Analysis of Bio-briquette Electrical Energy from The Utilization of Combustion Ash in A Boiler Furnance (Ash Boilers) PKS PT. Adei Plantation & Industry, MPOM

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***Abstract* – PT. ADEI PLANTATION & INDUSTRY is a palm oil processing factory that has a plantation area of 11,047 hectares. This factory produces solid and liquid waste. solid waste is reused as boiler fuel and liquid waste is used for biogas. Combustion in the boiler produces boiler ash, 70% of which is used as organic fertilizer and the remaining 30% is simply thrown away. This research aims to utilize boiler ash waste in bio-briquettes and determine the electrical energy potential of bio-briquettes using the carbonization combustion method in boiler furnaces (boiler ash). The test results for the calorific value of bio-briquettes from the use of residual ash from combustion in boiler furnaces (boiler ash) were 2,214.99 cal/gr. From 1 kg of boiler ash, 11 pieces of bio-briquettes weighing 100 gr/piece, with a calorific value of 24,364 cal/gr, are produced. PT. ADEI PLANTATION & INDUSTRY in one day produce 7,536 tons of boiler ash, which will produce 82,896 pieces of bio-briquettes with a heating value of 179,903,776 cal/gr, a total flow rate of heat energy of 792,020 Watts and electrical energy of 950,424 kWh. From the PLTU efficiency of 5.12%, the potential electrical energy produced in one month is 28,512,720 kWh with 188.4 tons of boiler ash and 2,261 tons of boiler ash in 1 year has the potential to become 346,904,760 kWh of electricity. The electrical energy potential of bio-briquettes can meet the needs of 70% of the electricity load at PT. ADEI PLANTATION & INDUSTRY, MPOM.**

Keywords: Bio-briquettes, Boiler Ash, Carbonization, Electrical Energy, Palm Oil Solid Waste

I. INTRODUCTION

Energy electricity is needed primarily Which is a supporting factor for every human activity starting from activity industry, House ladder, education, business, and so on. This states that energy is a basic need in human life, especially in the current modern era. However, currently, the energy crisis is the world's top topic of conversation. This has a huge impact on Indonesian society because the majority of Indonesian people still depend on fossil fuels. This means that the increasingly depleting fossil fuels must be immediately balanced with the provision of renewable alternative energy, abundant raw materials, and cheap prices so that they can be affordable to the wider community [1]. Therefore, it is necessary to develop alternative energy, one of which is alternative energy from biomass. In general, biomass is better known as dry matter from organic material or material left over from plants that do not contain water content. Biomass itself is very easy to find in everyday life in the fields of agriculture, animal husbandry, and plantations [2] [3]. The potential that exists in Indonesia for the livestock sector is 99 business entities, agriculture 70 million hectares, and plantations 15,008 million hectares as of 2021. Plantations have the greatest potential in Indonesia, one of which is oil palm plantations.

Riau Province is a region that has the largest oil palm plantations in Indonesia. The area of oil palm plantations in Riau province has reached 2.9 million hectares as of 2021 [4]. There are several oil palm plantations in Riau province, one of the PTs established in Riau province which has oil palm plantations is PT. ADEI PLANTATION & INDUSTRY, which is located on JL.Raya Pekanbaru-Duri Km.101, Bengkalis, Riau. The area of the oil palm plantation is 11,047 ha and has a palm oil processing factory in it. This palm oil processing factory operates and processes FFB (Fresh Fruit Bunches) with a capacity of 60 tons/hour. The results of the FFB processing produce solid waste, namely shell, fiber, and empty fruit bunches, while liquid waste is in the form of POME. Solid waste is used as fuel in boilers for steam power plants (PLTU) with a capacity of 1,600 kW. Meanwhile, POME waste is used for gas engine power plants with a capacity of 1,025 kW x 3 and 1,200 kW [5].

Boiler fuel produces 2 types of solids, namely, bottom ash (boiler ash) and fly ash (fly ash) which come out of the boiler combustion furnace it become waste whose use has not been maximized [6].

According to PP No.101 of 2014, boiler ash waste is categorized as B3 waste [7]. Based on direct observations and interviews with the Public Relations of PT ADEI PLANTATION & INDUSTRY, Arif Suyitno stated that currently the use of boiler ash waste from the boiler combustion furnace is used to make 70% organic fertilizer which is useful for oil palm plants. The remaining 30% has not yet been maximized.

Several studies are using solid waste from palm oil. This research [1] examines the calorific value of utilizing palm oil mesocarp fiber in briquettes using the carbonization method. Research [2] studied the calorific value of oil palm fronds in briquettes using the pyrolysis method with tapioca flour adhesive. Research [1] and [2] conducted a study on the utilization of solid waste from palm oil into bio-briquettes using different methods. The results of research [1] show that a charcoal composition of 2:1 provides high test parameter results for burn time, water content, and low ash content. Meanwhile, the results of research [2] show that with an adhesive composition of 50% the average burning time is 1 minute/g, and the calorific value is 5.361 cal/g which is still within the SNI standard. Both methods have advantages and disadvantages, namely that in the pyrolysis process the water content of the raw material is still high, it is not efficient in making large-scale reactors because it still leaves residue, so it takes a long time to make briquettes into the bio-briquette flame process. Meanwhile, in the carbonization process, the water content of the raw material is already low, so making it into bio-briquettes will speed up the flame.

Bio-briquettes are fuel and the most important parameter is the calorific value content. Several studies have studied increasing the calorific value of bio-briquettes by varying the stages of making bio-briquettes. Research [8] studied the effect of briquetting pressure and the percentage of briquettes mixed with peat and palm leaf midrib charcoal on the burning characteristics of the briquettes. In research [1][2] compared the adhesive composition of bio-briquettes. Based on research [8] at a composition of 90%:10% with pressure using a hydraulic press to get the best results for the quality of bio-briquettes. The comparison of bio-briquette adhesive composition was obtained with the best results of 2:1, with a calorific value reaching 5,000 cal/gr with an ash content of 7.6% and a water content of 22.5% based on research [1][2]. Research [8] provides variations in pressure and adhesive material in bio-briquettes which will improve the quality of the bio-briquettes produced due to the better characteristics of the bio-briquettes. Good characteristics will make the briquettes ignite faster, take longer to burn the briquettes, reduce the burning rate of the briquettes, and increase the burning temperature of the briquettes.

The calorific value content of bio-briquettes shows the quantity of energy contained in the fuel. Caloric content testing can be tested in several ways. Research [9] conducted a study on testing the calorific content of bio-briquettes using a bomb calorimeter measuring instrument. Research [10] by measuring manually. Based on research [9] and [10], testing the heating value of bio-briquettes using a bomb calorimeter is the best way to test the heating value, because it is more accurate no heat is lost to the environment and is very flexible, and can be done indoors.

Bio-briquettes can be used as fuel in power plants. The heat content contained in bio-briquettes can be converted into electrical energy. Based on research [11] conducted a study by converting bio-briquette energy into electricity from kJ to kWh. Research [12] converts the heat content of bio-briquettes into electricity using a turbine and generator system. In research [11] the heat conversion of bio-briquettes only involves changing energy units, while in research [12] using the 1st and 2nd laws of thermodynamics to analyze the quantity and quality of energy produced in the electrical energy conversion system. From research [11][12] it was found that biomass waste can be made into bio-briquettes and converted into electrical energy as a substitute for fossil energy.

Utilization of boiler ash waste resulting from boiler combustion furnaces into bio-briquettes can be done using 2 methods, namely pyrolysis and carbonization. In this research, we will use a carbonization method because PT ADEI PLANTATION & INDUSTRY has implemented a carbonization system for burning solid waste through combustion in a boiler furnace. Carbonization is the combustion process of converting an organic substance into carbon or carbon-containing residue in the combustion process to produce charcoal, with unlimited air, and in a closed room. Improving the quality of the bio-briquettes produced is carried out by varying the stages of making the bio-briquettes, namely varying the adhesive mixture and pressure. These two variations were chosen because using tapioca flour adhesive in making bio-briquettes affects the quality standards of bio-briquettes and applying pressure using a hydraulic press can create good bio-briquette burning characteristics in terms of faster briquette ignition, reducing the bio-briquette burning rate, and increasing the briquette burning temperature. The calorific value content of bio-briquettes will be tested using a bomb calorimeter measuring instrument. This measuring instrument was chosen because it is more accurate, no heat is lost to the environment, and is very flexible and can be used indoors. The heat content in bio-briquettes will be converted into electricity by analysis using the 1st and 2nd laws of thermodynamics for the quantity of heat energy from burning bio-briquettes and the quality of energy from power plants and the electrical energy produced. This research will study the potential calorific value of bio-briquettes and the potential electrical energy produced from the use of boiler ash waste from boiler combustion furnaces.

II. METHODS

Research related to the use of boiler ash in bio-briquettes can be started by:

A. Boiler Ash Potential Data

This stage collects secondary data by looking at the data results from the palm oil mill on a yearly and monthly scale. From the boiler ash data, we will analyze how much boiler ash and how much bio-briquettes are produced from using boiler ash using the carbonization method. This can be seen in Table 1. The potential of Boiler Ash PT. ADEI PLANTATION & INDUSTRY.

Table 1. The potential of Boiler Ash PT. ADEI PLANTATION & INDUSTRY, MPOM

Element	Information
Boiler Ash per month	188.4 tonnes
Boiler Ash per year	2,261 tons

B. Boiler Ash Potential Data

Boiler ash bio-briquettes in this research use the carbonization method. The stages can be seen in Figure 1 below.

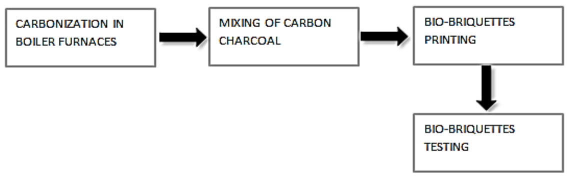

Figure 1. Diagram of Making Boiler Ash Bio-briquettes

1. Carbonization

Carbonization is defined as the combustion process of converting an organic substance into carbon or carbon-containing residue in the combustion process to produce charcoal, liquid, and gas. This burning is carried out at a temperature of 270°C according to the biomass to be carbonized, namely fiber and shell. If the biomass is dense, the temperature required is higher, and vice versa, and uses sufficient air in a closed room. In this carbonization process, the biomass is touched by fire directly in the boiler combustion furnace. In a boiler combustion furnace, two forms of solid waste will be produced, namely boiler ash and fly ash. The waste used to make briquettes is boiler ash waste. It can be seen in Figure 2, namely the boiler.

Figure 2. Boiler

2. Carbon Charcoal Mixing
   1. The carbon charcoal manufacturing stage is carried out using the carbonization method. To get raw material for boiler ash.
   2. After that, filter the boiler ash with mesh 60, and mix the boiler ash with an adhesive made from tapioca flour. Researchers will mix adhesive with a 2:1 composition, namely 2 boiler ash and 1 adhesive, with a solvent size of 400 ml [1] [2].

3. Briquette Mixing

This briquette printer is used to print briquette dough which has been mixed with tapioca flour adhesive so that it forms dense chips. This tool has a hydraulic press iron frame with a width of 35cm, a height of 50cm, a base length of 60cm, and a base width of 15cm. For the mold size of the bio-briquette pieces, the diameter of the iron pipe is 7.5cm, the pipe height is 5cm, and the diameter of the round plate inside the pipe is 7.4cm. Then the mixed boiler ash is put into the iron pipe mold and pressed using a 2-ton jack [10][13]. The results of printing these briquettes are to obtain a mass of bio-briquettes per piece. Then the bio-briquettes that have been printed in pieces are dried in the sun for 24 hours.

4. Testing the Calorific Value of Briquettes

In this test, the calorific value of the briquettes, we must first understand the steps to obtain the calorific value of the briquettes. The first step is to understand the combustion process in a boiler furnace which is included in the carbonization category, where this process occurs due to combustion without a certain temperature and using sufficient air in the combustion chamber. After the boiler ash is obtained, the next step is to filter it with a 60 mesh and add a mixture of tapioca flour adhesive, which we use in a 2:1 ratio, namely two carbon charcoal and one adhesive with a mixture of 400 ml of adhesive solution, and after that we go to the printing stage. with hydraulics and given a certain pressure so that it can become a solid block which will make it easier for these briquettes to ignite [1][8].

Testing the calorific value content of briquettes using an Oxygen Bomb Calorimeter. This tool is used to measure the calorific value that has been released during complete combustion (in excess O2) of a compound, such as food and fuel [13]. The charcoal in this briquette fuel is tested for its calorific value first and weighed per 1 gram to be put into a container threaded, then put into a testing vessel, pressure from an air compressor of 3 Mpa is given into the vessel and put into bomb calorimeter. After that, the device is given electricity to work, and 15 minutes later the bomb calorimeter will produce data on the calorific value of the increase in temperature. And the results obtained are the calorific value content of the bio-briquettes [14].

C. Electric Pontential Calculation.

Calculation of the electrical potential of bio-briquettes can be done using the 1st & 2nd law of thermodynamics formula to obtain values for *the boiler heat flow rate* and PLTU efficiency. PLTU efficiency is the ratio between clean energy and heat flow rate in the boiler. The heat flow rate in the boiler will be calculated based on the value of the heat content of the bio-briquettes produced and the mass of the bio-briquettes produced in the carbonization process. The following is the calculation process for obtaining energy from burning bio-briquette fuel at a PLTU plant.

1. PLTU Efficiency

$$\eta = \frac{\dot{W}net}{Qin} \text{ X } 100\% \quad (1)$$

Wnet = $\dot{W}$turbine - $\dot{W}$pump
Qin = Heat Flow Rate in the Boiler (Watts)
$\dot{W}$turbine= Work Flow Rate in the Turbine (Kw)
$\dot{W}$pump= Work Flow Rate in the Pump (Kw)

$$Qin = \dot{m}\,(h_3 - h_2)$$
$$\dot{W}turbine = \dot{m}\,(h_4 - h_2)$$
$$\dot{W}pomp = \dot{m}\,(h_2 - h_1)$$

Potential Fuel Power = Total Calorific Value Content X Mass Flow of Bio-briquettes (2)

Electrical Energy Potential = Fuel Power X Life Duration X PLTU Efficiency (3)

Electrical Energy Potential = Total fuel potential times PLTU efficiency (kWh)

Fuel Power = Energy potential from the output produced (Watts)

PLTU Efficiency = PLTU Efficiency (5.12%)

In calculating electrical energy, we use the PLTU efficiency, which is 5.12%, which is obtained from the results of calculations using the 1st and 2nd laws of thermodynamics formula.

III. RESULTS AND DISCUSSION

A. Boiler Furnace Combustion Result

In the proces of making Bio-briquettes from boiler ash raw materials, the author carries out several stages of making boiler ash Bio-briquettes which can be seen in figure 3.

(a) (b)

(c) (d)

(e)

Figure 3. Making Bio-briquettes (a) Boiler Ash, (b) Boiler Ash Filtering, (c) Boiler Ash Mixing, (d) Bio-briquette Printing, and (e) Bio-briquette Results

The combustion process uses a boiler furnace, which is a carbonization process at a temperature of 270°C. In the boiler furnace, there are fibers and shells resulting from waste from palm oil processing with a composition ratio of fuel entering the boiler combustion furnace, namely 2:1, with two fibers. and one shell. The combustion process in the boiler furnace produces 2,261 tons of boiler ash which is obtained from the processing of 287,630,110 tons of FFB (Fresh Fruit Bunches) per year. The boiler operates for 24 hours of burning time and produces boiler ash every 3 hours, which will be filtered to obtain mesh 60, molded into bio-briquette chips per 100 grams, and dried in the sun for 24 hours. It can be seen in Table 2 that there is a lot of potential for bio-briquettes resulting from processing fiber and shell waste raw materials.

Table 2. Number of Bio-briquettes Produced from the Processing Process

Ash Boilers	Adhesive	Bio-briquette Unit Weight	Produced Bio-briquettes
1 kg	0.5kg	100 gr/piece	11 pieces

The experimental results from a 1 kg sample can produce 11 pieces of bio-briquettes weighing 100 grams per piece. If the combustion potential in the boiler furnace per day is 7,536 tons, it can produce 82,896 pieces of bio-briquettes weighing 100 grams per piece. If the potential for *boiler ash waste* in the palm oil factory environment of PT. ADEI PLANTATION & INDUSTRY reaches 188.4 tons per month, it can produce 2,072,400 pieces of bio-briquettes weighing 100 grams. The annual potential for boiler ash reaches 2,261 tons, so it can produce 24,871,000 pieces of bio-briquettes weighing 100 grams.

Figure 4. Testing the Calorific Value of Bio-Briquettes

Testing the calorific value using an Oxygen Bomb Calorimeter. This bio-briquette charcoal will be tested for its calorific value, first, the net weight will be weighed and the net weight will be obtained, namely 100 grams per piece. After that, it is ground again using a ball mill to get a mesh of 60, then weighed per 1 gram to be put into a container and given thread, then put into the testing vessel, automatically pressure from the air compressor of 3 Mpa is given into the vessel and put into bomb calorimeter. After that, the tool is given electricity to work, and within 15 minutes the bomb calorimeter tool will print data on the heating value from the increase in temperature contained in the bio-briquettes. In this test, the results were obtained in Table 3 by testing the bio-briquette pieces.

Table 3. Testing of Bio-briquettes in Pieces

Heavy Bio-briquettes Unit	Mark Heat Which Contained
100 grams/puck	2,214.99 cal/gr

The test results using a bomb calorimeter of 100 gr of boiler ash bio-briquettes produced a calorific value of 2,214.99 cal/gr. If 1 kg of boiler ash produces 1,100 grams of pure bio-briquettes, it can produce a calorific value of 24,364 cal/gr. If in one day the PKS PT. ADEI PLANTATION & INDUSTRY produces 7,536 kg of boiler ash, it will produce 8,289,600 grams of pure bio-briquettes which can produce a calorific value of 179,903,776 cal/gr. If the PKS PT. ADEI PLANTATION & INDUSTRY produces 188,400 kg of boiler ash per month, it will produce 207,240,000 grams of pure bio-briquettes which can produce a calorific value of 4,497,594,400 cal/gr. And if in a year the PKS PT. ADEI PLANTATION & INDUSTRY produces 2,261,000 kg of boiler ash, it will produce 2,487,100,000 grams of pure bio-briquettes which can produce a calorific value of 53,990,624,000 cal/gr.

B. Energy Pontential of Bio-Briquette Fuel

From the potential of 1 kg of boiler ash and added adhesive, it can produce a pure bio-briquette weight of 1,100 gr or 11 pieces of bio-briquette, and produce a calorific value of 24,364 cal/gr. If the potential is 7,536 tons and added adhesive, it can produce a pure bio-briquette weight of 8,289,600 gr or 82,896 pieces of bio-briquette, and produce a calorific value of 179,903,776 cal/gr. If the potential is 188.4 tons and added adhesive, it can produce a pure bio-briquette weight of 207,240,000 gr or 2,072,400 pieces of bio-briquette, and produce a calorific value of 4,497,594,400 cal/gr. If the potential is 2,261 tons and added adhesive, it can produce a weight of pure bio-briquettes of 2,261,000,000 or 24,871,000 pieces of bio-briquettes, and produce a calorific value of 53,990,624,000 cal/gr.

Table 4. Energy Potential of Bio-briquette Fuel

Amount Potency waste leaf dry	Bio-briquettes Which Generated	Mark heat
1kg (trial)	1,100 gr	24,364 cal/gr
7,536 tonnes (potency per day)	8,289,600 gr	179,903,776 cal/gr
188.4 tonnes (potency per month)	207,240,000 gr	4,497,594,400 cal/g r
2,261 tons (per year)	2,487,100,000 gr	53,990,624,000 cal/gr

C. Potential Electrical Engery from Bio-briquettes

After calculating and getting the results of the bio-briquette fuel potential, the next step is to calculate the efficiency of the PLTU, calculating the potential electrical energy and power potential of the bio-briquette fuel using equations 1, 2, and 3. In table 5 the calculation results.

Table 5. Energy Efficiency Results of PLTU PKS PT. ADEI PLANTATION & INDUSTRY, MPOM

PLTU Efficiency Result Parameters	Mark (Unit)
Turbine Working Flow Rate	1,600 kW
Pump Working Flow Rate	90 kW
Turbine & Pump Clean Work	1,510 kW
Heat Flow Rate in Boilers	29,475.05 kW
Efficiency of PLTU PKS PT. ADEI PLANTATION & INDUSTRY, *MPOM*	5.12%

The efficiency of the PLTU is calculated using the results of subtracting the sum of the working flow rates of the turbines and pumps and the result is 1,510 kW, while to calculate the heat flow rate in the boiler using property table interpolation to get the enthalpy value and determine the incoming heat value based on the results of the enthalpy values for state 2 and state 3 thus producing a value of 29,475.05 kW, then divided by the total heat flow rate in the boiler times 100% to get the efficiency result of PLTU PKS PT. ADEI PLANTATION & INDUSTRY, MPOM of 5.12%.

Table 6. Potential Fuel & Electrical Energy Results of Bio-briquettes

Parameters of Bio-briquette Potential Fuel & Electrical Energy Results	Mark (Unit)
Mark heat bio-briquettes 100 gr	9,267.51 kj/kg
Mass Flow of Bio-briquettes	0.08 kg/s
Fuel Power Potential	792,020 Watts
Electrical Energy Potential	973,234 KWh

From the results of using boiler ash waste in bio-briquettes, a calorific value of 179,903,776 cal/gr for 1 day was obtained, while the bio-briquette's fuel power was 792,020 Watts. The electrical energy produced by bio-briquettes is 973,234 kWh in 1 day, 29,197,020 kWh in 1 month, and 355,230,410 kWh in 1 year. The potential electrical energy produced from utilizing boiler ash waste into bio-briquettes can be used to meet electricity needs around the PT. ADEI PLANTATION & INDUSTRY, MPOM palm oil mill. In this study, the bio-briquettes produced had a lower calorific value, namely 2214.99 cal/gr when compared with previous research, namely 6468.85 cal/gr, and still below the Indonesian National Standard with a value of 5000 cal/gr [4] [13]. The influencing factors are the length of time of the carbonization process in the combustion furnace in the boiler so that what is produced is very fine *boiler ash* and the adhesive composition will also affect the quality of the calorific value of this bio-briquette. To utilize this bio-briquette fuel for electrical energy, the power output of the bio-briquette fuel is assumed to be the efficiency of the PLTU in the palm oil mill of 5.12% with 1 day of use. This potential electrical energy will increase in value if we increase the efficiency value of the PLTU in the energy conversion process.

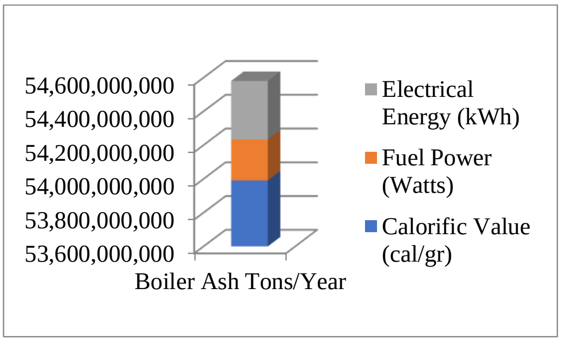

Figure 5. Boiler Ash Potential Graph

From the graphic results in Figure 5, the potential for *boiler ash* a year to produce a calorific value of 53,990,624,000 cal/gr, fuel power of 289,087,300 Watts, and electrical energy of 346,904,760 kWh. To produce electrical power, bio-briquettes are usually used in thermal power generation systems. In this system, bio-briquettes are burned to produce heat, which is then used to produce steam. This steam is then used to spin a turbine connected to an electric generator, producing electrical power. If the calorific value content of bio-briquettes increases, the amount of heat produced by burning bio-briquettes also increases. This higher amount of heat will increase the temperature of the steam produced by the boiler, which in turn increases the pressure and flow rate of the steam passing through the turbine. The higher the pressure and steam flow rate, the higher the electrical power produced by the generator. Thus, if the calorific value content of bio-briquettes increases, the electrical power produced will increase. This is due to the higher efficiency in converting thermal energy into mechanical energy (which is then converted into electrical energy).

IV. CONCLUSION

The laboratory test results showed a calorific value of 2,214.99 cal/gr, the calorific value of the bio-briquettes produced was still far below the Indonesian National Standard (SNI), namely 5,000 cal/gr. Based on the results that have been obtained, it can be concluded that boiler ash waste is the result of combustion residue in boiler furnaces (boiler ash) using the carbonization method, the electrical energy potential of bio-briquettes can meet the needs of 70% of the electricity load at the PKS PT. ADEI PLANTATION & INDUSTRI, MPOM. My suggestion for further research is to add bio-briquette composition with palm frond charcoal and KCLO3 so that it can increase the quality of the bio-briquettes produced and comply with the Indonesian National Standard (SNI):

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