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OPTIMIZING THE ROLE OF PLTSA BENOWO IN ENERGY MITIGATION AND TRANSITION TO NET ZERO EMISSION

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Abstract:
Every human being always produces waste in his life, be it organic waste or inorganic waste. With the increasing number of people worldwide, the amount of waste produced will increase. To address these challenges, we need technology that can convert waste into renewable energy, as exemplified by the PLTSa Benowo in Surabaya. At PLTSa Benowo, waste is used as a renewable energy source in two ways: landfill gas recovery (LFG) and gasification. The two processes will produce gas, which will be used to generate 11 MW of electrical energy. Waste can be used as a source of electrical energy, which provides many benefits for humans. Besides overcoming the problem of urban waste, which is increasingly piling up, it can also provide an electricity supply for PLN. The author uses descriptive methods through a qualitative approach, and this study intends to understand what phenomena are experienced by the research subjects. The research results will provide additional knowledge about PLTSa Benowo in Surabaya.

Keywords: Renewable Energy, Benowo PLTSA, Waste

INTRODUCTION

The environment is not only about nature but also includes the human-made world. It includes school, home, workplace, and community. Environmental cleanliness is an ecological balance that needs to be achieved between humans and the environment to ensure the best human health. Many problems will occur if the environment is not healthy and clean. These environmental problems have a significant impact on public health.

Developments marked by increased human and economic activities will lead to higher volumes of waste. It makes it difficult to only stick to the old management paradigm. Waste management is only based on collection, transportation, and disposal activities. These activities sometimes require an ever-increasing budget and will cause many operational problems if available. Problems that often arise include the waste not being transported to the landfill, management of facilities that need to follow technical provisions, facilities that do not meet requirements and the waste area will run out.

Indonesia is one of the ten countries with the largest population in the world. Most of the population living in other countries also experience the same problem, including the problem of piles of garbage and piles of garbage. With various community activities and increased commodities and goods purchased, waste that exceeds capacity will undoubtedly be formed until a certain period can no longer be used as a landfill.

Population growth is one of the phenomena that creates a double-edged sword for a country. On the one hand, population growth will also support economic growth because it will increase consumption and productivity. However, population growth also has the potential to have a negative impact if it is not managed correctly, such as waste problems. Each person is assumed to produce 0.7 kg of waste per day so that the waste pile will reach 64 million tons annually (KLHK, 2019). For big cities with a population of 1 million and above, the waste generated can reach 1300 tons per day, and plastic waste can reach 15%.

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With Surabaya as the provincial capital and the largest city in East Java, East Java Province has a population of more than 4 million people and is expected to grow over the years. As the population increases, the amount of waste will also increase. Currently, 1,500 tons of waste flow into the Benowo TPA every day. The population of Surabaya in 2021 will be 2.97 million (DLH Surabaya, 2022).

Law of the Republic of Indonesia Number 18 of 2008 concerning Waste Management states that "waste is the residue of human daily activities and natural processes in solid form, produced by every human being as a result of activities that produce waste." Like urban waste not disposed of in landfills, waste must be handled immediately to avoid contamination. Solid waste generated by cities disposed of in landfills will pose serious environmental threats, including greenhouse gas emissions due to the methane content in landfills (Cudjoe & Han, 2020).

Garbage is still a complicated problem to solve, especially in some big cities and creates environmental problems if there are no practical solutions. It should be noted that the waste management problem occurs in big cities in Indonesia and most cities worldwide. It is undoubtedly inseparable from human activities as waste producers. The volume of waste that is increasing and is not accompanied by expansion or even an increase in the number of final disposal sites (TPA) will undoubtedly become a problem if it is not handled carefully. Garbage is one of the producers of methane gas (CH4), which can affect the climate (Johnke, 2002).

The volume of waste is also influenced by population density growth. The more people there are, the more activities will cause waste. Indonesia's population is increasing year by year. Based on Worldometer data, Indonesia's population 2019 reached 269 million people, equivalent to 3.49% of the world's population. Such a large population will undoubtedly affect the amount of waste generated. In Indonesia, there are many cities with high population density. One of the cities with a high population is Surabaya.

Waste management through stages with the old provisions (collection, transportation, and final disposal) will have a harmful impact. This is due to the increasing complexity of the problem. Handling waste using a new frame of mind requires prioritizing, reducing, and utilizing waste (waste minimization). Minimizing waste generation is an effort to reduce the volume, concentration, toxicity, and hazardous waste content from the production process using reduction according to the origin and utilization of waste. PLTSa is a tool for handling waste using a new frame of mind by reducing the source or utilization of waste.

PLTSa is a relatively new program to be implemented in Indonesia. Edited from existing reports, PLTSa has been operating in Surabaya for three years and works with PLN to sell power plants. Of course, to support the success and sustainability of this PLTSa, a more complex mechanism or system is needed that only allows the power plant to operate with waste. We may know that garbage is always available where people live, but the participation of the community is also significant in the system we operate. Community involvement and participation in its implementation help achieve the goals. The creation of orderly behavior in sorting waste, free of waste, and creating a beautiful environment, as well as other goals expected from the construction of PLTSa.

Using PLTSa as a power plant, in addition to increasing energy security and energy independence, is a greenhouse gas (GHG) because biomass is part of renewable energy or clean energy (green energy) and increases the potential for reducing emissions. The construction of the Biomass PLTU and the acceleration of sustainable energy development.

Based on the above background, this study aims to explain the mechanism of the research subject. This research will identify, explain and understand the description of the stages of implementing the gasification of power plants and other features contained therein. The power plant

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gasification process aims to utilize waste as fuel, which is then used to generate electricity. This, of course, can be used to overcome the waste disposal problem at TPA Benowo Surabaya.

Rubbish. Various human daily activities, both household and production activities in the industrial sector, will produce the remnants of unused materials; the rest is called garbage. Waste is said to be a material or object that has no value or value. Specifically, waste can be interpreted as goods that have poor quality (defective or damaged) in manufacturing or can also be in the form of more material or material that is rejected or discarded (Mitchell, 1997). The definition of waste is also contained in Law No. 18 of 2008 concerning Waste Management. Based on the law, waste is defined as residual in solid objects produced from human daily activities and natural processes.

Garbage can be divided into two types, namely, based on chemical properties and based on physical properties (Damanhuri, 2010). Types of waste based on chemical properties can be divided into two, namely:

1. Organic waste is waste that comes from nature, and it is composed of compounds that make up animals and plants.
2. Inorganic waste is usually produced by industrial processes, where the raw materials are non-renewable natural resources.

Types of waste based on its physical properties can also be divided into two types, namely:

1. Wet waste can decompose or rapidly decay because it consists of organic material.
2. Dry waste is waste that does not decompose or decay slowly and can be burned. It is made from inorganic and organic materials.

Eddi and Tanudi (2014) specify the types of waste into several groups, as shown in the following table:

Table 1. Types of waste according to Eddie Sukardi and Tanudi.

Based on the ingredients	
Garbage type	Example
Organic trash	Vegetable waste, fruit waste, animal carcasses, leaf waste, food waste
Inorganic Garbage	Glass, Plastic, Iron, Steel, Styrofoam.
By Source	
Garbage type	Example
Household waste	Food scraps, household furniture scraps.
Industrial Waste	Industrial waste, residual raw materials, defective goods.
Based on its nature	
Garbage type	Example
Weathered Garbage	Leftovers
Garbage Not Easily Weathered	Wood, Cans
Rubbish Hard Weathered	Plastic, Glass
Combustible trash	Wood, Paper, Plastic, Styrofoam
Non-Combustible Garbage	Iron, cans

Soewedo (1983) argues that the classification of types of waste can also be done based on its origin. Based on its origin, waste can be classified into waste generated by household activities (including waste generated from hospitals, dormitories, offices, hotels, etc.) such as food waste and

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household appliances; Waste from agricultural and livestock activities; Waste resulting from trading activities, such as market and shop waste; Waste resulting from industrial activities, such as the rest of raw materials and waste from production; Road trash. Waste resulting from development activities, such as waste materials, packaging of raw materials, etc.

Garbage is grouped into four groups including:

1. Human Excreta is waste in the form of waste material released by humans, such as feces (feces) and urine (urine).
2. Sewage is wastewater from industrial and household activities, such as detergent water from washing clothes and industrial liquid waste containing chemicals.
3. Refuse is waste from household by-products and industrial activities, such as paper waste, broken pans, unused kitchen utensils, food waste, plant waste, and unused industrial equipment.
4. As the name suggests, industrial waste is generated from industrial activities in the form of remaining raw materials, no longer used equipment, and production waste (Damanhuri, 2010).

Furthermore, waste grouping is usually done based on its composition, for example, as a percentage of weight (wet weight) or volume percentage (wet) of waste. Several factors influence this composition. According to Damanhuri (2010), these factors include:

1. Weather and the level of water content in an area will affect the humidity of the waste in the area.
2. Season, the type of organic waste, such as fruit, is also influenced by the ongoing season.
3. Frequency of Collection: The high frequency of garbage collection will cause garbage to pile up, although organic waste will decompose faster because the decomposition process is faster.
4. Per Capita Income, the amount of waste produced by people with a low economy will tend to be smaller and more homogeneous than that of people with a higher economic level.
5. Socio-Economic Level: The type of waste produced by low-income people will differ from that produced by people with higher economics. Regions with a high economic level of canned waste, paper, and waste that are difficult to decompose are higher than regions with a lower economic level.
6. Product packaging, especially plastic and can packaging, is difficult to decompose and causes garbage to accumulate. In other words, product packaging will affect the amount of waste.

Several stages must be passed in processing waste. Monicce and Perinov (2016) argue that the steps that must be taken in managing waste include:

1. Collection. The existing waste is collected and dried using a press machine at this stage. The pressed waste is separated from the newly arrived ones and stored at a set temperature.
2. Displacement. This stage is the process of transferring the pressed waste to the Flail Mill.
3. Grouping and separation. Transferred waste will be grouped using a magnetic separator, shredder, or belt conveyor. This stage separates mixed organic and inorganic waste. After going through this stage, the waste will turn into dry powder, which can then be used as raw material to heat the boiler.
4. Change from waste to energy. At this stage, the raw materials produced from the previous process will be further processed by entering the material into the combustion chamber.
5. Physical Chemical Processing. The burning process produces residue in solid and liquid form. At this stage, this residue is processed chemically and physically to reuse as fuel or into drinking water, granulated, and so on.
6. Biological processing. Wet waste not used as raw material for combustion will be processed through a biological process to produce benefits, such as composting.

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7. Special processing. This stage aims to provide special treatment to waste that cannot be recycled, such as plastic waste, which will be processed and formed into pallets.
8. Materials manufacture. This stage aims to utilize plastic pallets and the rest of the combustion process as solids to be reprocessed into goods of economic value.

Waste processing at the urban level with an area scale that aims to reduce the volume of waste and create a recycling industry with the community as the manager and the local government can be done through a zero-waste concept approach. In its application, the concept of zero waste uses the principle of reducing, reusing, and recycling (3R) and minimal transport costs by placing the waste processing area close to the source of the waste to minimize the burden of transportation costs.

Sanitary Landfill. Sanitary landfills process waste by stockpiling it using soil in a curved place. The backfilling process is carried out many times until the crooked land is level with the surrounding area, which can increase the selling price of the land.

The Sanitary Landfill system is designed so that leachate (water contained in garbage) does not seep into the ground by installing linear clay and geo-membranes. The leachate is produced from the waste decomposition process carried out by microbes. Microbial activity causes physical- and biological changes simultaneously in the waste. Factors such as waste composition, temperature, and landfill age influence the leachate formation process. Newly created landfills have lower pollutant concentrations than landfills that have been around for years. The increase in the concentration and quality of these pollutants depends on the temperature because, at a specific temperature, the microbes will work better, affecting the chemical reactions.

Garbage Power Plant. A waste power plant (PLTSa) is defined as a power plant that uses waste as raw material for combustion or heating boilers. In the boiler, there is water that turns into steam when heated so that it can drive a generator to produce electricity. In general, the process PLTSa goes through to generate electricity is the same as that of PLTU, except it uses different fuels. To determine the electrical power output of PLTSa, several steps need to be taken as follows:

1. Calculation of the amount of waste heap. It is essential to know the amount of waste buried because this is related to the waste used as fuel. In other words, calculating the amount of buried waste will be related to sustainability and the electricity supply (kWh).
2. Waste heat testing. The waste collected at the Final Collection Place (TPA) will vary greatly, ranging from waste from markets, settlements, shops, and so on. This very varied type of waste will cause the heat and gas content to be different every day, so it is necessary to test the heat and gas content of the samples taken from the landfill.
3. Total Calorie Calculation. The heat test results and the gas content of the samples taken will then be recalculated against the amount of available waste so that the total heat from the waste pile is obtained.
4. Determination of boiler capacity and amount of water. The result of calculating the total amount of heat from the stockpile will then be used as a reference when determining the boiler capacity and calculating the amount of water used while generating steam.
5. Calculation of turbine capacity. The turbine capacity is determined based on the calculation of the boiler capacity and the amount of water.
6. Calculation of generator capacity. The results of the boiler capacity calculation will be used as a reference to determine the type and capacity of the generator used and whether to use several units with a small capacity or one with a large capacity.
7. Economical calculation. This calculation determines the total cost required for construction, payback time, current value, and electricity tariffs issued.

The basic principle of operation of PLTSa. In the operation of PLTSa, there are five basic principles, namely:

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1. TPS stockpile waste, which was previously transported to PLTSa by garbage trucks. Incoming trucks are weighed before the waste is dumped into the garbage bunker. Empty trucks from the PLTSa also enforce weighing to determine the net weight of waste dumped into the concrete wall bunker. The garbage disposal is a closed room, and the air in the room is sucked in by a fan so that the smell of garbage does not come out of the room but is sucked in by a fan and sent to the incinerator. This results in the air around the landfill being odorless. The dimensions of the bunker must be able to absorb waste for 5 to 10 days. Waste that is still damp in the bunker is left (dried) for 3-5 days to reduce the surface water content, and seepage water is channeled to the sewage treatment plant so as not to pollute the environment. During dormancy, stir the debris regularly to reduce water. The calorific value of the waste left for several days is 800 to 1400 kcal/kg, and the water content is ± 50-60%.
2. Dry waste is brought to the chamber by handles mounted on the overhead traveling crane and operated remotely from the control room. The garbage from the grabber is gradually fed into the furnace hopper, which enters the furnace gradually through the garbage injection mechanism. All waste can be burned completely, and toxic gases such as dioxins and furans can be removed. When starting, achieving this high combustion temperature requires additional fuels such as gas, oil, and coal. After reaching the desired temperature, the waste must burn itself. The remaining incineration in the form of bottom ash is automatically removed and collected before being sent for further use. The dust generated is 5% by volume or 20% by weight of the original waste.
3. Furthermore, the hot air from the combustion process evaporates the water in the boiler tube. The hot air path from the furnace is set so that the temperature when hot air hits the boiler does not become too high. Similarly, the pressure and temperature of the steam in the tube are regulated so that the temperature difference between the hot gas and steam does not cause condensation in the boiler tube or cause corrosion. Boiler tubes are usually sprayed with acetylene gas to remove scale using an atomizer.
4. Hot steam with high pressure and temperature is then used to drive a turbine connected to a generator to generate electricity. The characteristics of the turbine used significantly affect the amount of water needed to produce steam to turn the turbine and produce electricity. The water vapor is not discharged directly but condensed in the condenser and returned to the boiler. When water is recirculated, it is usually necessary to add ±10-15 percent of boiler water to prevent steam leaks from occurring.
5. The combustion gas used to produce steam is then channeled to the exhaust gas processing site to be neutralized so that the acid gas content in the combustion gas does not pollute the surrounding air. Exhaust plants in China and Singapore use wet scrubbers combined with activated carbon and additional limestone to remove acid gases before being discharged into the air. Gas that has passed the acid gas stage The remover is then channeled to the dust filter. The dust filter can be used with a regular filter (cloth filter or airbag) alone or combined with an electrostatic precipitator (EP). European factories use only ordinary EP, but China and Singapore usually use filters. The ash trapped at this stage is called fly ash. Fly ash obtained can be used for the same purpose as bottom ash. In addition to the above equipment, removing the dioxin content in the flue gas can also be done by equipping a treatment system with a catalyst. Bottom ash is the ash left in the furnace after the waste-burning process. Fly ash from waste combustion is an excellent stabilizer for soft soils. The strength of clay mixed with fly ash is increased by 75 times, water absorption is good, and the compressibility and plasticity of the soil are reduced by 23% and 69%, respectively.

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METHODS

The research method the researcher uses is the descriptive method through a qualitative approach. This study intends to understand the phenomenon experienced by the research subject. The descriptive method is one of the research methods used to determine the status of an object, group of people, circumstances, ideas, and phenomena currently happening. Subagyo (2011) argues that every research certainly has a purpose, as well as descriptive research that is used to find the meaning or meaning of the existence of a situation or event that is real and as it is.

Based on what was said earlier, this research uses a qualitative descriptive method to provide a clear picture of the Waste Management process in a Waste Power Plant (PLTSa) at TPA Benowo Surabaya. Research informants are critical people who can provide information about the object under study. Therefore, key informants who master and have a relationship with the research topic must provide valid information.

In this study, the informants referred to are apparatuses who joined the PLTSa Benowo program in Surabaya City. A purposive sampling technique was used in this study to obtain information. The informant in this study was the Head of the Surabaya City Environmental Service. In this study, the authors use primary data sources and secondary data as follows:

1. Primary data is obtained in writing, recording the source of the data through interviews and observations and seeing, hearing, and asking questions related to implementing the Zero Waste City Program in Surabaya, a combination of what to do. The language and behavior of the interviewees observed are the most critical data sources in this study. The primary data was from presentations and interviews with the Department of Cleanliness and Clean Environment (KLH) of Surabaya City.
2. Secondary data is obtained from parties unrelated to the object or topic of research. It can also be obtained through library studies, such as books, literature, documents or reports, as well as official archives supporting the PLTSa program in Surabaya.

The following are data collection techniques used by researchers to support research:

1. According to Arikunto (2006), observation is the direct observation of the object of research in the environment using sensing. The data obtained is then recorded in the observation record, which is part of the observation.
2. According to Sugiyono (2016), interviews are a data collection technique if you want to conduct a preliminary study to find the problems to be studied. Researchers carry out observation activities directly by asking respondents questions. Researchers can develop related issues according to the desired issue to start digging deeper into information in the future.
3. Documentation is a technique for collecting data through written materials, photos, procedures, policies, or electronic documents (recordings).

The discussion of research studies can be done with the following steps:

1. Conduct a literature study by seeking information from various sources related to the issue or research topic of handling waste problems in Surabaya. In addition, a literature study was conducted to discover the technology used to convert waste into electrical energy, which is one of the sustainable energy alternatives.
2. Analyzing descriptively related to thermal technology with the application of plasma gasification technology in the management of waste in electricity.
3. Provide conclusions and suggestions on how waste management can be carried out effectively and optimize the right technology according to the type and condition of waste in Indonesia to support sustainable energy.

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RESULT AND DISCUSSION

Conversion of Garbage into Energy. Waste-to-energy conversion technology is a technology that can convert waste into heat energy or electrical energy. This way, the circulating waste can be utilized and minimized to create sustainable energy. In 2021, it was recorded that 1500 tons/day of the volume of waste from the City of Surabaya entered the Benowo TPA, which was converted into electrical energy of up to 2 MW using a technology called Landfill Gas Collection. Organic waste will produce methane gas, which will be utilized in this Landfill Gas Collection technology.

PLTSa Benowo uses two technologies: a landfill gas recovery (LFG) system and a gasification power plant. A landfill gas recovery system that converts landfill waste into energy in the form of biogas. The LFG system also converts combustible waste into high-calorific value materials. Developments with landfill gas collection and gasification technology have different processes for processing waste into electricity.

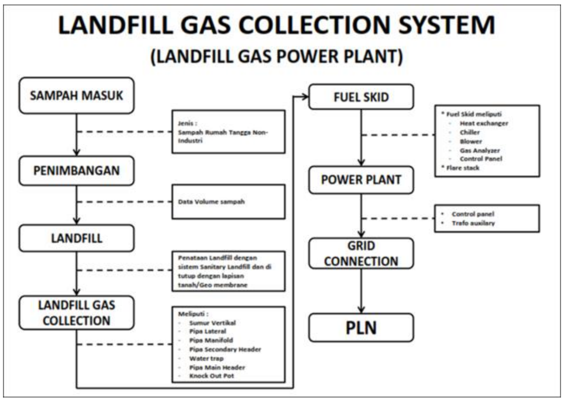

Figure 1. Landfill Gas Recovery PLTSa Benowo Flowchart

Traditional gasification technology burns solid waste in the combustion chamber at high temperatures with less oxygen, producing syngas, liquid and charcoal fuel. Most of the 1,500 tons/day of waste channeled to the Surabaya TPA in 2021 is converted into electricity, reaching 2 MW by using a landfill gas collection technology system. The waste collected at the Benowo TPA is then processed to produce methane gas (CH4). Methane gas is the most essential raw material for power generation. The Benowo TPA gas collection technology system generates 2 MW of daily electricity.

TPA Benowo Surabaya has also developed and implemented a gasification technology system for processing waste production. This step converts waste into electricity and is environmentally friendly. Therefore, at TPA Benowo Surabaya, waste processing technology has been implemented and developed, namely through a landfill gas collection technology system and a gasification technology system. Development through landfill gas collection and gasification technology has different stages of processing waste into electricity.

Landfill Gas Recovery (LFG). The technology used in this landfill gas is WtE (energy waste), the most straightforward technology. Although this technology uses a biological decomposition technique, namely anaerobic fermentation, this LFG technology does not use microorganisms to digest organic matter. Instead, it utilizes the capacity of the landfill environment itself. Landfills can produce methane gas from waste after being closed; it will take up to 30 years to produce gas. It can also be considered when designing the LFG model that will be used.

Landfills can be utilized like biogas by drilling with a series of pipes. LFG is an attractive technology for Indonesia because it can recycle waste. Indonesia has introduced an ideal waste

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management system based on a waste management hierarchy. However, if a landfill accepts only inert substances, it will produce gas from organic waste dumped years ago.

Landfill gas recovery is one of the most common, inexpensive, and straightforward options for converting waste into energy. Landfills naturally produce gas because organic matter decomposes under anaerobic conditions to produce methane, carbon dioxide, and hydrogen sulfide. If not appropriately managed, the methane gas produced will be released into the atmosphere, increasing greenhouse gas emissions. To address this, landfills can capture and burn the gas, reducing the potential impact of greenhouse gases by up to 25 times. Collecting and burning gas to generate electricity is a small step that brings significant benefits. That is

1. Reducing greenhouse gas emissions that contribute to global climate change.
2. Balanced use of non-renewable resources.
3. Improve air quality.
4. Additional income from landfill
5. LFG Energy Reduces energy costs for consumers.
6. Create job opportunities and invest in local businesses.

In the landfill gas recovery system process, waste collected in a particular place in the Benowo TPA can be compacted and left for approximately 3 weeks to 1 month to produce methane gas (CH4). The methane gas is then processed by sending it through a pipe to a generator and connecting it to a generator. PLN network.

Methane Gas Collection and Transport System. Methane gas produced from the decomposition process of Benowo TPA waste can harm the environment and society, so please do not release it directly into nature. Methane gas must be added value to its use and managed as an asset.

Methane gas harms society and the environment and is not released directly into nature. Garbage stored in landfills must be covered with a cover to prevent anaerobic processes and the direct natural release of methane gas. A protective layer in the form of geotextiles or soundproof sheets must also be placed at the bottom of the pile not to contaminate soil and groundwater.

Gas extracted from landfill pipes contains a variety of gases, including methane, carbon dioxide, nitrogen, sulfur, and other gases. The extracted gas must be washed first to achieve good purity for use as electricity. Nitrogen, sulfur and siloxane gases must be removed during the primary treatment. The main treatments used are adsorption and absorption. Adsorption uses silica to remove siloxane. Silica then removes the concentration of siloxane in the gas. Absorption removes sulfur by reacting it with chemicals. The concentration of carbon dioxide is reduced by washing with water. Water purification uses water to dilute the gas entering the system and perform the carbon dioxide reduction process. The gas from the landfill is supplied to the reactor, pressurized water is sprayed, carbon dioxide, nitrogen and oxygen are dissolved with water, and methane gas with low dilution capacity flows into pure high-purity methane gas. Rate of 96-99%. The exhaust gases are collected and burned in the flaring process.

Vertical wells are the most common form of active gas production, in which gas is pumped through vertical perforated pipes. It is the easiest and most reliable method of LFG extraction. Usually, the pipe is installed in a closed cell by making a hole with a bucket eye or similar device.

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Figure 2. Benowo Hydropower Plant Vertical Well

The LFG becomes saturated when it comes out of the gas extraction well. Because the air is very humid, condensate is produced when LFG cools – in the same way, water droplets form outside a cold drink glass or when a glass is brought to a humid place. The amount of condensate depends on several factors, including the temperature and pressure of the gas. The higher the pressure and the lower the temperature that affects the gas condition when it comes out of the gas well, the greater the volume of condensate produced. Calculating condensate volume using psychometric charts is possible. However, this is only necessary when measuring the required pump, perhaps in gas pre-treatment processes where high pressures and low temperatures can maximize condensate removal. As LFG is collected from the garbage heap, it begins to cool in the pipes, and condensed water builds up, especially at night when the cooling system cools. The resulting condensate can block or completely block the gas flow in the "GCCS" gas capture and conveyance system, significantly if the pipe is tilted or tilted.

Even after removing the condensate, the gas stream may still contain harmful contaminants such as chlorine, fluorine, sulfur, organic silicon compounds, hydrocarbons and ammonia, all fans and other generators. It may damage the equipment. Effective removal of all contaminants from the gas stream is an expensive process, a factor to consider when selecting blower and generator technology. Taking gas samples for gas trace analysis in gas utilization projects is essential.

The blower is an essential part of GCCS. A blower is a pump that functions as an exhaust to collect LFG from waste. The fan also provides the pressure to push the LFG into the chimney discharge or power generation unit. Blowers are usually located at the base of the landfill gas collection system next to the substation and emission generator stacks. Depending on the size required, the fan and smoke extraction units are often mounted in the same frame, making them a very convenient system for quick installation and removal. The gas flows into the blower, the inlet vacuum is adjusted to meet the GCCS requirements, and the exhaust pressure is adjusted to meet the exhaust and generator requirements. GFR is usually measured through a weighing system. LFG flow rates collected by GCCS. The measurement system includes flow rate measurement. However, a methane monitoring system to measure the mass flow rate of methane in landfill gas is also needed and should be required.

The technology of methane gas converted into electricity by Benowo PLTSa is a gas engine. A gas engine's operation principle is to induce gas from the landfill with air in the combustion chamber. This technology is easy to manufacture and can be used for up to 20 years with proper care. This technology has a high noise level of 80-110db, so noise reduction technology is needed.

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Gasification Power Plant Capacity 9 MW. Next, the development of waste cultivation technology at the Benowo TPA is the gasification technology system, which is different from the landfill gas collection technology system. Power Plant Gasification Technology tries to burn the collected waste and create charcoal. The charcoal is heated to 1000 0 C to warm water to a boil and create steam, which is then used to drive a generator engine connected to a generator and finally generate electricity. The Gasification Technology System will be implemented in 2021, which can generate 9 MW of electricity from 1,000 tons of waste fuel per day. These two waste management technologies can be tried to develop and improve to be even better. It is essential to tackle waste problems so that they are helpful for residents and the region.

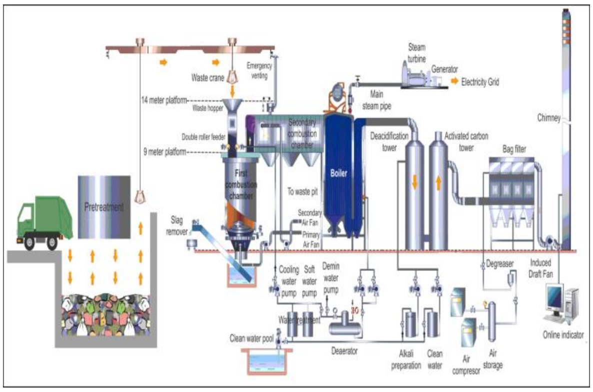

Figure 3. Power Plant Gasification Flow

Gasification transthermochemical methods solid fuel into a gas by thermochemist required is smaller than the air used for combustion. Gasification alters solid fuels into combustible gases (CO, CH4, H2) through combustion with a limited air supply, which is between 20% and 40% stoichiometric air. During the gasification process, a process zone is created for temperature distribution in the gasification reactor.

These areas are drying, pyrolysis, reduction and combustion. Each region occurs in temperature ranges between 1000C to 30000C, 30000C to 90000C, 40000C to 90000C, and 90000C and above (Styana et al., 2019). Gasification aims to convert liquid or solid fuel into flammable gas using a gasifier reactor (Oktaviari et al., 2023). Of all the available gasifier types, the Updraft type reactor is the simplest and easiest to apply in the community as a substitute for LPG gas for daily cooking needs.

Gasification at the Benowo PLTSa is a profitable WtE technology. Waste processing facilities with gasification technology are available all over the country but are primarily found in Japan, where this technology was developed and well-known distributors started. There has yet to be a generator of this kind working in Indonesia. This generator uses slagging gasification technology, and in 2013, WSP speculated that there were 122 waste processing plants or RDF working in Japan working 6 915 870 tons per year, and 9 other waste processing plants informed again in the design method with the anticipated combined capacity. Reach 1,047,300 tons per year.

The International Solid Waste Association (ISWA) (Ref 7) said that technology such as gasification could be a profitable business sector in Japan because power capacity is generally not an influential pioneer in determining WtE technology there (an important priority is the limited waste storage land). The processing fee is higher (Sarita et al., 2024). bigger than anywhere else. It illustrates the desire that must be considered when calculating the data submitted by producers and their implementation in Indonesia. An essential part of the gasification of the power plant at PLTSa Benowo is the Furnace, Boiler, Steam Turbine, or

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Generator Set and Transformer. The following are the stages of the process that occurs at PLTSa Benowo and their explanations:

1. Control Room and Pre-Conditioning. A place to monitor and control the activity stages in the gasification process using DCS (distributed control system) technology. The water content in the feedstock above 30% will cause a small gasification thermal capacity because it will affect the performance at the time of combustion in the reactor, after which it requires more energy in the process. Therefore, a drying system is needed so that the water content decreases. The drying method can be tried by mechanical pressure procedures, air drying or heat treatment (Eksandy, 2024).

After that, the size of the municipal waste component can be reduced by enumeration so that heat transfer in the feedstock is faster. Due to the high organic composition of Indonesia's ideal municipal solid waste, a complete pre-treatment of municipal waste is required before gasification (Gasification Module).

Figure 4. Gasification Module

Pre-conditioning of waste increases the caloric value of waste by reducing the water content and separating materials that can be used for recycling into gasification. Suppose the waste material in the gasification process has met the required calorific value. In that case, there is no need to repeat the conditioning process, and it can be directly put into the landfill during the gasification process. This process's end product is solid recovered fuel (SRF). This SRF will be further processed in gasification.

2. Waste Storage Pit. This organic waste collection site can accept waste with a capacity of up to 4,584 tons. Since this room requires adverse pressure conditions to reduce the odor produced, this garbage collection is designed to be closed entirely.

This garbage shelter is installed with a grill and reinforced concrete arrangement with a particular slope where leachate can flow at the bottom. This leachate will then be channeled to the wastewater treatment system, ensuring that the waste entering the gasification furnace does not have high humidity.

3. Material Feeding System. A grab-type elevator picks up garbage and puts it into the hopper. The feeding hopper accommodates waste before entering the gasification furnace. A double roller regulates the volume of waste that enters the gasification furnace.

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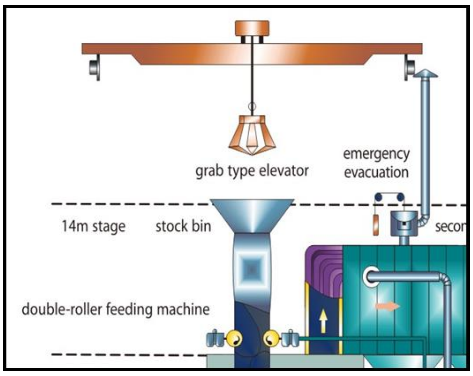

Figure 5. Material Feeding System

4. Primary Gasification Chamber and Secondary Combustion Chamber. The primary gasification chamber serves as a waste heating area, heating the waste at a high temperature to reduce the volume of waste and produce synthetic gas. In the second furnace, the synthetic gas produced from the primary gasification chamber is burned at a temperature above 850°C. The hot air from the combustion is then flowed into the boiler.

5. Chemical Water Treatment System and Boiler. This system prepares water for boilers and radiator cooling systems in gasification. In the boiler, heat energy from the secondary combustion chamber is used to heat water to a high temperature, causing it to become water vapor and flow to the steam turbine.

6. Steam Turbine & Generator. Steam turbines change the enthalpy of water vapor from the boiler, which is converted into mechanical energy to drive a generator. The generator converts mechanical energy from the steam turbine into electrical energy.

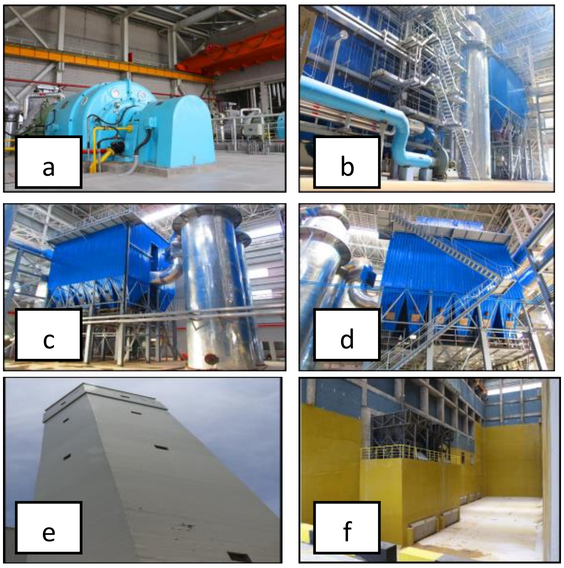

Figure 6. (a) Steam Turbine and Generator, (b) Boiler, (c) Deacidification Tower, (d) Dust Collector, (e) Chimney, (f) Waste Storage Pit

7. Deacidification Tower. The flue gas from the secondary combustion chamber is channeled to the deacidification tower, which processes flue gas into ready-to-exhaust gas following air pollution emission standards.

8. Dust collector and Chimney. The dust collector filters dirt, such as dust or residual disposal (fly ash), so that it does not fly and pollute the surrounding environment. The chimney is between 30 and 60 meters high and releases hot air from the flue gas after treatment at the deacidification tower and dust collector.

CONCLUSION

Based on the results of research that the author has done, it can be concluded that:

1. Waste power plants (PLTSa) are one effective way to overcome the waste problem. However, PLTSa can only work correctly with a sound system and standardization.
2. Municipal waste, an organic material, can be processed with Landfill Gas Recovery (LFG) technology to produce methane gas as fuel. The fermentation results of fermented organic waste can be composted.
3. Inorganic waste that cannot be processed using the Landfill Gas Recovery (LFG) system can be used as fuel using a Gasification Power Plant.
4. Waste problems that cause environmental pollution can be solved comprehensively. Changing the point of view that waste is not a problem but can be a source of energy. Waste that is managed well can generate income from the sale of electrical energy and compost.

Suggestion.

1. It is necessary to conduct a thorough feasibility study on adding capacity to the Waste Power Plant (PLTSa) to utilize unused waste or the estimated addition of waste every year. The study of additional capacity is reviewed from the Technical, Economic, Aesthetic, and EIA studies.
2. Further research is needed on waste disposal from the waste management process into electricity. Further research needs to be done on utilizing Fly Ash and Bottom Ash (FABA) combustion residues. The study of the use of FABA can be viewed from the economic and environmental aspects.

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