Jurnal REP Vol 8/ No.1/2023

Jurnal REP (Riset Ekonomi Pembangunan)
http://jurnal.untidar.ac.id/index.php/REP
P-ISSN: 2541-433X E-ISSN: 2508-0205

RENEWABLE ELECTRICAL ENERGY FROM WASTE (CASE STUDY OF WASTE AT JATIBARANG LANDFILL SEMARANG)

DOI: 10.31002/rep.v8i1.610

Hastarini Dwi Atmanti [1]✉, I Made Bayu Dirgantara[2], Yuliani Setyaningsih[3]
[1,2,3] Universitas Diponegoro
✉ hastarinidwiatmanti@live.undip.ac.id

Abstract

Renewable energy from waste can be an alternative as a power plant. This study aims to analyze the potential of waste in the Jatibarang landfill Semarang to be converted into electrical energy.The analytical method used is descriptive analysis. Around 850 tons of waste are dumped daily at the Jatibarang landfill. Due to the declining landfill capacity caused by this circumstance, the age of the landfill is decreasing. Waste must therefore be controlled by turning it into electrical energy. With a capacity of about 20 MW, this waste can be exploited as a power source.An environment with a sustainability quality will result from the conversion of waste into electrical energy.

Keywords*: *waste; Jatibarang landfill; electrical energy; sustainable environment

Received: February 20, 2023
Accepted: April 23, 2023
Published: April 27, 2023

Jurnal REP (Riset Ekonomi Pembangunan)
Published by Department of Economic Development, Faculty of Economics, Universitas Tidar

INTRODUCTION

A negative impact of population growth is increased waste generation (Hosseinalizadeh et al., 2021). The increase in the global population is expected to increase the amount of waste generated, particularly solid waste in urban areas by 2025.

Table 1. Municipal Solid Waste Estimation in 2025

Wilayah	Total urban population (millions)	Municipal Solid Waste Generation Per Capita (kgs/day)
Africa	518	0.85
East Asia and Pacific	1230	1.52
East and Central Asia	240	1.48
Latin America and the Caribbean	466	1.56
Middle East and North Africa	257	1.43
OECD	842	2.07
South Asia	734	0.77
Total	4287	1.42

Source: Rogoff (2019)

Table 1 indicates that as the global population increases, waste production also increases (Shah et al., 2021). The world produces about 2.01 billion tons of municipal solid waste and 33% of it is not handled properly. Moore poorly managed waste occurs in developing countries (Ibáñez-Forés et al., 2019). This condition also occurs in Indonesia, where the population of Indonesia continues to grow. Indonesia has a total population of 275.77 million as of July 2022. This number based on (BPS, 2022) increased by 1.13% over the same period last year. This demographic increase is impacting the increase in waste in Indonesia. Over the course of the pandemic, waste has grown by 68.5 million tonnes and plastic waste by 11.6 million tonnes (www.cnnindonesia.com, 2022).

Waste handling in developing countries is always done in a conventional way, where waste ends up in a final disposal site (TPA) (Ganguly & Chakraborty, 2021). Waste that ends up in the TPA is also treated conventionally, which is free disposal. Open disposal is a means of managing waste that is openly disposed of in landfill (Siddiqua et al., 2022). The waste handling process with open dumps will cause problems. According to Mohan and Joseph (2021), open dumping results in problems such as air, water, and soil pollution. It can also make locals sick (Ferronato and Torretta, 2019), have an adverse effect on the environment (dos Muchangos and Tokai, 2020), and shorten the life of landfills (Mulyanto, 2018).

The implementation of open dumps is often found in landfills in developing countries, including Indonesia. According to katadata.co.id (2019) if all the waste ends up in the landfill in 1 hour, 7300 tons of waste will be collected. It is similar to the possibility of covering half of the National Monument. It is comparable to being able to lend up the

Gelora Bung Karno Main Stadium with a height of around three times as much if the waste ends up in the landfill each day. If the waste ends up in the landfill, as much as 175,000 tons of waste will be gathered. If every piece of waste is dumped in a landfill, 64,000 tonnes of waste might be gathered in ten years. The waste is compared to being able to drown Jakarta because it will stretch from Thamrin to Senayan and be nearly five times as high as the Monas Monument.

In view of this, open disposal is not recommended for waste management. So as to create zero waste, waste can be converted into energy (Waste to Energy/WTE). Waste into renewable electrical energy is not a necessity. Based on study by dos Santos et al. (2019), it is possible to use the waste in Brazilian landfills to generate electricity and meet the needs of almost 38,000 people.

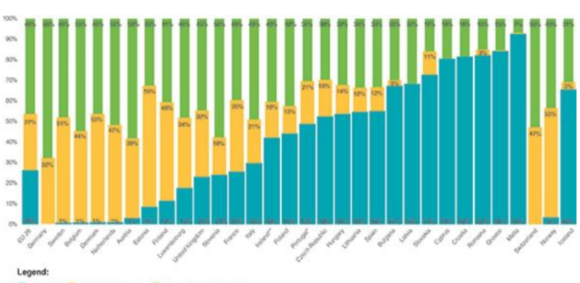

Figure 1. Waste Management in European Countries
Source: Rogoff (2019)

Out of the 32 countries in Europe, 27 have implemented WTE, according to Figure 1. Estonia, as a country in Europe, has the largest percentage of WTE waste. WTE has been widely practiced by countries in Europe as well as Japan since the 1960s. This is because there is a shortage of land for landfills, even though the waste still appears every day (Rogoff, 2019). So far, the number of WTE around the world has gone up.

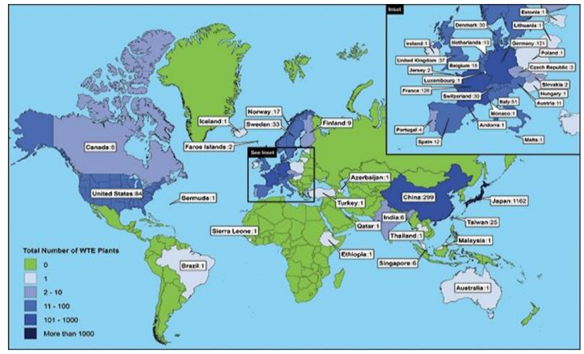

Figure 2. WTE Global Breakdown Map
Source: Rogoff (2019)

Figure 2 illustrates the global breakdown of the WTE.It seems that some countries around the world have implemented sound waste management and others have not. Proper waste management is about converting waste to energy so that no waste can be created (Lee et al., 2020).

According to Law No. 18/2008 about Waste Management, waste management in Indonesia has not up to this point been in compliance with environmentally sound waste management methods and procedures, which can have a detrimental effect on human health and the environment. Consequently, in order to reduce the volume of waste in landfills and improve public health and environmental quality, waste can be managed in renewable electric energy.

This is regulated in PERPRES No. 35 of 2018 concerning the Acceleration of Development of Installations for Processing Waste into Electrical Energy Based on Environmentally Friendly Technology. Waste is transformed into renewable electric energy because waste is considered to have an economic and environment value (Börrnert & Bürki, 2010). The potential of waste to become renewable electricity has not been used in an optimal manner. According to BPSDM PU data for 2019, the potential and installed capacity of Indonesian energy sources are as follows.

Table 2. Potential And Installed Capacity For Energy Resources In Indonesia

Nu.	Energy Source	Potency	Installed Capacity (May 2013)	Percentage
1.	Water	75GW	6.8GW	9.1
2.	Geothermal	29GW	1.4GW *)	4.8
3.	Biomassa (Waste)	50GW	1.6GW	3.3
4.	Solar	4.8kWh/m³/day **)	27GW	n/a
5.	Wind	3-6m/s **)	1.4MW	n/a
6.	Sleep	49GW	0.01MW	0
7.	Natural Gas	150.7TCF ***)	3.17TCF/year (2012)	2.1% *)

Note: * installed capacity May 2015; ** The size of the potential for solar PV and wind power depends on the size of the area allocated for solar panels and wind turbines.; *** Installed capacity in 2012 according to RUPTL 2015---2024 (PLN, 2015).

Source: bpsdm.pu.go.id (2018a)

The Jatibarang Landfill in Semarang City manages waste as part of a government scheme to turn it into renewable electrical energy. Semarang City is one of the Indonesian cities with the highest garbage production rates, according to information from the National Waste Management Information System (SIPSN). According to the findings of an interview performed on September 5, 2022, with Mr. Wahyu Heryawan, the Head of the Jatibarang Landfill, Semarang City, the Jatibarang Landfill is currently over. This situation is brought by by the daily growth of the trash mounds entering the Jatibarang Landfill. The Jatibarang Landfill carrying capacity is gradually diminishing. The Jatibarang Landfill receives between 850 and 900 tons of waste each day. Because of this, the purpose of this paper is to assess the potential for electrical energy generated from waste at the Jatibarang Landfill in Semarang City.

THEORETICAL BASIS

Waste Management

According to Law No. 18 of 2008, waste management is a systematic, all-encompassing, and ongoing activity that encompasses waste processing and reduction. The purpose of waste management is to enhance environmental quality, public health, and resourcefulness.

The waste management hierarchy helps waste management starting from planning towards a more environmentally friendly concept to final processing so as to produce minimal waste waste. The waste management hierarchy is crucial in assisting organizations in achieving their zero waste to landfill objectives (Pariatamby dan Fauziah, 2014).

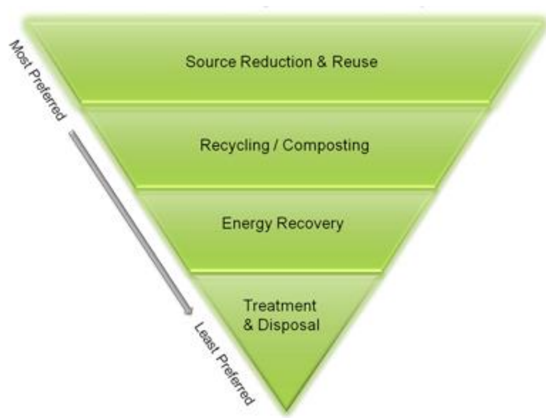

Figure 3. Waste Management Hierarchy
Source: www.epa.gov., 2022

Energy recovery is a part of waste management hierarchy. Through a variety of processes, such as combustion, gasification, pyrolysis, anaerobic digestion, and landfill gas recovery, non-recyclable waste materials can be converted into heat, electricity, or fuel that can be used in a variety of ways. Waste-to-energy (WTE) is a common name for procedure. By displacing the need for energy from fossil fuels and lowering methane production from landfills, the conversation of non-recyclable waste materials into electricity and heat creates a renewable energy source and lowers carbon emissions. After energy is recovered, about 10% of the volume is left as ash, which is typically dumped in a landfill (www.epa.gov., 2022).

RESEARCH METHODS

A qualitative descriptive study is what this investigation is. Qualitative research, as defined by Creswell and Poth (2016), is a type of study in which specific actions or occurrences will be investigated or made known. The information used was gathered through field notes, literature reviews, and interviews with The Jatibarang Landfill head. In September 2022, field interviews and documentation will be conducted. This study demonstrates how waste at The Jatibarang Landfill could potentially be converted into electricity.

RESEARCH RESULTS AND DISCUSSION

The Jatibarang Landfill is situated in Kedungpane Village, Mijen District, Semarang City. 46183 Ha is the size of the Landfill. In March 1992, the Jatibarang

Landfill started operating. Residents of 16 Semarang City subdistricts bring their waste to the Jatibarang Ladfill for storage. The amount of waste that can be accommodated is approximately 4.15 million m3. The Sanitation and Landscaping Office of the City of Semarang oversees Jatibarang Landfill, but as of 2016, the Environment Agency of the City of Semarang has taken over that responsibility. The Jatibarang Landfill is currently overflowing with about 800-850 tons of waste entering it each day (interview with the Head of the Jatibarang Landfill, 5 September 2022).

The waste that will be disposed of at the Jatibarang Landfill and transported by a trash truck is depicted in Figure 4 as being weighed first. The volume of waste produced each day is to be determined by this waste weighing. Waste that is transported to the Jatibarang Landfill.

Figure 4. Waste Weighing
Source: personal records on 5 September 2022

Table 3. Estimated Waste Production per Day (m3), Volume of Waste Transported per Day (m3) and Percentage of Waste Transported (%), 2017-2020

Year	Estimated Waste Production per Day (m^3)	Transported Waste Volume per Day (m^3)	Percentage of Transported Waste (%)
2017	5163	4544	88
2018	5248	4645	88.5
2019	5163	4544	88
2020	5248	4645	88.5

Source: (BPS, 2018, 2019, 2020, 2021)

According to the information in Table 3, the amount of waste transported to the Jatibarang Landfill represents 88% to 88.5% of the total amount of waste generated. This demonstrates that waste is still not being collected. Transported waste that is deposited in the landfill has not been properly managed in its entirety. A power plant installation with an incinerator is currently in the bidding process. The head of Jatibarang Landfill claims that a power plant made from waste that uses an incinerator will provide a solution to the waste issue, particularly in urban areas where there is zero waste or no waste residue.

Figure 5. A membrane for a power plant covers waste at the Jatibarang Landfill.

Source: personal records (5 September 2022).

In Figure 5, waste in the Jatibarang Landfill that is turned into electricity is shown to be covered by a membrane. Methane gas from the waste is collected and used to power generators to produce electricity when it is released from waste that has been covered with a membrane. The technology used to manage waste into electrical energy varies. The waste is thermally burned at extremely high temperatures if there is going to be zero waste. Electricity is produced using the steam produced when waste is burned. Using the methane gas produced by the waste is another technology for turning waste into energy. Methane gas (CH4) and carbon dioxide (CO2) are the gases produced by waste piles (Pawananont and Leephakpreeda, 2017). At the Jatibarang Landfill, methane gas is converted into approximately 800 kV of electrical energy, which can power 800-1000 homes.

Figure 6. Power Plant Installation with Biogas Technology (Methane Gas)

Source: personal records (5 September 2022)

In Figure 6, a power plant that produces electricity from methane gas is installed. It has been in operation since the end of 2019 for PLTSa with biogas technology. PT. PLN purchased the electricity produced by PLTSa under an eight-year cooperation agreement from PLN for a price of IDR 1,114 per kW. Stable waste supply is a requirement for the use of waste as an electrical energy source (bpsdm. pu. go. id, 2018b). The supply of methane gas at the Jatibarang Landfill has decreased, according to (Nurhadi et al., 2020). A decrease in electricity production results from the fact that PLTSa with biogas currently operates commercially at 200 kW from a 954 kW installed capacity.

A supply of electrical energy derived from waste using thermal technology is attempted under these circumstances. According to Artharini (2016) and bpsdm.pu.go.id (2018), the electrical energy produced by the thermal process is greater than the electrical energy produced by the biogas process. The amount of residue produced by PLTSa using thermal technology is less than PLTSa using biogas technology. There have been studies done on building waste-to-energy incinerator installations. 1,000 tons of waste at the Jatibarang Landfill will be converted using PLTSa thermal technology into approximately 19 MW of electrical energy (Following an interview with the Jatibarang Landfill's Head.).

According to a study by Utomo and Hariningrum (2020), waste at the Jatibarang Landfill has the potential to be thermally processed into electrical energy.

Table 4. Installed Power Plant Capacity by National Generator Type (MW) from 2013-2020

Year	PLTU	PLTG	PLTGU	PLTD	PLTA	PLTM	PLTMH	PLTB	PLTBg	PLTBm	PLTP	PLTS	PLTSa	PLT Hybrid
2013*	19.384,58	4.165,40	9.800,97	3.562,21	5.044,18	92,93	73,98	1,46	24,80	1.339,87	1.398,30	18,65	-	0,08
2014*	20.897,58	4.351,40	9.880,97	3.673,46	5.048,59	111,26	76,95	1,46	28,80	1.359,87	1.403,30	22,74	14,00	0,08
2015*	22.712,58	4.495,56	10.293,47	3.824,07	5.068,59	148,71	90,15	1,46	54,72	1.671,29	1.438,30	33,36	15,65	3,58
2016*	24.316,97	4.969,24	10.293,47	3.979,40	5.343,59	211,40	95,87	1,46	64,16	1.703,29	1.533,30	43,12	15,65	3,58
2017*	26.733,07	4.976,24	10.418,47	4.396,35	5.343,59	240,55	103,76	1,46	100,62	1.740,54	1.808,30	50,90	15,65	3,58
2018*	27.488,17	5.348,44	11.220,10	4.630,90	5.399,59	267,79	104,76	143,51	108,62	1.758,54	1.948,30	60,19	15,65	3,58
2019	30.406,17	5.348,44	11.669,54	4.779,68	5.558,52	311,14	106,36	154,31	112,42	1.758,54	2.130,70	145,81	15,65	3,53
2020	32.336,86	5.348,44	12.235,71	4.863,53	5.638,67	375,84	106,36	154,31	117,82	1.762,04	2.130,70	147,28	15,65	3,58

Information:
PLTU: Steam Power Plant
PLTP: Geothermal Power Plant
PLTS: Solar Power Plant
PLTG: Gas Power Plant
PLTSa: Waste Power Generation
PLTGU: Gas and Steam Power Plant
PLT Hybrid: a power plant with different energy sources
PLTMG: Gas Engine Power Plant
PLTBm: Biomass Power Plant
PLTD: Diesel Power Plant
PLTA: Hydroelectric Power Plant
PLTM: Oil Power Plant
PLTMH: Microhydro Power Plant
PLTB: Wind Power Plant
PLTBg: Biogas Power Plant
*) correction in 2019

Source: Kementerian-ESDM-Dirjen-Ketenagalistrikan (2021)

Since any kind of waste can be turned into electrical energy, thermal technology with an incinerator was chosen. The use of this incinerator is a potential solution to the issue of urban waste, which is experiencing a waste emergency and the Landfill's capacity has been exhausted (Paleologos et al., 2016). Incinerator-based thermal technology, which is superior to other thermal technologies, can reduce waste by up to 1300 tons per day, according to Qodriyatun (2021). An incinerator's primary benefit, according to Thomas and Soren (2020), is that it can reduce waste by 90–95%.

The Jatibarang Landfill is facing a new challenge in waste processing: the thermal process with an incinerator. The Landfill is past its prime while the amount of waste entering it is rising. The management of waste in Landfills by converting it to energy requires quick actions. The capacity of electrical energy from PLTSa is still less than that of other power plants, despite being compared to other power plants. It's displayed in Table 4.

CONCLUSIONS AND SUGGESTIONS

Conclusions

It is urgent to deal with the waste emergency in Semarang City. The generation of waste has outpaced population growth, marking the end of the Jatibarang Landfill era. There are still efforts being made to lower waste generation at the Jatibarang Landfill. Waste can be converted into renewable energy as a potential remedy.

Thermal power and biogas can be used to generate electrical energy from waste. While the thermal power plant is currently up for auction, the biogas power plant that uses waste from the Jatibarang Landfill has been in operation since 2019. The capacity of generators powered by waste is lower than that of generators powered by other energy sources, but efforts to turn waste into electricity can lessen the amount of waste that is generated in landfills. One way to achieve sustainable environmental quality is by using waste to generate electrical energy.

Suggestion

The waste can be turned into electricity to help reduce the growing volume of waste in landfills. There is no certainty in this. Future waste management regulations in Indonesia can be used to ensure that the planet is sustainably managed.

REFERENCES

Artharini, I. (2016). Bisakah kita mengubah sampah jadi energi listrik? *BBC News Indonesia*.

Börrnert, T., dan Bürki, T. (2010). *Waste heat conversion into electricity*. Paper presented at the 2010 IEEE-IAS/PCA 52nd Cement Industry Technical Conference.

BPS. (2018). *Statistik Lingkungan Hidup*. Jakarta: BPS.

BPS. (2019). *Statistik Lingkungan Hidup*. Jakarta: BPS.

BPS. (2020). *Statistik Lingkungan Hidup*. Jakarta: BPS.

BPS. (2021). *Statistik Lingkungan Hidup*. Jakarta: BPS.

BPS. (2022). Jumlah Penduduk Pertengahan Tahun (Ribu Jiwa), 2020-2022. Jakarta: BPS.

bpsdm.pu.go.id. (2018a). *Modul 01 - Kebijakan Dan Strategi Pengembangan Waste to Energy*. Jakarta: bpsdm.pu.go.id.

bpsdm.pu.go.id. (2018b). *Modul 5 – Teknologi WtE Berbasis Proses Biologi Landfill Gas*. Jakarta: bpsdm.pu.go.id.

bpsdm.pu.go.id. (2018c). *Modul 6 - Pengantar Konversi Termal*. Jakarta: bpsdm.pu.go.id.

Carolyn, R. D., dan Wibawanti, E. (2022). *Potret 5 (Lima) TPA Memanfaatkan Gas Metan (CH4)*. Jakarta: Direktorat Inventarisasi Gas Rumah Kaca dan Monitoring, Pelaporan, Verifikasi–Direktorat Jenderal Pengendalian Perubahan Iklim, Kementerian Lingkungan Hidup dan Kehutanan. .

Creswell, J. W., dan Poth, C. N. (2016). *Qualitative inquiry and research design: Choosing among five approaches*: Sage publications.

Dos Muchangos, L. S., dan Tokai, A. (2020). Greenhouse gas emission analysis of upgrading from an open dump to a semi-aerobic landfill in Mozambique–the case of Hulene dumpsite. *Scientific African, 10*, e00638.

Dos Santos, R. E., Dos Santos, I. F. S., Barros, R. M., Bernal, A. P., Tiago Filho, G. L., dan da Silva, F. d. G. B. (2019). Generating electrical energy through urban solid waste in Brazil: An economic and energy comparative analysis. *Journal of environmental management, 231*, 198-206.

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

Ganguly, R. K., dan Chakraborty, S. K. (2021). Integrated approach in municipal solid waste management in COVID-19 pandemic: Perspectives of a developing country like India in a global scenario. *Case Studies in Chemical and Environmental Engineering, 3*, 100087.

Hosseinalizadeh, R., Izadbakhsh, H., dan Shakouri G, H. (2021). A planning model for using municipal solid waste management technologies- considering Energy, Economic, and Environmental Impacts in Tehran-Iran. *Sustainable cities and Society, 65*, 102566. doi:https://doi.org/10.1016/j.scs.2020.102566

Ibáñez-Forés, V., Bovea, M. D., Coutinho-Nóbrega, C., dan de Medeiros, H. R. (2019). Assessing the social performance of municipal solid waste management systems in developing countries: Proposal of indicators and a case study. *Ecological indicators, 98*, 164-178.

Katadata.co.id. (2019). *Kelola Sampah Mulai dari Rumah*. Retrieved from Jakarta:

Kementerian-ESDM-Dirjen-Ketenagalistrikan. (2021). *Statistik Ketenagalistrikan*. Jakarta: Kementerian ESDM Dirjen Ketenagalistrikan.

Lee, R. P., Meyer, B., Huang, Q., dan Voss, R. (2020). Sustainable waste management for zero waste cities in China: potential, challenges and opportunities. *Clean energy, 4*(3), 169-201.

Mohan, S., dan Joseph, C. P. (2021). Potential Hazards due to Municipal Solid Waste Open Dumping in India. *Journal of the Indian Institute of Science, 101*(4), 523-536.

Mulyanto, A. (2018). Strategi Memperpanjang Umur Tempat Pengolahan Akhir (TPA) Sampah di Indonesia. *Jurnal Rekayasa Lingkungan, 4*(1).

Nurhadi, N., Windarta, J., Ginting, D., Sinuraya, E. W., dan Pasaribu, G. M. (2020). Evaluasi Pemanfaatan Gas TPA Menjadi Listrik, Studi Kasus TPA

Jatibarang Kota Semarang. *Jurnal Energi Baru dan Terbarukan, 1*(1), 20-27.

Paleologos, E. K., Caratelli, P., dan El Amrousi, M. (2016). Waste-to-energy: An opportunity for a new industrial typology in Abu Dhabi. *Renewable and Sustainable Energy Reviews, 55*, 1260-1266.

Pariatamby, A. dan Fauziah, S. H. (2014). Sustainable 3R Practice in the Asia and Pacific Regions: The Challenges and Issues. In A. Pariatamby dan M. Tanaka (Eds.), *Municipal Solid Waste Management in Asia and the Pacific Islands Challenges and Strategic Solutions* (pp. 15-40). Singapore: Springer.

Pawananont, K., dan Leephakpreeda, T. (2017). Feasibility analysis of power generation from landfill gas by using internal combustion engine, organic Rankine cycle and Stirling engine of pilot experiments in Thailand. *Energy Procedia, 138*, 575-579.

Qodriyatun, S. N. (2021). Pembangkit Listrik Tenaga Sampah: Antara Permasalahan Lingkungan dan Percepatan Pembangunan Energi Terbarukan. *Aspirasi: Jurnal Masalah-masalah Sosial, 12*(1), 63-84.

Rogoff, M. J. (2019). The Current worldwide WTE Trend. *MSW Management*.

Setkab.go.id. (2016). 7 Kota Ini Ditetapkan Sebagai Pilot Project Pembangunan Pembangkit Listrik Berbasis Sampah [Press release].

Shah, A. V., Srivastava, V. K., Mohanty, S. S., dan Varjani, S. (2021). Municipal solid waste as a sustainable resource for energy production: State-of-the-art review. *Journal of Environmental Chemical Engineering, 9*(4), 105717.

Siddiqua, A., Hahladakis, J. N., dan Al-Attiya, W. A. K. (2022). An overview of the environmental pollution and health effects associated with waste landfilling and open dumping. *Environmental Science and Pollution Research*, 1-23.

www.epa.gov. 2022. Sustainable Materials Management: Non-Hazardous Materials and Waste Management Hierarchy.