International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2022): 7.942

Lessons Learned from Developing Waste-to-Electricity Installations in Semarang City, Indonesia

Adang Sudrajat[*], Syafrudin[**], Endang Kusdiantini[***]

[*]Master of Energy, Postgraduate, Diponegoro University, E-mail: adangs.11992[at]gmail.com
[**]Master of Energy, Postgraduate, Diponegoro University, E-mail: syafrudin[at]lecturer.undip.ac.id
[***]Master of Energy, Postgraduate, Diponegoro University, E-mail: endangkusdiyantini[at]lecturer.undip.ac.id

Abstract: ***Converting waste to electrical energy is an effective waste management method because it can reduce the volume of municipal solid waste disposed of at the Final Disposal Site, and the electricity generated can be used as a commodity to be sold to the utility company, reducing waste management costs. However, sustainability depends on the technology chosen to process waste into electrical energy. This study explores the development of waste-to-electrical energy installations in Semarang City, Indonesia. It examines the effectiveness of gasification landfill and incinerator technologies, highlighting the challenges encountered and the lessons learned from their implementation.***

Keywords: Waste Management, Electrical Energy, Gasification, Incinerator, Sustainability

1.Introduction

Waste is the remains of daily human and or natural activities in solid form. If it is not managed well, it can damage the beauty of the environment, become a breeding ground for disease, and even gases produced from piles of waste can cause greenhouse gas emissions, which cause global warming and climate change and will affect the continuity of human life on earth.

Waste management is not a simple job that we can do casually. This work needs serious attention from all parties so that the handling can be carried out quickly, effectively, and efficiently and provide optimal benefits to all parties. Handling that is not serious will cause the waste management process to drag on, which can cause no small impact in terms of both material and spiritual losses.

Recently, waste management in Indonesia, especially in big cities, is still not meeting the goals of waste management mandated by Indonesian Law No.18 of 2008 [1], namely improving public health and environmental quality and making waste a resource. Many big cities in Indonesia are currently in a waste emergency situation because the production of municipal waste in big cities continues to increase every year in line with the increasing number of urban residents, while the capacity of municipal solid waste at the Waste Final Processing Site (WFPS) is limited, constrained by the availability of land.

There were many innovative programs to reduce the volume of waste disposed of at the WFPS landfill carried out by the Government of Indonesia, including the 3R program (reduce, reuse, recycle). However, as stated by the Ministry of Forestry and Environment, only about 10% of the waste can be managed through the 3R program, while more than 60% still has to be disposed of and piled into the WFPS landfill, and the remaining 30% is not managed properly and pollutes the environment. [2]

One of the big cities in Indonesia is Semarang City, the capital city of Central Java Province, which had a population of around 1.65 million people in 2020, with waste production reaching 1, 270 tons per day and a projected 2, 000 tons per day in 2040. Based on data from the Ministry of Forestry and Environment, around 80% of waste disposed of in the WFPS Jatibarang.

To reduce the volume of waste disposed of in the WFPS Jatibarang, the Semarang City Government has built a waste-to-electrical energy installation unit using a gasification landfill-type ("gasification unit") with a capacity of 200 kW. The gasification unit has been operating since 2020 and has not reduced the volume that is disposed of and stockpiled in the WFPS Jatibarang, even when it has to stop operation because the gas produced from the landfill area is no longer sufficient to generate electricity as required in the Power Purchase Agreement (PPA) with Utility Company PLN, so that the developer loses money and stops the operation of the gasification unit.

Furthermore, referring to Presidential Regulation No.35 of 2018 [3], the Semarang City Government plans to build a waste-to-electrical energy installation with incinerator technology ("incinerator unit"). The preparation for the development has started since 2019, including the feasibility study, but the procurement process to appoint the developer has not finished yet. Even though, through Presidential Regulation No.97 of 2017 [4], the development of the waste management installation is included in the Indonesian Government's strategic policy program and targeted for completion in 2025, What are the constraints, the causes, and the recommended solutions?

What lesson can be learned from the process of developing waste-to-electricity installations in Semarang City?

2.Literature Survey

Presidential Regulation Number 18 of 2016 [5] provides directions for accelerating the construction of waste-based power plants in seven major cities in Indonesia: Jakarta,

Tangerang, Bandung, Semarang, Surakarta, Surabaya, and Makassar. Furthermore, Presidential Regulation No.97 of 2017 [4] concerning National Waste Management Policy and Strategy was issued to strengthen the direction of acceleration, including the acceleration of the development of a waste power plant, which must be completed by 2025. In addition, the government, through Presidential Regulation No.35 of 2018 [3], sharpens the direction of acceleration by emphasizing the selection of waste to electrical energy technology that is environmentally friendly and can significantly reduce the volume of waste.

Semarang City needs to accelerate the development of a waste-to-electricity energy installation because waste production in the city of Semarang continues to increase significantly every year, and 80% of the daily waste production must be disposed of and landfilled at the WFPS Jatibarang, whose capacity is limited.

The location of the WFPS Jatibarang is in Kedungpane Village, Mijen District, Semarang City, about 11 km west of Semarang City Center (Simpang Lima). The WFPS Jatibarang has been operating since March 1992. The total area of WFPS Jatibarang is 46, 183 Ha, of which 60% is waste landfill and the remaining 40% is supporting infrastructure. Assuming the slope of the WFPS is 24%, the estimated capacity of the WFPS Jatibarang is around 4.15 million cubic meters.

In 2020, Semarang City's waste production was around 1200 tons per day. According to the Vise Mayor of Semarang (8/8/22), with the current waste production of Semarang, the WFPS Jatibarang landfill will be fully occupied in 2023 and cannot accommodate Semarang City's waste disposal [6]. Therefore, the Municipal Government of Semarang is trying to increase capacity by expanding the WFPS Jatibarang area, despite the many objections from the people living around it. In addition, the Semarang City Government is also trying to immediately implement the acceleration of the construction of waste management installations into electricity according to Presidential Regulations No.18 of 2016 [5] and No.35 of 2018. [3]

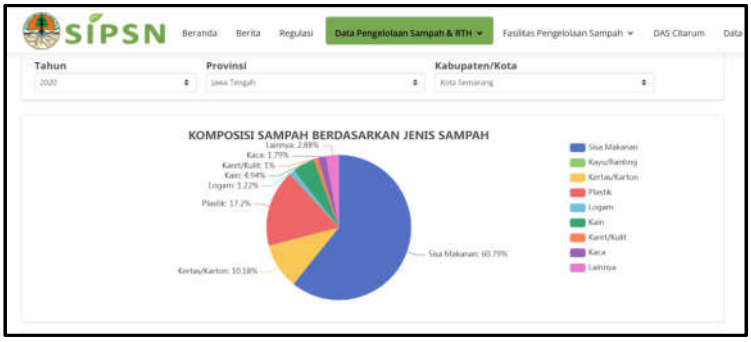

Figure 1: The Composition of Waste of Semarang City
(Source: Waste Management Monitoring System, Ministry of Forestry and Environment)

Based on data from the Waste Management Monitoring System of the Ministry of Environment [6], Semarang City's waste production in 2020 will be around 1200 tons per day, and the projected waste will increase to 2000 tons per day in 2040. The structure of waste consists of 65% organic waste, of which 60% comes from food waste, while the remaining inorganic waste is around 35%. Organic waste is biomass, which is a renewable energy source with low quality.

According to Prabir Basu in his book Biomass Gasification and Pyrolysis: Practical Design and Theory, there are two ways to change or convert biomass (organic waste) into energy, namely the biochemical method (biochemical) and the thermochemical method (thermochemical), as shown in Figure 2. [7]

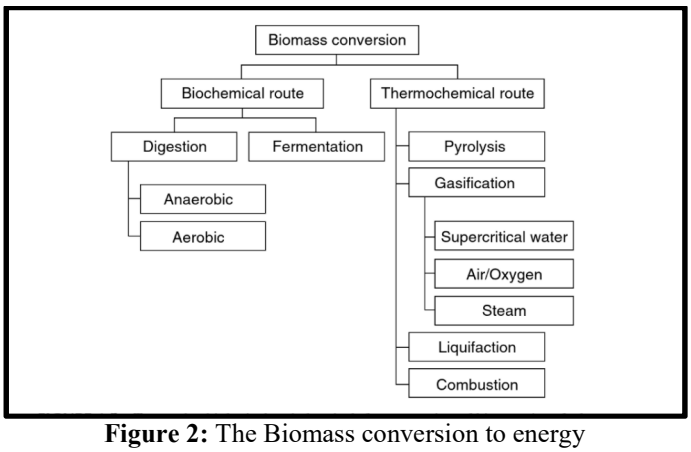

Figure 2: The Biomass conversion to energy
(Source: Biomass Gasification and Pyrolysis: Practical Design and Theory, PrabirBasu 2010)

The energy conversion of biomass using biochemistry involves breaking down biomass molecules into small molecules using bacteria or enzymes. The duration of the conversion process using biochemistry is relatively long compared to thermochemistry, but the biochemical method does not require external energy. In the thermochemical conversion process, biomass converts into gas and is then synthesized into the desired chemical through pyrolysis, gasification, and liquefaction processes, or it can also be used directly through combustion.

Meanwhile, the conversion process of waste into energy can be implemented for both organic and inorganic waste using an incinerator with a very high combustion temperature of > 850°C. However, what needs to be considered when using this concept is what must be added to the power plant to reduce emissions.

In the Guidebook for Accelerating the Development of Waste into Energy published by the Ministry of Energy and Mineral Resources of Indonesia [8], the technologies for converting waste into energy are divided into four groups:

a. Incineration

Incineration is a technological term for converting waste into energy using a direct thermal conversion of waste (both organic and inorganic waste) through combustion with high oxygen levels at temperatures above 850°C.

b. Gasification

Gasification is to convert organic waste into energy. There are many forms of technology (biochemistry or thermochemistry) to convert waste into energy based on gasification. Before starting the gasification process, it is necessary to carry out several pre-processing activities to produce consistent raw materials (shape and size), including separating glass, metal, and debris. The raw materials that have gone through pre-processing are then converted in a partial oxidation process (in the presence of limited oxygen/air), with a conversion temperature of 900°-1.100° C with air content and 1.000°-1.400°C with oxygen content.

c. Pyrolysis

Pyrolysis is a process of thermal degradation of organic waste in conditions without oxygen. Like gasification, waste treatment using pyrolysis technology may require several pre-processing activities to produce a consistent feedstock. Gasification of commercial-scale waste processing on a global scale is currently limited. The pyrolysis installation requires an external heat source, and the temperature of combustion maintain at 400°-850°C. This technology produces syngas, pyrolysis oil (fuel), solid residue (charcoal), and ash/metal residue.

d. Refuse Derived Fuel

Refuse Derived Fuel (RDF) is made through a waste processing process to produce fuel with consistent quality. Usually, to make RDF with consistent quality, sort the waste to get flammable waste (high NCV) such as plastic, easily decomposed waste, etc., which is then dried and chopped to increase its NCV. Any thermal treatment plants can utilize RDF.

As an implementation of Indonesian Law No.18 of 2008 [1] concerning Waste Management, the Government of Semarang City plans to build an installation for processing waste into electrical energy at the WFPS Jatibarang site. The Government of Semarang City carried out a pre-feasibility study in 2015, and the technology chosen was gasification. In line with the issuance of Presidential Regulation No.18 of 2016, the pre-feasibility study was followed up by a feasibility study. Based on the feasibility study result, the estimated potential gas landfill is 600 m3 per hour, and the estimated potential electricity generation is a maximum of 1.3 MW. Furthermore, to implement the results of the Feasibility Study, the Municipal Government of Semarang utilized the Environmental Support Program (ESP) work program between the Government of Indonesia and the Government of Denmark.

The ESP aims to support the Indonesian government in improving the economy based on sustainable development through improved environmental governance, mitigation, and adaptation to global climate change. Through this collaboration program, the Semarang city government appointed the Regional Owned Enterprise, PT Bhumi Pandanaran Sejahtera (PT BPS), to implement a sustainable waste processing system at the WFPS Jatibarang site by building an installation gasification unit in Zone 1 and Zone 2 areas at the WFPS Jatibarang site by making nine gas channels from landfill areas. The PPA was signed by PT BPS as operator and Utility Company PLN as off-taker.

On the other hand, to accelerate the construction, the development of waste to electrical energy installations was designated a national strategic development project by Presidential Regulation No.97 of 2017 [4], with a target of completion in 2025. Even though the construction of the gasification unit has not finished, the President also issued another Presidential Regulation No.35 of 2018 to accelerate the waste-to-electrical energy installation development with new criteria and conditions. It's just that the installation criteria used must be able to reduce the volume of waste significantly in a short time.

The construction of the gasification unit was carried out in October 2018 and completed in December 2019. The planned installed generating capacity is 954 kW. However, during the performance test for 3x24-hour operation, the generator failed to meet the requirements. The plant only operates for 4 hours with a capacity of 800 kW, then the volume of gas drops below 40%. Finally, the gasification unit of Jatibarang operates commercially at a net power capacity of 200 kW from an installed capacity of 954 kW. As a result, The Net Power Capacity of the waste to electrical energy put in the Power Purchase Agreement (PPA) with Utility Company PLN is 200 kW. Finally, the first waste-to-electrical energy installation

(landfill gasification) in Semarang City successfully got the certificate of commercial operation date (COD) on April 2, 2020.

The operating performance of the installation gasification unit Jatibarang continues to decline over time. Starting commercial operation with a net power capacity of 200 kW in April 2020, the operation capacity of the gasification unit will only be 40 kW in 2022. The operation and maintenance costs are higher than the revenue. PT BPS, as the operator of the gasification unit, has lost its way. Finally, at the beginning of 2023, PT BPS could no longer bear the costs of operating and maintaining the gasification unit and decided to stop the operation of the installation.

Furthermore, referring to Presidential Decree No.35 of 2018, the Semarang City Government plans to build another waste-to-electricity processing installation with incinerator technology because the construction duration is very fast, it can burn large volumes of organic and inorganic waste, and the combustion generates heat to produce electricity with a bigger capacity.

There is a difference from the previous unit installation development process that used the Indonesian and Danish ESP programs; the new unit installation development uses the Public Private Partnership (PPP) financing concept [9] [10]. As a reference, in the installation development of waste-to-electricity in other countries, such as China, the procurement process with the PPP concept is faster and more effective. The planned waste volume reduction target is 1, 000 tons per day, and the capacity of the power plant is 15-20 MW.

3.Methodology

The methodology used a combination of questionnaires, interviews, discussions, and a review of previous research. The respondents for this research were the Semarang City Government, Prospective Developers, and PLN as the off-takers of the electricity generated by the installation of waste to electricity.

The purpose of previous research was to enrich understanding regarding waste management by compiling questionnaires and conducting interviews with respondents. The types of previous research reviewed were research related to waste management by the Semarang City Government, research on waste management using incinerator technology, and the use of PPP funding schemes in many countries.

4.Result and Discussion

Analysis of the data obtained from the results of the development of waste-to-electrical energy in Semarang City in this study, among others:

1. In principle, converting waste into energy is one of the best ways to manage waste so that daily waste production can be used to produce energy, especially electricity, so that the remaining waste that has to be disposed of in WFPS (landfills area) is significantly reduced.
2. Installation of waste to electricity with gasification technology:
   a. The pre-feasibility study of the conversion of waste into electricity with gasification technology was done in 2015 and follow up with feasibility study in 2016.
   b. Using the Environmental Support Program (ESP) work program between the Government of Indonesia and the Government of Denmark, the Semarang city government appointed the Regional Owned Enterprise, PT Bhumi Pandanaran Sejahtera (PT BPS), to implement a sustainable waste processing system using waste to electricity with gasification technology at the WFPS Jatibarang. The PPA was signed by PT BPS as operator and Utility Company PLN as off-taker.
   c. The construction of the gasification unitwith an installed capacity of 945 kW was completed at the end of December 2019, but during the performance test to determine the Net Power Capacity (NPC) as required at the PPA with PLN, NPC was only achieved and agreed upon at 200 kW. The capacity could not reach 945 kW because of a lack of continuity in gas supply from the landfill area.
   d. Finally, the first waste-to-electrical energy installation (landfill gasification) in Semarang City successfully got the certificate of commercial operation date (COD) on April 2, 2020.
   e. The operation of the gasification unit is disrupted by a lack of gas. Many of the gas canals in landfill areas are blocked or damaged due to being trampled scavengers by cattle and because the delivery of organic waste to landfill sites is not according to plan. That's why the volume of waste has not significantly decreased. It will affect the cash flow of PT BPS. Investment costs will not return, and PT BPS may suffer losses.
3. Installation of waste to electricity with gasification technology:
   a. The feasibility study of the development of a waste-to-electricity installation (incinerator) was carried out in 2019, including the Financial Business Case (FBC) since the procurement of the PLN IPP scheme. However, the FBC analysis has not been completed yet because regulations in President Regulation No.35 of 2018 impose constraints that limit funding.
   b. The mechanism for selecting developer partners is through an open bidding process with a financing scheme for Government Business Entity Cooperation, namely Public Private Partnership (PPP) and Built Operational Transfer (BOT) types of PPA with a duration of 23 years, including 3 years for construction. The selection of procurement using the PPP concept was not simple, even in other countries, such as China. [9] [11] The waste-to-electricity procurement process using the PPP concept ran smoothly. [12] [13]
   c. Following Presidential Regulation No.35 of 2018, The technology chosen is an incinerator. Based on experience in several countries, the incinerator technology could process more than 1, 000 tons of waste per day, and 80% of this waste would be

burned. Residue from the waste burning could be used for other activities.

d. In the activities of the Indonesia-Japan Virtual Business Forum, there are indications that the required tipping fee is 780, 555 Rupiahs because the investment costs are relatively expensive, around 1.5-2.5 Trillion Rupiahs for a capacity of 19 MW. The indication tipping fee is higher than the budget allocation fund set by President Regulation No.35 of 2018 of 500, 000 Rupiahs. Foreign investors expect guarantees from the Central Government.
e. The lack of budget based on Presidential Regulation No.35 of 2018 should be borne by the Regional Government and the Central Government; however, the amount is limited to only 500, 000 Rupiahs per ton. The budget from the Local government in Semarang is 100 billion Rupiahs only per year, or 274, 000 Rupiahs per ton. The Viability Gap Fund (VGF) provided by the Government is a maximum of 49% of the Tipping Fee.
f. Even though the electricity tariff generated from the instillation incinerator unit stipulated by Presidential Regulation No.35 of 2018 is above the production cost of electricity in PLN, the investment return is not sufficient to meet reasonable expectations. PLN must apply for an additional subsidy from the Government to cover the difference between the production cost and the tariff paid to the Developer and provide cash to pay their invoice. Related to this, the Corruption Eradication Commission (KPK) has indicated the possibility of state losses due to additional subsidies to PLN.

4. The target development of the incinerator unit is not to produce electricity because Utility Company PLN's electricity system has a surplus. Therefore, the Government should focus the funding provided on overcoming the problem of waste management, not producing electricity.

5.Conclusion

Based on the results of the research described above, the lessons learned from the Semarang city government in making a planning program for handling waste problems by converting waste into energy through the construction of waste-to-electrical installations are as follows:

1. Planning the development of power plant installations such as waste-to-electricity requires sufficient time to produce optimal results. The best practices for planning power plants should be followed strictly. Planning that is not mature will cause development results that are not optimal and can even fail.
2. The Presidential Regulations were issued to accelerate waste handling management in big cities by converting waste into electricity. However, the regulations are ineffective because many people understand that they were issued not for waste management but for the development of power plants, even though the Indonesian electricity system managed by PLN is surplus.
3. The focus of waste management execution is disrupted by matters related to electricity problems, such as electricity tariffs that are set higher than the production cost of electricity for PLN as an off-taker. The Corruption Eradication Commission is concerned about the additional subsidy to PLN because PLN has to buy the product of waste-to-electricity.
4. The investment costs of gasification installation units are relatively cheap; however, it takes a long time for the preparation of gas channels in landfill areas. The investment in incinerator installation is expensive and cannot be optimally reduced by tipping fees because the budget for tipping fees is limited. Although the Law on the State Budget allows for additional funds because they are included in the national strategic policy program.
5. Many investors who wanted to participate in the construction of waste management installations have withdrawn because the source of finance is the government's regional budget and depends on central government policy. They ask for a guarantee from the central government.
6. The PPP concept in several countries, such as China, is the best solution for the PLTSa procurement process. In Indonesia, the funding process through PPP requires a relatively long time because it involves many institutions, even though developers expect government guarantees for return on investment.
7. The City Government of Semarang has to solve social problems at the WFPS Jatibarang site because many scavengers and cattle breeders are in the landfill area. The City Government of Semarang has to find wise solutions to avoid any disruptions during operations due to social problems.

6.Future Scope

Because the waste problem urgently needs to be addressed, the Government should issue new President's Regulations to replace or complement the articles that can accommodate the handling of the problems described based on the results of this research, such as tariffing electricity to PLN, limiting tipping fees, and simplifying procedures for the PPP scheme. Further study should continue to check the effectiveness of the new regulations.

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