

Waste to energy implementation using gasification technology in Tinggi Island

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Abstract. The existence of electricity can encourage the improvement of the quality of life of the community. However, there are several problems with the provision of electricity in remote areas, including difficulties in delivering electrical equipment and fuel. One solution to solve this problem is implementing local waste utilization as fuel for power plants. This study aims to implement Waste to Energy using gasification technology on Tinggi Island, South Bangka. The methods used in this research are to calculate the potential amount of waste, design the equipment specification, make the supporting facilities, and do a testing experiment. Due to the low waste potential in Tinggi Island, local communities' waste processing is carried out in Toboali. The waste processing stages are sorting, fermentation, chopping, drying, and pressing. The waste pellets from Toboali are sent to the powerhouse in Tinggi Island. From the performance and reliability test in the electrical side, it can be concluded that the voltage and the frequency generated is stable and within the safe limits according to Regulation of the Minister of Energy and Mineral Resources No. 03 of 2007. The consumption of waste pellets needed to generate electricity during the reliability test (75% loading) is ten kg/45 minutes. Through the continuous implementation of waste to energy, Tinggi Island can be electrified all day long and solve the waste problem.

1 Introduction

The existence of electricity can encourage the improvement of the quality of life of the community. However, there are several problems with the provision of electricity in remote areas, including difficulties in delivering electrical equipment and fuel. One solution to solve this problem is implementing local waste utilization as fuel for power plants.

Tinggi Island is located off the South Bangka Regency coast, with an area of 424 m². Tinggi Island has 37 electricity consumers with a peak load of 7.5 kW. The electricity load is supplied by the 40 kW Diesel Power Plant, which only operates for 12 hours a day (6 pm

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to 6 am). South Bangka Regency has the potential for a waste of 94.83 tons per day, which can be used as a biomass energy source. There are 291 waste processing sites process 11.72 tons of waste every day, which are operated by local people.

Gasification is one way of utilizing solid biomass waste into energy through thermal decomposition of organic material by applying heat under limited oxygen intake conditions to produce synthesis gas. Because of this background, this study aims to implement Waste to Energy using gasification technology on Tinggi Island, South Bangka. Apart from getting alternative fuels, this can also help solve the waste in the surrounding environment.

2 Method

2.1 Waste processing and gasification technology

There are several thermal waste processing technologies, incineration, gasification, pyrolysis, and Refuse-Derived Fuel (RDF) [1]. Implementation of Waste to Energy in Tinggi Island uses gasification technology. A gasifier requires waste pellets with some specifications to operate, so several stages of the process are needed to convert waste into pellets [2].

2.2 Processing waste into pellets

2.2.1 The sorting process

The sorting process aims to separate waste into several categories, waste that can still be recycled, waste that can be processed into pellets, and materials that cannot be processed into pellets (residue).

2.2.2 Fermentation

Fermentation is a process that aims to increase the calorific value of waste, reduce odor, accelerate drying, and reduce the volume of waste. Fermentation is carried out by putting the trash into a bamboo basket and splashing with a bio activator every 10 cm of layers. The fermentation process takes about 7-12 days, depending on the type of waste [3].

2.2.3 The chopping process

After fermentation, the next step is chopping to reduce the area of waste. The chopping machine that can be used is a hammer mill type.

2.2.4 The drying process

The drying process can be done using a rotary dryer or solar dryer dome. Through this drying process, the pellet moisture drops to 10% [4]. High ambient temperatures can aid in the natural drying process.

2.2.5 The pellet pressing process

The pellet pressing process aims to reduce the volume of waste. After being pressed, the pellets will have a denser structure with dimensions that match the gasifier specifications.

2.3 Downdraft gasification

Gasification is one way of utilizing solid biomass waste into energy through thermal decomposition of organic material by applying heat under limited oxygen intake conditions to produce synthesis gas (syn-gas) [5]. The gasification process consists of 4 stages, drying ($T > 150^{\circ}\text{C}$), pyrolysis ($150 < T < 700^{\circ}\text{C}$), oxidation ($700 < T < 1500^{\circ}\text{C}$), and reduction ($800 < T < 1000^{\circ}\text{C}$) [6][7]. The drying, pyrolysis, and reduction processes are heat-absorbing (endothermic), while the oxidation process is heat-releasing (exothermic) [8]. Based on the direction of gas flow, gasification is divided into updraft gasification, downdraft gasification, and cross draft gasification [9][10].

In downdraft gasification, the flow direction of the gas and solid agents is downward. Downdraft gasification of biomass connected to an IC-engine unit for power production has an increased interest worldwide during the past decade [11]. The tar content that appears is less than the updraft type because the tar content resulting from the pyrolysis process is carried away with the gas and then enters the partial oxidation process and reaches temperatures of up to 900°C , at which temperature the tar content breaks down into lighter compounds [12]. The refined and cooled syn-gas output can feed directly into the diesel engine [13].

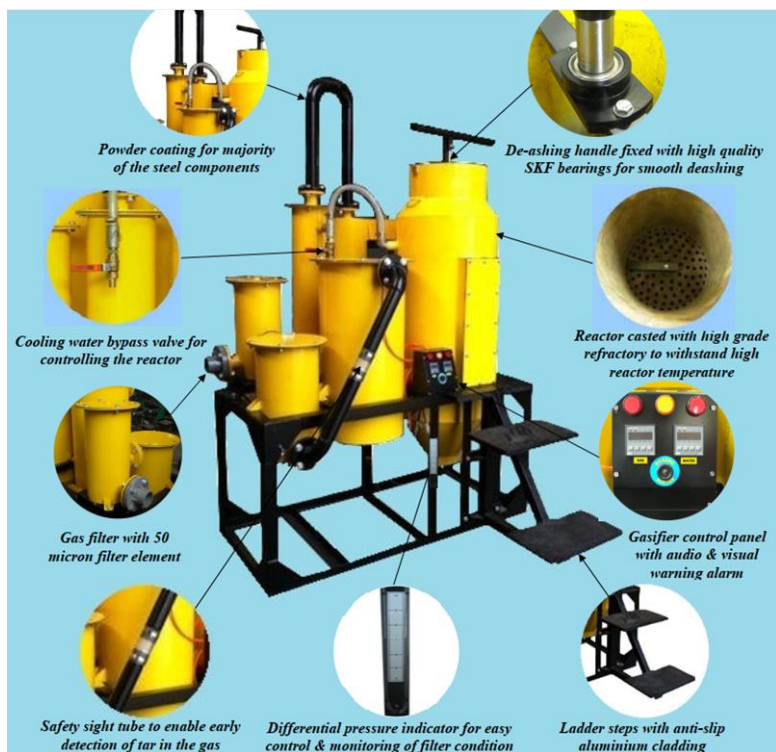


Fig. 1. Downdraft Gasifier [14]

2.3.1 Reactor

A reactor is a room for the biomass gasification process that can withstand high temperatures. Biomass is supplied into the reactor periodically, so a thermo-chemical reaction occurs and produces CO , H_2 , methane gas (CH_4), water vapor (H_2O), and carbon dioxide (CO_2) [15].

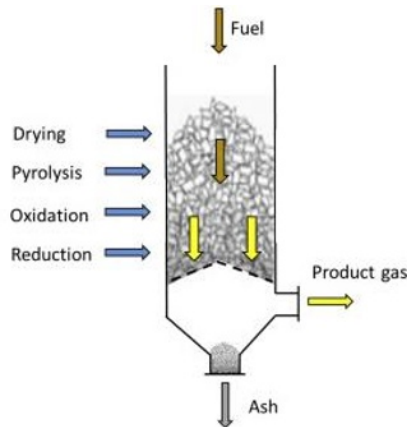


Fig. 2. Reactor [14]

The air moves to the gasification zone at the bottom so that the resulting pyrolysis smoke passes through the hot gasification zone so that the tar contained in the smoke burns, so the gas produced by this reactor is cleaner [15]. This type of reactor can operate for continuous gasification operation by adding fuel through the reactor's top, but an ash-removal system is required.

2.3.2 Tar separator

The tar separator functions separately and collects tar, ash, charcoal particles, and water droplets from the reactor.

2.3.3 The gas cooling tower

The gas cooling tower serves to cool the gas to room temperature so that the engine operates without excessive temperature.

2.3.4 Filtration system

The filtration system function is to filter tar and absorb air vapor. System filters are designed for long period operation. In the gas filter channel, there is a temperature sensor to monitor the gas temperature.

2.3.5 The air recycling pump

Downdraft gasifier has a water pump with a minimum capacity of 150 liters per minute.

2.3.6 Control panel

All parts of the gasifier are equipped with a temperature sensor to maintain the coolant temperature and gas output. All temperature sensors and switches are installed and controlled from the control panel. In this section, there is also an alarm and a solenoid valve.

2.4 Waste to energy implementation in Tinggi Island

The methods used in this research are to calculate the potential amount of waste, design the equipment specification, make the supporting facilities, and do a testing experiment.

2.4.1 The potential amount of waste

According to data from the Environmental Service Office of Bangka Belitung Province, the estimated amount of waste per capita is 0.47 kg/person/day. With a population of 240 people in Tinggi Island, the potential amount of waste is 113 kg/day, so that the potential amount of pellets is around 34 kg/day (30% of waste mass). With a population of 201.782 people in South Bangka, the potential amount of waste is 94,83 tons/day, so that the potential amount of pellets is around 28,45 tons/day.

Table 1. Composition of waste in South Bangka (2018)

Types of Waste	Percentage
Food residue	37,46
Wood, twigs, leaves	19,99
Paper	10,04
Plastic	17,92
Metal	1,32
Fabrics and textiles	1,95
Rubber and leather	2,01
Glass	1,84
Others	7,97

2.4.2 Equipment specifications

Table 2. Equipment specifications

Equipment	Model	Input	Capacity
Hammer Mill	KSHM7.5-420B	Electric power 7,5 kW, 3 phase	250-350 kg/hours
Rotary Dryer	Rape RDG-300	Electric power 1 kW, 1 phase	300 kg
Pelletizer	KSPMR7.5200 C/R/R-Type	Electric power 7,5 kW, 3 phase	60-100 kg/hours
Downdraft Gasifier	TG-30	Biomass 16 kg/hours	Output syn-gas 37m ³ /hours
Gas engine	Trillion TGG-20	Syngas 37m ³ /hours	Electric power 16 kW

2.4.3 Supporting facilities

2.4.3.1 Waste processing house

It is recommended that the waste processing house be located as close as possible to the waste source. So the waste processing house is located in Toboali. The waste processing house contains the sorting box, fermentation boxes, hammer mill, rotary dryer, and pelletizer. The layout of the machines is adjusted to the order of waste processing.

2.4.3.2 Powerhouse

It is recommended that the powerhouse be located as close as possible to the electrical load. So the powerhouse is located on Tinggi Island. The powerhouse contains the gasifier and the gas engine.



Fig. 3. Powerhouse

2.4.3.3 Cooling water treatment

The gasifier is expected to operate for 24 hours, so a cooling system is needed to keep the gasifier in optimal condition. This cooling system requires a pool to accommodate water discharge. In Tinggi Island, a cooling pool with dimensions of 3mx10m was built.



Fig. 4. Cooling water treatment

2.4.4 Schematic diagram and testing scenario

Due to the low waste potential in Tinggi Island, the waste is taken from the landfill in Toboali City, and then the waste processing is carried out by the local community in the waste processing house. The stages of waste processing are sorting, fermentation, chopping, drying, and pressing. The waste pellets from Toboali are sent to a powerhouse on Tinggi Island. Waste pellets as fuel are put into the gasifier and converted into syn-gas. This syn-gas will be converted into electrical energy by the gas engine.

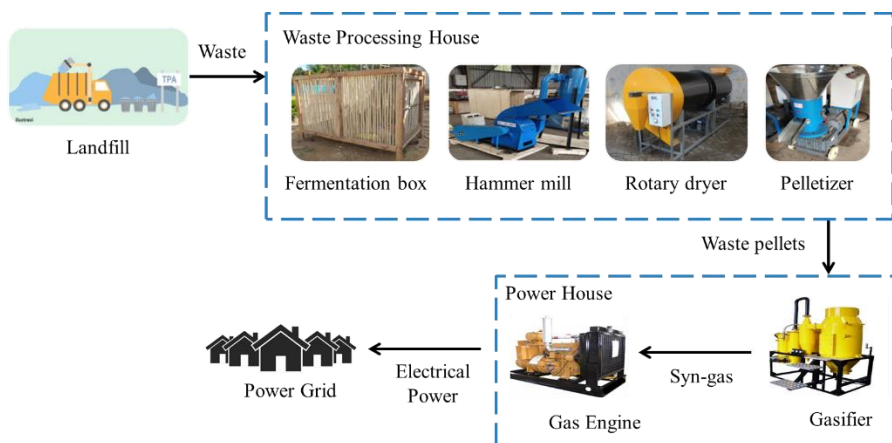


Fig. 5. Schematic diagram

Before the system is implemented to the electric grid at Tinggi Island, the electricity generation's reliability must be tested first. Electricity generation is tested under various loading scenarios for a specific time duration, described as follows.

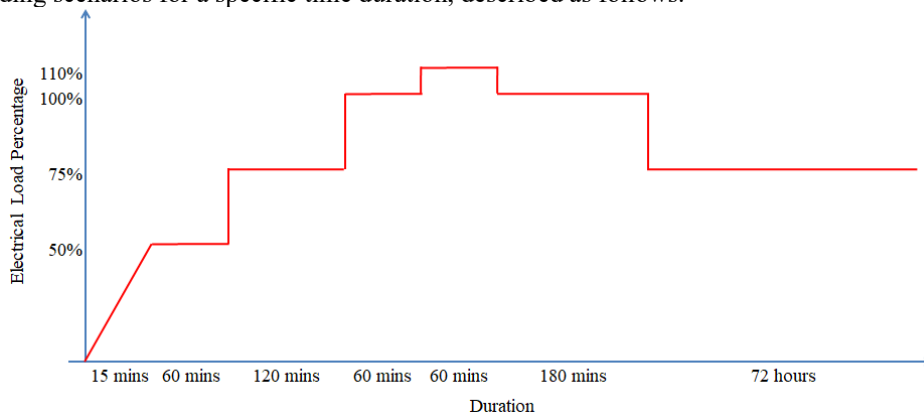


Fig. 6. Testing scenario

3 Results and discussion

In this study, the waste processing results are waste pellets, which will be converted into syn-gas. This syn-gas is fuel for the gas engine.

3.1 The result of waste processing

In the waste processing house, there are seven fermentation boxes with a capacity of 7x1 tons each. Every day 1 ton of waste is processed so that the waste is processed continuously seven days a week. After the fermentation process, the waste gross calorific value increased from 2,638.23 cal/g to 4,088.62 cal/g, and the waste volume is reduced by 50%. After the drying process using a rotary dryer, the humidity of the waste drops to 10-15%. This measurement indicates that the humidity of the waste is safe for the gasifier, and the

chopped waste is ready for the pressing process. After the pressing process, the output waste pellets are 6 mm in diameter.



Fig. 7. Chopped waste



Fig. 8. Waste pellets

3.2 The syn-gas output from the gasification process

The blue syn-gas color indicates that the syn-gas has a high calorific value and low air content. The blue flame that results from burning syn-gas indicates that the syn-gas is ready to be used as fuel for the gas engine.

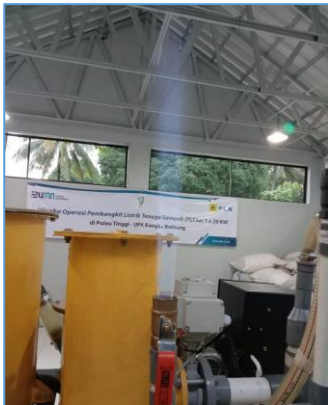


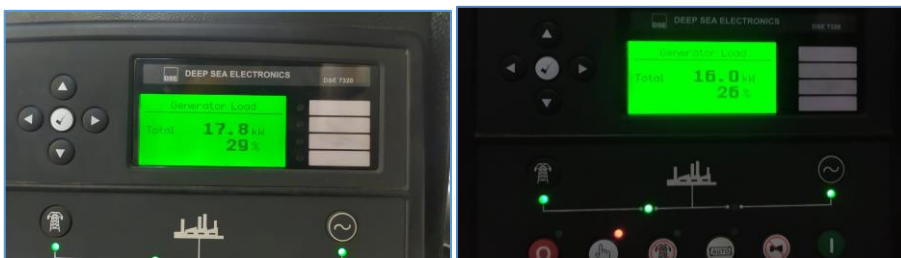
Fig. 9. Flare from syn-gas produced by the gasifier



Fig. 10. Gasifier display when operating

3.3 The electrical output from the gas engine

Generator performance analysis using the electrical parameters that measured every 10 minutes.



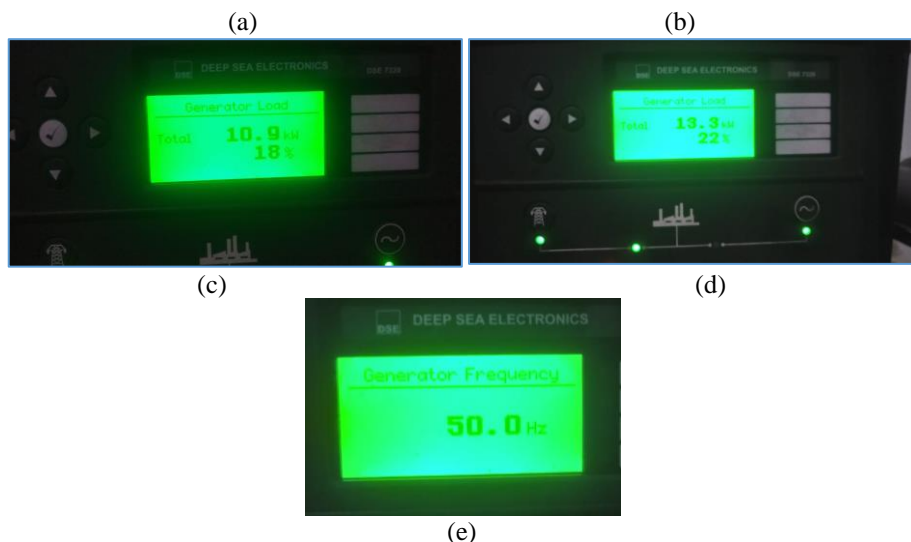


Fig. 11. Gasifier display when operating (a) 110% loading (b) 100% loading (c) 75% loading (d) 10,9 kW loading (e) gas engine output frequency when 100% loading

From the performance and reliability test in the electrical side, it can be concluded that the voltage and the frequency generated is stable and within the safe limits according to Regulation of the Minister of Energy and Mineral Resources No. 03 of 2007. The consumption of waste pellets needed to generate electricity during the reliability test (75% loading) is ten kg/45 minutes.

4 Conclusion

Waste to Energy implementation in Tinggi Island has been carried out with gasification-based technology. Due to the low waste potential in Tinggi Island, waste processing is carried out by local communities in Toboali, the waste pellets are sent to Tinggi Island. Testing experiments have been done then the waste power plant is ready to operate. Through the continuous implementation of waste to energy, Tinggi Island can be electrified all day long and solve the waste problem.

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