of composting and biogas in the region, waste incinerating to produce energy could also be regarded as one of the viable engineering approaches to cope with the abundant biodegradable municipal solid waste toward zero disposal at the landfill site.

If we refer to the waste management hierarchy on the way to sustainable development, see, for example, studies by McDougall et al. (2008); Marshall & Farahbakhsh (2013); Morrissey & Browne (2004), the easiest to the hardest approaches, from the viewpoints of financial investment and technological know-how, could be summarized as the followings:

- Waste disposal. This is the easiest handling system as collect-transport-dispose and forget, without necessarily thinking about sustainability. Because of this nature, the poor countries' waste management system is largely dependent on landfill sites.
- Waste reuse. The reuse depends on the customs and culture of the people. This approach would be easy to accomplish without the involvement of technology and investment.
- Waste reduction and prevention. This approach is relatively easy to accomplish depending on the lifestyle and social construct of the nation. Waste reduction needs no huge financial investments and advanced technology. Therefore, the poor countries would be able to accomplish it.
- Waste recycling and composting. It needs technology and investment to a certain degree. However, no advanced technology and great investment are necessary.
- Waste recovery. Waste recovery is easy but it needs large capital to develop the material recovery facilities to mechanically separate and convert the waste to energy. This nature is not possible to accomplish by most poor countries without adequate assistance from developed countries, including technical and financial assistance.

The above sequence could be varying from nation to nation depending on the capacity and paradigm of waste management. However, this study limits the discussions to only those associated with the engineering ways to solve waste management to minimize the disposal at the landfill site. The engineering approach might not be able to eliminate all the waste disposal, but it makes the residual wastes are easily controllable and gradually reduce to zero.

3.2 Waste Minimization

Waste minimization is the best way to accomplish zero waste at the disposal site, since waste minimization aims to produce less waste from the sources, therefore eliminating the negative environmental impacts due to byproducts of the process. However, it requires significant sacrifice from the waste producers i.e. citizens by complying with a controlled lifestyle, for example, by reducing consumption. The industries and commercials as the largest waste producers should also revisit their raw materials, the technology used and their products, including ecological footprints of the process to comply with environmental sustainability. At the local level, it requires major changes in consumer and producer patterns. We should remember that the million tons of waste generated require costly disposal efforts as well as land for the disposal site. It is, therefore, thought since pre-process production would help to minimize waste production.

The waste minimization process can be seen from upstream to downstream. At the upstream, waste minimization may involve lifestyle and culture, as the effort to minimize the waste produced by an individual, household, and society depend on these two aspects, which are lifestyle and culture. No engineering and technology are required at this phase. On the other hand, the downstream phase may involve engineering and technology since the objective of the waste minimization at this part is to minimize the waste disposed at a landfill site. The waste minimization downstream should therefore be supported by other aspects of waste management, for example, reuse and waste recycling to avoid the waste being disposed of directly at a landfill site.

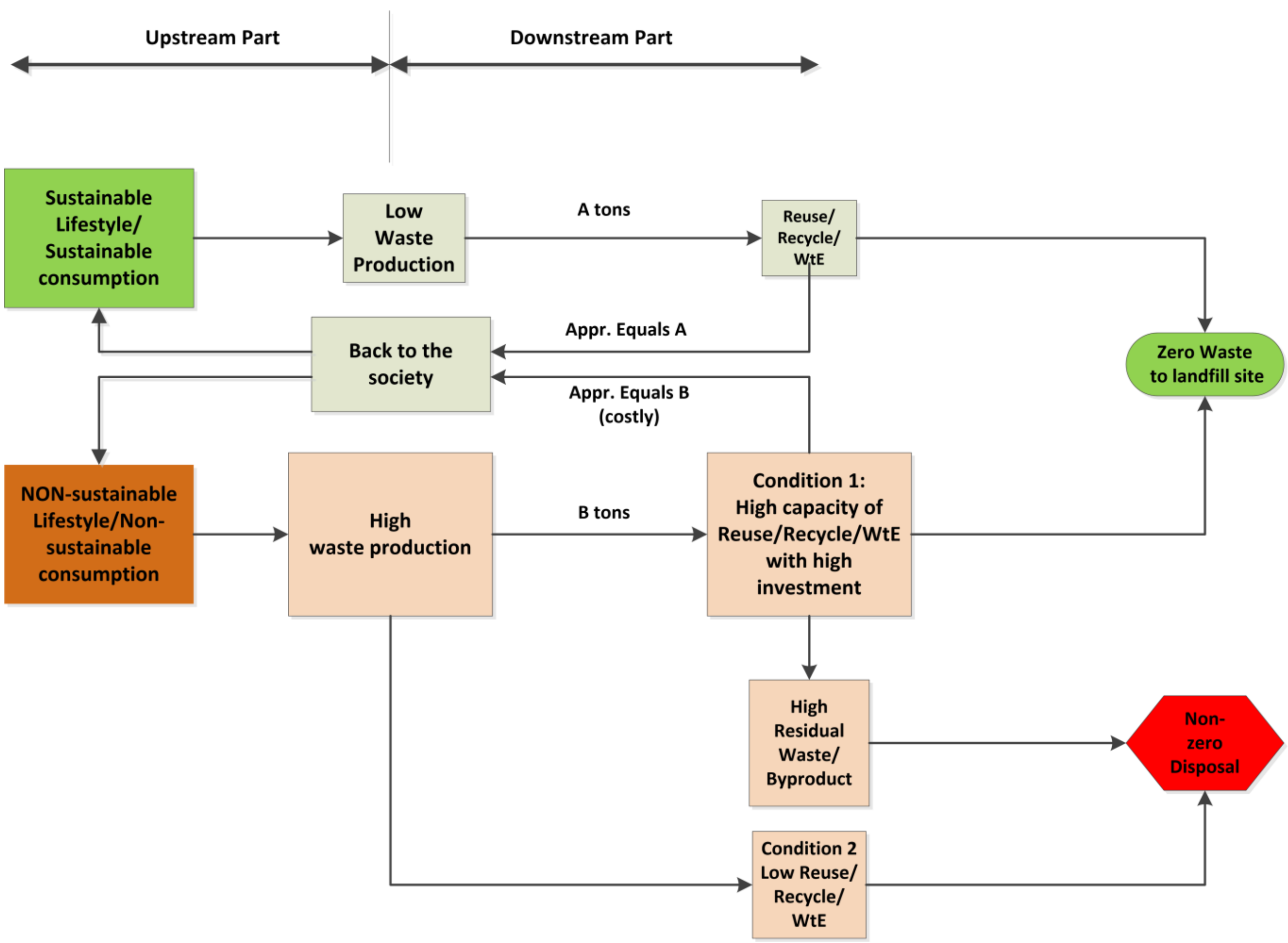

Figure 3 Two paths of Waste Minimization toward Zero Waste

As whatever lifestyle may not be able to produce any waste, the focus is then given to the downstream part of the process (Figure 3). The figure shows two paths of waste minimization based on sustainable or non-sustainable lifestyle and consumption toward zero waste to a landfill site. The sustainable lifestyle path produces low waste production by the society. Zero disposal may be accomplished with low investment in reuse, recycling, and waste-to-energy programs, since the whole waste production can be returned to society sustainably by employing the existing capacity of reuse, recycle, and waste-to-energy programs. The insignificant residual waste or byproduct may be formed, but it can be ignored, and thus zero waste to landfill sites can be accomplished. On the second path (bottom part), the non-sustainable lifestyle produces high waste production. To anticipate this high waste production, a large investment may be required for the accomplishment of zero waste to the landfill site (condition 1). If the investment in recycling and waste-to-energy program was low (condition 2), the high waste products cannot be accommodated, as a result, waste disposal at landfill sites cannot be avoided. Zero disposal cannot be achieved.

As figure 3 demonstrates, waste minimization is largely depending on the lifestyle of the citizens in producing the waste. On the other hand, someone's lifestyle could not be intervened by the country's authority. It is therefore dependent on the awareness of the citizens and the communities to adopt a sustainable lifestyle. The authority, however, should constantly be encouraging the communities to implement life with fewer disposals. There are some rooms for industries and commercials to help promote waste minimization, by designing and producing environmentally friendly packaging such as biodegradable, reusable, recyclable packaging and products.

3.3 Waste-to-energy

With biodegradable waste as the predominant waste, the choices toward zero waste to the landfill site is limited, and at the same time, the option of the waste-to-energy program utilizing biodegradable waste is widely open and viable. The common waste-to-energy programs, with biodegradable waste as the main source, comprise the following processes:

- Producing biogas from the biodegradable waste by using an anaerobic digester. The biogas can be the fuel to generate electricity, or direct use of the gas for cooking, heating, and cooling. The gases produced by biodigester are 50-80 percent of methane, 15-40 percent of carbon dioxide,0-10 percent of nitrogen, and other gases of hydrogen, hydrogen sulfide, and oxygen with maximum content of 2 percent.
- Solidifying the biodegradable waste into a brick-like incendiary material. The materials can be burned to run a steam engine to generate electricity.

The hindrances of both processes are they might produce a high amount of residual waste, in terms of ash and sewage. The burning of incendiary materials and unburnt biogas might also produce air pollutants as well as a greenhouse gas. The biogas digester could be designed to serve the size of individual households and communities. A rough estimate of 100 kg of biodegradable waste may produce around 231 MJ of energy per day for a period maximum of 45 days. However, some input materials might still produce biogas for a period longer than 45 days. Table 1 shows the biogas production and period of production.

Table 1 Biogas Production and the Period of Production (from various sources)

Raw Material	Biogas yield per kg of fermented materials (in m3)	Percentage of biogas production in days		
		0-15	15-45	45-75
Cow dung	0.12	11.0	33.8	20.9
Pig manure	0.22	19.6	31.8	25.5
Human waste	0.31	45.0	22.0	27.3
Water Hyacinth	0.16	83.0	17.0	0.0
Rice straw	0.23	9.0	50.0	16.0

Another way to produce energy from biodegradable waste is to produce incendiary materials to yield heat by burning the material in the incinerator-cum-boiler and steam turbine to produce electricity. This process needs a large investment for the system, in comparison to constructing biodigester to produce biogas. The approximate electric production through a waste-to-energy program for various types of waste is shown in Table 2. The advantage of this process is that almost all wastes, not only biodegradable, are combustible. Therefore, this program can be placed at the most downstream part of the municipal waste management system toward zero waste at a landfill site, as exhibited in Figure 4.

Table 2 The approximate potential production of electricity for various types of waste per 1000 kg biodegradable waste (from various sources)

Raw Material	Biogas Yield (m3)	Electricity Yield (kWh)	Heat produce (MJ)
Grocery store waste	75.0	170.0	900
Trimmed grass	175.0	342.0	1,930.0
Maize silage	185.0	331..0	1,871.0
Cattle manure i.e. cow dung	45.0	88.0	497.0
Chicken manure	80.0	156.0	882.0
Pig slurry	45.0	95.0	536.0

From Tables 1 and 2, an economic and environmental feasibility study can be done by comparing the benefits and the shortcomings of two methods of converting biodegradable waste to energy. However, for the first phase of the conversion, in which no spectacular investment and advanced technology are required, it seems that constructing biodigester to produce biogas is a good start to reduce waste disposal at the landfill site at the same time producing cheap energy for the society. The biodigester can be designed for an individual household.

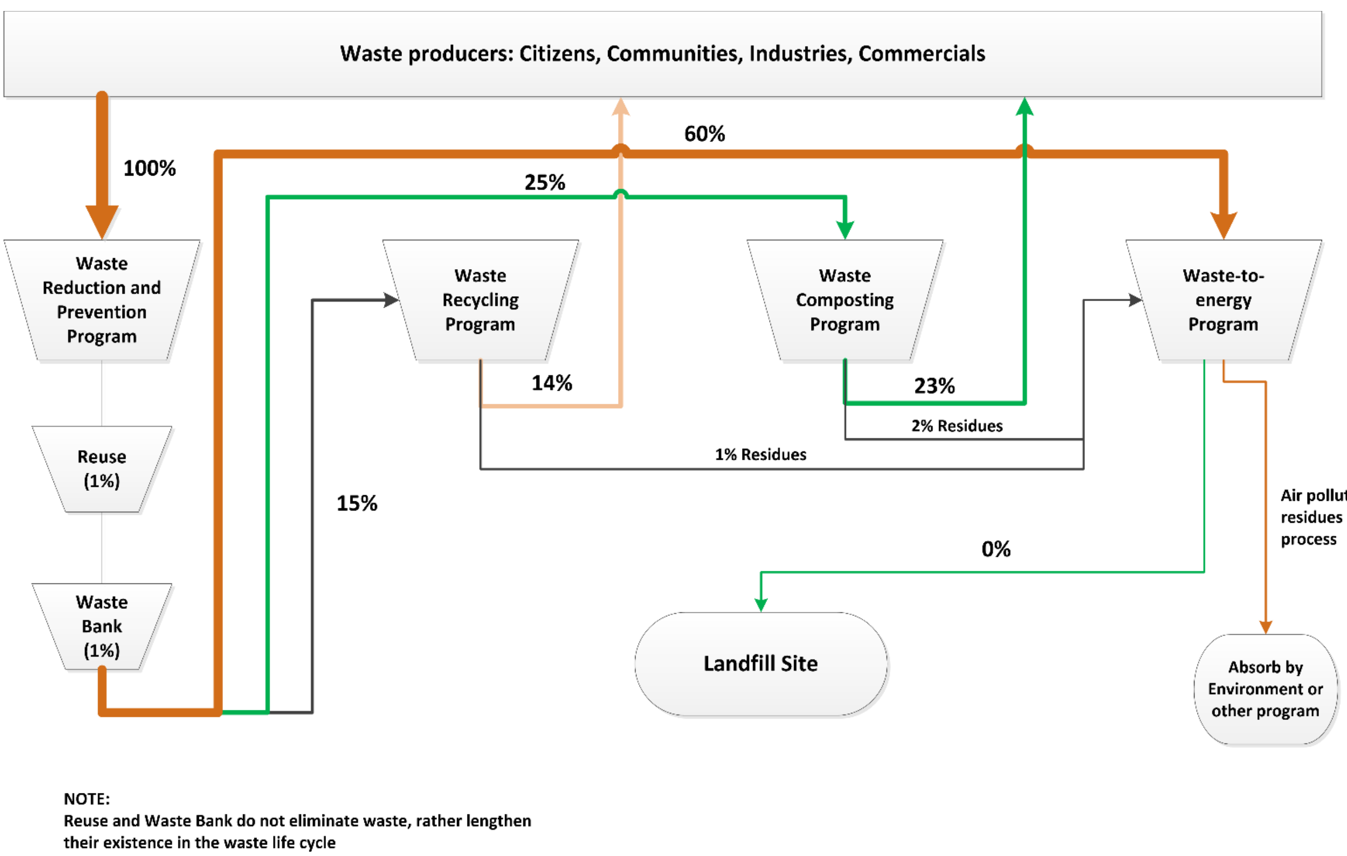

Figure 4 Waste Production and Elimination Process toward Zero Waste

Considering biodegradable waste is the largest predominant quantity of waste in the study area, it could not be wholly absorbed by the waste composting program. On the other hand, the waste-to-energy program is practically able to absorb any kind of waste. It is, therefore, more efficient if the waste-to-energy program is placed as the last resort of the entire municipal waste management program. The waste-to-energy program could, to some extent, eliminate the hazardous waste, given the hazardous waste incinerator friendly waste i.e. without creating severe byproducts. Another consideration is that the waste elimination and transformation process would be more efficient if the process follows practicality and the pre-processing cost minimization. For example, it would be more efficient if unsorted waste produced by individual households, were separated in advance. By these considerations, the sequence of waste elimination and transformation should follow the order as exhibited in Figure 4. The authority foster waste prevention and reduction program for the waste producers i.e. citizens, communities, industries, and commercials. Within the program, reuse, waste bank, and other community-based program can be included. The waste producers should also have done waste separation, which segregates recyclables, compostable wastes, and others. Separated waste could help transfer the waste to recycling centers, composting facilities, and waste-to-energy plants. The transfer process would be smoother with the interconnectivity of those centers, facilities, and plants coordinated under local authority.

3.4 Waste Composting

Waste composting is the simplest and inexpensive way to convert waste into something useful i.e. compost or natural fertilizer, rather than direct disposal at a landfill site. Composting has some benefits if the compost (the composting product) is poured into the soil to enrich, help retain moisture and suppress plant diseases and pests in the soil, reduce the need for chemical fertilizers, encourage the production of beneficial bacteria and fungi that break down organic matter to create humus, and indirectly reduce methane emissions from a landfill site. Any work that diverts the waste from disposals to something beneficial, would directly contribute to zero waste.

Almost all biodegradable materials are compostable. However, the materials with a ratio of Carbon to Nitrogen of 30 to 1. Too much carbon would slow down the composting process, and too much nitrogen would generate more heat in the composted material and would kill composting organisms, as a result, the compost product would not be optimum. No hazardous waste could be composted. Table 3 shows some materials those suitable and unsuitable for composting.

Table 3 Compostable and Non-compostable materials

Suitable material for composting		Non-suitable materials	
Materials	C : N	Materials	C : N
Vegetable waste	10-12:1	Leaves with high Carbon	30-80:1
Grass	12-25:1	Straws	40-100:1
Poultry litter	13-18:1	Corn stalks	60:1
Coffee ground	20:1	Bark	100-130:1
Cow manure	20:1	Wood chip	100-500:1
Horse manure	25:1	Paper	150-200:1

Source: The University of Massachusetts Amherst, https://ag.umass.edu/crops-dairy-livestock-equine/fact-sheets/waste-management-composting (retrieved on March 30, 2022).

With the condition that not all biodegradable wastes are compostable, the zero waste to landfill site could not be accomplished with only composting. Another matter is that composting and compost are limited from the viewpoint of producers and consumers. A huge capacity of composting production requires a large capacity factory. From the consumer viewpoint, the consumer of compost would not be that large. By this condition, composting could only be regarded as a subsidiary or supplementary program toward zero waste at the landfill site.

3.5 Waste Recycling

We subscribed to one of some definitions of recycling (Worrell and Reuter, 2014), which is the reprocessing of the used materials at the end of product life and returning them to the supply chain. The recycled materials are then secondary materials, despite the same chemical content as the primary materials, which are extracted from the environment. The recycling process is therefore to reduce the primary materials extracted from nature by returning them to the production line and thus contribute to environmental sustainability.

Recycling waste requires huge investment in its process despite it needs no advanced technology, which many developing countries have been able to do the recycling process. Depending on the starting point, there are two or three recycling loops along the course of a product from cradle to grave. The earliest recycling process is carried out during material processing. The earliest recycling process is not pure recycling as the material recycled is the same material, in which the physical characteristics did not change. The second recycling is during the fabrication process, for example, the residual cuts, the material is recyclable and can be resent to the production line. The third recycle is after the products are used, and no longer usable. Since the first and the second recycling process are within the industrial production process itself, we would skip the discussion. The focus of discussion in this recycling process is waste recycling, in which the product is considered waste, and the processors are different industrial entities, which are recycling centers, not the producers of the materials or products.

Despite the marginal quantity of recyclables in the study area, the most predominant recyclables are plastics, papers, and steel. The technology used to recover the recyclables are varies. Recovered papers, for example, used the technology to convert the recyclables into recycled pulp. The main purpose of this process is to remove the detrimental substance from the fibers that potentially reduce the quality of paper produced. For recyclable waste of plastics, one needs to know that not all plastics can easily be recycled. There are basically two types of plastics: (a) thermoplastics, the polymers that do not undergo a chemical change when heated and therefore could be molded again, (b) thermosets, the polymers that take shape after solidification. The thermoplastics could be easily recycled, for example, polyethylene (HDPE or LDPE), polypropylene (PP), polystyrene (PS), polyvinyl chloride (PVC). The thermosets, however, could not be easily recycled as the process could only be done by a chemical process. The plastic recycling process uses an agglomeration process and extrusion process. The extrusion process is cheaper and easier in comparison to the first one. Conventional technology of smelter is commonly used in reprocessing the steel product to return to the supply chain. However, the current smelter uses a more energy-efficient process in comparison to the old smelter.

Steel and other metals are highly recyclable as the chemical contents do not change along with the lifespan, besides, the lifespan of products made from steel is sufficiently long. Table 4 shows the lifespan of steel-made objects.

Table 4 Lifespan of steel-made products

Products	Lifespan (Years)
Can	< 1
Vehicle	5-15
Consumer durables	7-15
Railway	25
Heavy industrial machinery	30
Major industrial machinery	40
Bridge, building	20-60

The recycling of lead from the acid battery is also important as the current use of internal combustion engines and future use of electrical cars uses the battery, particularly the acid battery, as lead is used in this type of batter. For the electric car, the Lithium battery might be used.

4. Conclusions

The waste problem will always accompany human civilization, and we cannot avoid it. What we can do is minimize waste production to minimize our ecological footprint, and thus sustain our life. As the waste products cannot be zero, the waste safely disposed to the landfill site is not impossible to be zero. The idea of zero waste disposal was inspired by the fact that the problem of landfill sites including NYMBI-ism is perpetual. With the possibility of zero waste disposal at a landfill site, the efforts could be focused on the supply chain and production line along with the lifespan of the materials from the extraction of the raw materials to the disposal of the products made from this material, from cradle to grave. It largely depends on many factors, particularly, the financial and technological capacity of the authority (the local government), the awareness of the waste producers (citizens, communities, industries, commercials), the existing and the future vision of the municipal waste management system, availability of the technology in the market and society, the current policy of the city or municipality. If the financial capacity and technological know-how of the city authority are commendably high, then there would be no problem in undertaking municipal waste management toward zero-waste disposal at a landfill site. However, if the contrary situation exists, then the municipal waste management toward zero waste to landfill sites would require persistent and deterministic actions from the stakeholders i.e. enablers, waste producers, and waste management operators. The actions must gradually drive in the direction of high capacity of the waste stakeholders to accomplish zero waste.

Apart from the reality that municipal solid waste management in the city in developing countries is at the current level, where the zero-waste disposal at the landfill site is still a long way to go. The following path of municipal waste management is worth ensuing:

- The actions on the waste reduction or prevention, waste composting, waste recycling, and waste-to-energy program must be in place for whatever level of development.
- Waste reduction or prevention at the waste producers should be placed in the upstream part of the system, as the first screening to reduce the waste flow to the downstream. The actions can be accompanied by other compatible actions such as waste reuse and waste bank.
- The composting facilities must be available at a sufficiently high capacity commensurate with the biodegradable waste production in the city. The facilities are the second screening in the municipal waste management system.
- The recycling centers must be available in cooperation with the private sector. The private sector might be interested in doing the business as recyclables have a certain degree of economic value.
- The waste-to-energy program i.e. biogas digester program and incinerator-cum boiler to produce heat and energy should be able to eliminate all residual waste from the upstream part. The zero-waste program depends mainly on this downstream screening. The existing actions should be directed to the development of a waste-to-energy program. This program should be able to increase the capacity in line with municipal waste production.

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References

Asim, M., Batool, S. A., & Chaudhry, M. N. (2012). Scavengers and their role in the recycling of waste in Southwestern Lahore. Resources, conservation and recycling, 58, 152-162.

Besiou, M., Georgiadis, P., & Van Wassenhove, L. N. (2012). Official recycling and scavengers: Symbiotic or conflicting? European Journal of Operational Research, 218(2), 563-576.

Dixon, N., & Langer, U. (2006). Development of a MSW classification system for the evaluation of mechanical properties. Waste management, 26(3), 220-232.

Erkelens, P. A. (2003). Re-use of building components (Towards Zero Waste in Renovation). In Proceedings of the 11 th Rinker International Conference, CIB Deconstruction and Materials Reuse, CIB Publication (Vol. 287, pp. 7-10).

Ferronato, N., & Torretta, V. (2019). Waste mismanagement in developing countries: A review of global issues. International journal of environmental research and public health, 16(6), 1060.

Gallo, M. (2019). An optimisation model to consider the NIMBY syndrome within the landfill siting problem. *Sustainability*, *11*(14), 3904.

Geels, F. W., McMeekin, A., Mylan, J., & Southerton, D. (2015). A critical appraisal of Sustainable Consumption and Production research: The reformist, revolutionary and reconfiguration positions. *Global Environmental Change*, *34*, 1-12.

Komakech, A. J., Sundberg, C., Jönsson, H., & Vinnerås, B. (2015). Life cycle assessment of biodegradable waste treatment systems for sub-Saharan African cities. Resources, Conservation and Recycling, 99, 100-110.

Lehmann, S. (2010). Resource recovery and materials flow in the city: Zero waste and sustainable consumption as paradigms in urban development. Sustainable Development Law & Policy, 11, 28.

Liu, L., Liang, Y., Song, Q., & Li, J. (2017). A review of waste prevention through 3R under the concept of circular economy in China. Journal of Material Cycles and Waste Management, 19(4), 1314-1323.

Lorek, S., & Spangenberg, J. H. (2014). Sustainable consumption within a sustainable economy–beyond green growth and green economies. Journal of cleaner production, 63, 33-44.

Marshall, R. E., & Farahbakhsh, K. (2013). Systems approaches to integrated solid waste management in developing countries. Waste management, 33(4), 988-1003.

Mason, I. G., Brooking, A. K., Oberender, A., Harford, J. M., & Horsley, P. G. (2003). Implementation of a zero-waste program at a university campus. *Resources, Conservation and Recycling*, *38*(4), 257-269.

McDougall, F. R., White, P. R., Franke, M., & Hindle, P. (2008). Integrated solid waste management: a life cycle inventory. John Wiley & Sons.

Morrissey, A. J., & Browne, J. (2004). Waste management models and their application to sustainable waste management. Waste management, 24(3), 297-308.

Parizeau, K., von Massow, M., & Martin, R. (2015). Household-level dynamics of food waste production and related beliefs, attitudes, and behaviours in Guelph, Ontario. Waste management, 35, 207-217.

Periathamby, A., Hamid, F. S., & Khidzir, K. (2009). Evolution of solid waste management in Malaysia: impacts and implications of the solid waste bill, 2007. Journal of material cycles and waste management, 11(2), 96-103.

Pichtel, J. (2014). Waste managemet practices: municipal, hazardous and industrial. Second Edition. CRC Press.

Sebastien, L. (2017). From NIMBY to enlightened resistance: a framework proposal to decrypt land-use disputes based on a landfill opposition case in France. Local Environment, 22(4), 461-477.

Simsek, C., Elci, A., Gunduz, O., & Taskin, N. (2014). An improved landfill site screening procedure under NIMBY syndrome constraints. *Landscape and urban planning*, *132*, 1-15.

Shove, E. (2004). Changing human behaviour and lifestyle: a challenge for sustainable consumption. The ecological economics of consumption, 111-131.

Srinilta, C., & Kanharattanachai, S. (2019). Municipal solid waste segregation with CNN. In 2019 5th International Conference on Engineering, Applied Sciences and Technology (ICEAST) (pp. 1-4). IEEE.

Visvanathan, C., Adhikari, R., & Ananth, A. P. (2007). 3R practices for municipal solid waste management in Asia. Linnaeus Eco-Tech, 11-22.

Worrell E. & M. Reuter (2014). Handbook of Recycling: State-of-the-art for practitioners, analysts, and scientists. Elsevier, http://dx.doi.org/10.1016/B978-0-12-306459-5.00002-7

Zhou, M. H., Shen, S. L., Xu, Y. S., & Zhou, A. N. (2019). New policy and implementation of municipal solid waste classification in Shanghai, China. International journal of environmental research and public health, 16(17), 3099.

Zurbrugg, C. (2002). Urban solid waste management in low-income countries of Asia how to cope with the garbage crisis. Presented for: Scientific Committee on Problems of the Environment (SCOPE) Urban Solid Waste Management Review Session, Durban, South Africa, 1-13.