*Kiman Siregar Int. Journal of Engineering Research and Applications* www.ijera.com
*ISSN: 2248-9622, Vol. 6, Issue 1, (Part - 4) January 2016, pp.09-16*

RESEARCH ARTICLE OPEN ACCESS

# The Potential Application of Gasification for Biomass Power Generation in Isolated Area from National Electricity Company in Indonesia

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**ABSTRACT**
Indonesia has renewable energy source very large, as biomass. Installed capacity power plants of Indonesia now 53,585 MW, where the potential energy biomass is the largest of renewable sources of energy that owned by Indonesia. The machine of gasification is designed to produce combustible gas (CO, $H_2$, $CH_4$). These combustible gas are produced to replace fossil fuel as engine fuel to generate electricity. However, the properties and characteristics of these combustible gas should meet the characteristic of the engine as every engine has its own specific characteristic. In this research, Biomass Power Generation (BPG) which work more properly with CO was used. High level of tar contained in produced combustible gas contaminates the engine filter rapidly. Therefore, the machine cannot be operated at a longer time. The objective of this research was to study the potential application of downdraft gasification machine with high content of CO and low production of tar. Downdraft gasification machine which designed in this research had installed capacity as much as 50 kW with reactor diameter and height were 900 mm and 1000 mm, respectively. The testing result showed that power generated from this machine was 40 kW, efficiency 80 % and can be operated for 6 hours. The optimum combustible gas produced by this machine occurred at CO, $H_2$ and $CH_4$ content were 21.75 %, 13.12 % and 1.12 %, respectively. Besides of using active carbon, tar removal was carried out using dust trap system (wet scrubber). The potential reduction of value of greenhouse gases emission is about 37 until 67 %. Based on an analysis calculation of financial , a test performance of gasification, and analysis of environmental impact, the use of system gasification can be used on a system a power plant in the isolated area from national electricity company in Indonesia.
*Keywords* - Downdraft gasification, Biomass Power Generation, electricity, combustible gas, GHG emission

## I. INTRODUCTION

The growth of energy demand in Indonesia, not balanced with the availability of energy in the people. Currently, energy needs in indonesia continue to rise. Indonesia on economic growth, and energy needs to provision electricity continue to rise, while reserve fossil energy ( fossil fuel, gas, coal ) limited. Fossil energy can no longer dependable as a source of energy major in pushing economic growth in the future, besides fossil energy also produces emission takes damage the environment. On the other side indonesia has renewable energy source very large, as biomass. Installed capacity power plants in Indonesia now 53,585 MW, where the potential energy biomass is the largest of renewable sources of energy that owned by Indonesia (Directorate EBTKE [1]). The ratio of electricity in Indonesia is only around 80 % on a national scale. For several regions lagging the ratio of the electricity is still 60 %, as in the area which isolated from national electricity company in Indonesia (PT.PLN-Persero). At this region, electricity only life at night. One solution that can be done is use renewable energy sources. Renewable energy widely available in Indonesia, one of them is the biomass that can be used with of gasification technology. Biomass is organic matter to which derived from biological materials. An example of biomass that can be used among the other corn cobs, the fruit of candlenut, biomass of timber trees in the forest, the meadow, bunches of empty palm oil , the kneecap coconut, and others. The data from the ministry of forestry, said that in 2013 potency biomass in Indonesia; located on the island of Sumatra Sulawesi, Papua, the island of Java and other 261.99 million tons. The value of the heat engine wood around 17 MJ/kg, so that the availability of biomass energy reached 4.45 x $10^9$ GJ [1].

The process of gasification consisting of four stage of the process on the basis the difference range temperature conditions, which is drying (T > 150 °C), pyrolysis (150 °C < T < 700 °C), oxidation (700 °C < T < 1500 °C), and the reduction (800 °C < T < 1000 °C). The results of pyrolysis in the form of charcoal subjected to the process of combustion and a reduction process that generates a gas $H_2$ and CO (Pranolo, [2, 4, 5]). A product produced there are three parts those are solids, liquids and gases permanent. The process of gasification biomass follow Equation 1 (Reed and Das , [3, 7, 10]).

$$C_6H_{12}O_5 + O_2 = C_xH_z + C_nH_mO_k + CO + H_2 + Calor \tag{1}$$

Gasifier technology is old technology that still is well suited for the use of biomass. Raw materials such as biomass put into gasifier, so there the partial oxidation reaction with air, oxygen, water vapor or their mixtures. Gasifier technology very worthy used in the area with biomass source that many, and has not being passed an electricity network by national company of electricity in Indonesia (PT.PLN-Persero). In this area the price of diesel fuel is very expensive around IDR 50,000 per liter. So when, a Diesel Powered Electric Genarator station and the production of electricity per hour would be very expensive for all of them, for example, in the Island of Miangas North Sulawesi Indonesia.

The gasification is designed to produce combustible gas (CO, $H_2$, $CH_4$) [2, 5]. These combustible gas are produced to replace fossil fuel as engine fuel to generate electricity. However, the properties and characteristics of these combustible gas should meet the characteristic of the engine as every engine has its own specific characteristic. Some engines are designed working more properly with methane gas ($CH_4$) but some work more properly with carbon monoxide gas (CO). In this research, Biomass Power Generation (BPG) which work more properly with CO was used [6], So that the target of a system of gasification is that to designed and give more produce gas CO. High level of tar contained in produced combustible gas contaminates the engine filter rapidly. Therefore, the machine cannot be operated at a longer time.

The objective of this research was to study the potential application of downdraft gasification machine with high content of CO and low production of tar. A specific reason that is to produce gasification machine system with gas capable of fuel in the form of CO that is larger and produce a tar a little.

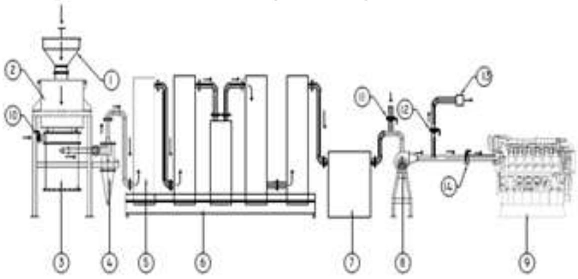
## II. METHODOLOGY

### 2.1. Materials and tools

The materials used in this research is coal calories low, wood, coconut shell. Equipment used in this research is a system gasification type downdraft and gas engine capacity of 50 kW as shown in **Fig.1**. Other equipment used are 1 HP blower [6], thermometer stem to measure the temperature inside the reactor of gasification and a laser thermometer to measure the temperature along the pipe, cyclone, and cooler, gasification reactor, hose of heat-resistant for media pipeline to transport the gas from the gas sample bag for testing to a laboratory, chipper (for cutter biomass), saws and machetes to cut biomass to be used as fuel.

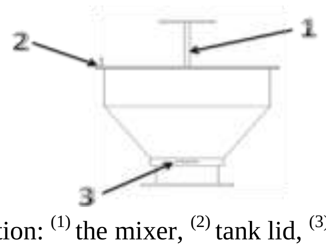
A method of working instrument consisting of the following stages this :

1. Drying of biomass and cutting of biomass
2. Inserting biomass into gasifier. The amount of biomass inserted to the operation of generators for eight hours.
3. Water tanks in full contents
4. The operation of a tank top biomass in **Fig. 2** namely: a tank opened completion of the biomass, biomass included, biomass filling the tank back and closed the drawer opened, then stirrer rotated to ensure that biomass down with perfect and drawers closed back.
5. Gasifier panel turned on, all turned water pump, ensure that water can circulate'
6. The gas generators are ready, valve with a new source of gas to which the vote, and pressed the button to open the generator will be able to operate on the use of gas fuel gasifier.



Description : (1)Charging biomass tank, (2)Biomass tank, (3)Reactor, (4)Cyclon, (5)Wet schrubber, (6)Water tank, (7)Filter, (8)Blower, (9)Engine gas genset with Cap.50 kW, (10)Air inlet nozzle (valve 1), (11)valve 2, (12)Valve 3, (13)Exhaust gas, (14)Valve 4

**Fig.1**. The schema of downdraft gasification for engine gas with capacity of 50 kW




Description: (1) the mixer, (2) tank lid, (3) chest of drawers

**Fig.2**. A tank top biomass

### 2.2. Research stage and calculation

Research began on the characteristics of the properties of the biomass used as fuel and the gasification process characterization is then performed using the type downdraft gasification reactor with continuous system. Selection of the type of reactor system downdraft gasification done to minimize the amount of tar in the syn-gas gasification. The method used in this study to minimize / reduce tar done in two ways, namely :

1. Using a scrubber system or catching tar (dirt) through a water trap.
2. Using activated charcoal as tar catcher placed after the cooler and before the filter engine.

Identification and calculations performed in this study, namely:

1. Heat loss from the reactor to the end of the exhaust pipe gasification results generated. Samplers capable fuel gas gasification conducted at 3 points, which is around the tube reactor, before and after the blower. In addition, the temperature data taken at the reactor, before and after cooler.
2. Efficiency of thermal (heat) conversion process of biomass into syn-gas (gas capable of combustion).
3. Characterization of engine performance includes the calculation of specific fuel consumption and exhaust gas temperature.
4. Finally perform calculations Cost of Production per kWh of electricity produced

## III. RESULT AND DISCUSSION

In general, the application of gasification biomass in island of Java in Indonesia is very small, because of subsidies and distribution system precious fossil fuel allowing the people in getting fossil fuel easily. Besides it, the PT.PLN as distribution extended to almost across in the island of Java. But difficulty transporting fossil fuel are often found out Java .This problem can cause scarcity and rising prices of fossil fuel, so technology of gasification was an option.

### 3.1.The results of the design gasification with engine capacity is 50 kW

Solid material referred to from a solid fuel to research this namely wood, coal calories low, and coconut shell as shown in **Fig. 3**.

(a) wood

(b) coconut shell

(c) coal calories low

**Fig.3**. Biomass fuel used in this research

The design type downdraft gasification for this study is a type of fixed bed gasification with the direction of air flow from bottom to top as shown in **Fig. 4**. The advantages of this type of downdraft is not overly sensitive to tar and can easily adapt to the amount of biomass feed. Gases of combustion of this type of downdraft gasification works by passed on the oxidation of combustion by means of flow pulled down so that the gas produced will be cleaner because the tar and oil will be burned (**Fig. 4**). This is reinforced by the data tar generated from various types of gasification were produced as shown in **Table 1.**

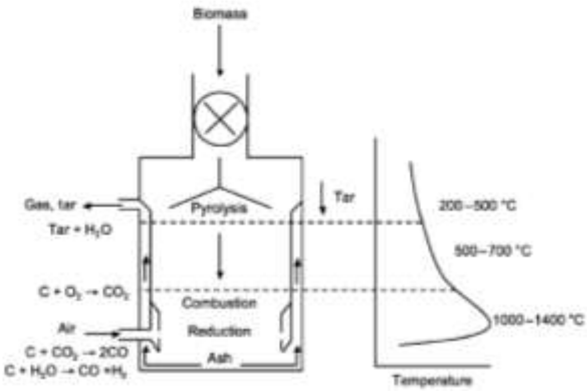



**Fig.4.** Scheme of downdraft gasifier (Reed, [3])

**Table 1**. Tar content resulting from various types of gasification produced

| Type of gasification | The average fuel gas concentrations in the tar is produced (g/Nm$^3$) | Tar percentage of biomass used |
|---|---|---|
| Downdraft | < 1 | < 2 |
| Fluidized bed | 10 | 1 – 5 |
| Updraft | 50 | 10 – 20 |
| Entrained flow | ignored | |

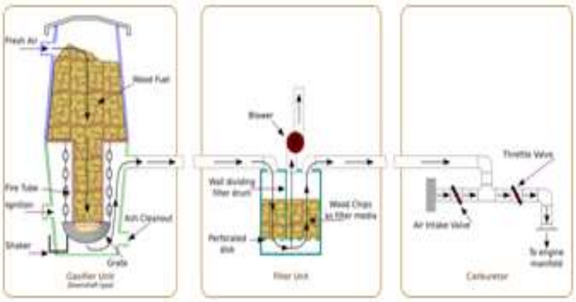


**Fig. 5**. Schematic of stratified downdraft gasifier

The design of downdraft gasification for this study is an Open Hopper, where in the top of the gasification machine is not closed, making it easier for the addition of biomass into a gasification machine for the gasification process. The design of gasification machine for this study is the classification of stratified downdraft gasification with the excuse that the top cover is open, then the man power (operator) would be more practical in adding fuel, and construction is more simple, so easy to be made, as shown in the schematic **Fig.1** and **Fig.5**.

The machine of gasification in **Fig.1** and **Fig.5** consists of: (1)Hopper is a place of biomass fuels, (2)reactor which serves as a combustion and gasification, (3)filter to filter out the rest of combustion in the form of ash and condensate, (4)Blower which serves to direct the flow of air and gas from the machine of the scheme stratified downdraft gasification in **Fig.1** and **Fig.5** is added also cooler, cyclone filters, condensate trap and scrubber for trapping dust and liquids condensed from the gas.

Specification : Capacity 1 ton/hour, power 4 kW, weight 250 kg, spindle speed 1500 rpm, cutter head diameter 500 mm

**Fig. 6.** W*ood chipper machine*

In **Fig.6** is shown wood chipper machine to cut biomass used in this study. Because in operational shape and size of different biomass fuels can lead to congestion the flow of raw materials to the tank biomass. If left unchecked, it will be even greater, so it will affect the pressure in the reactor and the gas flow out. With the shape and size of the fuel is relatively uniform, congestion can be avoided [4], so it is necessary to use cutting tools that can produce biomass size uniformity. And the physical image tool stratified downdraft gasification produced are shown in **Figure 7**. Biomass used in this study is wood, coconut shell, and coal calories low. In **Table 2** are shown examples of waste agriculture that can be used as fuel for the gasification which is a renewable energy source.

### 3.2. Performance test of gasification downdraft with capacity of engine is 50 kW

To ensure that the composition of the fuel gas content capable of being generated, then carried to the laboratory testing, and the results are as shown in **Table 3**, **4** and **5**. To ensure the most optimal composition according to the engine that will be used, then the gas sampling afford fuel, ie at the position after the blower (**Table 3**), before the blower (**Table 4**), and after the reactor (**Table 5**). And the results obtained were able to burn CO gas composition biggest in **Table 4**, which amounted to 21.76%.

One crucial factor in production applications of gasification for accuracy in the selection of the engine is adjusted engine capable of fuel gas results produced by gasification process. In **Table 6** are shown the type and kind of gas is able to burn required by the engine to be used. Because of the results obtained in laboratory testing that is able to fuel gas is the most dominant CO and $H_2$ gas, the gas engine used is the engine for a capacity of 50 kW in accordance with the initial design used for the capacity of 50 kW. And in **Fig.8** is shown the gas engine is used in this study.

**Table 2**. The content of agriculture biomass as fuel of gasifier

| Biomass | Empthy of bunches [1] (%) | rice husk [2] (%) | sawdust [3] (%) | rice straw [4] (%) | Lignite [5] (%) | Anthracite [6] (%) |
|---|---|---|---|---|---|---|
| Form | oval | Needle | circle | bar | square | square |
| H | 5.01 | 4.59 | 7.78 | 5.02 | 7.50 | 3.50 |
| C | 44.44 | 39.1 | 56.31 | 38.2 | 45.0 | 85.00 |
| O | 34.70 | 34.7 | 34.73 | 35.3 | 48.0 | 9.00 |
| N | 0.28 | 0.18 | 1.06 | 0.58 | 1.00 | 1.00 |
| Water content | 12.00 | 8.20 | 7.40 | 10.0 | 45.0 | 6.00 |
| Ash | 3.50 | 13.2 | 0.40 | 10.4 | 15.0 | 15.00 |
| The value of heat, MJ/kg | 16.90 | 14.2 | 21.30 | 12.3 | 17.5 | 31.40 |

Source : 1-4 (Krongkaew Laohalidanond, Jürgen Heil and Christain Wirtgen,2006) and 5-6 (Speight, 2005) [3, 4]

**Table 3**. The composition of the exhaust gas is able to burn wood samples of gasification with the sampling position after blower

| No | Component name | Concentration (%-vol) | Normalization 100 % |
|---|---|---|---|
| 1 | Hydrogen ($H_2$ | 7.35 | 8.52 |
| 2 | Nitrogen ($N_2$) | 59.81 | 69.35 |
| 3 | Carbon monoxide (CO) | 9.98 | 11.57 |
| 4 | Methane ($CH_4$) | 1.63 | 1.89 |
| 5 | Carbon dioxide ($CO_2$) | 7.48 | 8.68 |

**Table 4**. The composition of the exhaust gas is able to burn wood samples of gasification with the position of the sampling before blower

| No | Component name | Concentration (% -vol) | Normalization 100 % |
|---|---|---|---|
| 1 | Hydrogen ($H_2$) | 13.12 | 14.33 |
| 2 | Nitrogen ($N_2$) | 46.22 | 50.47 |
| 3 | Carbon monoxide (CO) | 21.76 | 23.76 |
| 4 | Methane ($CH_4$) | 1.12 | 1.23 |
| 5 | Carbon dioxide ($CO_2$) | 9.36 | 10.22 |

**Table 5**. The composition of the exhaust gas is able to burn wood samples of gasification with the position of the sampling of the reactor

| No | Component name | Concentration (% -vol) | Normalization 100 % |
|---|---|---|---|
| 1 | Hydrogen ($H_2$) | 8.48 | 9.58 |
| 2 | Nitrogen ($N_2$) | 51.84 | 58.55 |
| 3 | Carbon monoxide (CO) | 16.06 | 18.14 |
| 4 | Methane ($CH_4$) | 0.98 | 1.11 |
| 5 | Carbon dioxide ($CO_2$) | 11.17 | 12.62 |

**Table 6**. Description of the composition of the fuel required in accordance with the engine that will be used

| Symbol/code of engine | Type of fuel required |
|---|---|
| Without symbol | Natural gas ($CH_4$ > 80 %) |
| 1 | Biogas ($CH_4$ > 50 %) |
| 2 | Biomass (CO, $H_2$) |
| 3 | Liquefied Petroleum Gas (LPG : $C_3H_8$ and $C_4H_{10}$) |
| 4 | Coal bed gas ($CH_4$) |

Source : Weifang Naipute Gas Genset Co.,Ltd. [3, 5]


Description : (1)Reactor, (2) Biomass tank, (3)Cooler, (4)Cyclone, (5)Filter, (6)Blower, (7)Wet scrubber
**Fig. 7**. Downdraft machine gasification

After conducting testing in Diesel Power Electricity Generator for Miangas PT.PLN (Persero) Region North Sulawesi, the machine is able to work for 6 hours with power capable of 40 kW of installed power of 50 kW gas engine. In **Table 7** are shown the results of testing on the gas of diesel engine with 50 kW.


(a) Engine 50 kW

(b) Downgraft gasifier & gas engine 50 kW has installed at PLN in Indonesia

**Fig. 8**. Gas engine capacity of 50 kW used in this research

**Table 7**. Log sheet gas genset 50 GFT ND68D6 capasity is 50 kW

| Voltage (V) | | | Current (A) | | | Freq. | Rate of work | Power Factor | Oil Press. | Oil Temp. | Water Temp. | Exhaust Temp. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $V_{AB}$ | $V_{BC}$ | $V_{CA}$ | $I_{AB}$ | $I_{BC}$ | $I_{CA}$ | Hz | kW | COS ∅ | kPa | $^{O}C$ | $^{O}C$ | $^{O}C$ |
| 400 | 400 | 400 | 90 | 90 | 90 | 50 | 50 | 0,8 | 250-550 | 70-85 | 70-85 | 360 |

Description : (1)Water temperature normal is 70-85 $^oC$, T > 90 $^oC$ = alarm, T > 95 $^oC$ = trip; (2)Oil Temperature normal is 50-65 $^oC$, T > 70 $^oC$ = alarm, T > 75 $^oC$ = trip, (3)Oil pressure normal is 250-550 kPa, P < 220 kPa = alarm, P < 150 kPa = trip [3,4,7,8,9,10]

### 3.3. Study of Economy

Currently at the site Miangas Diesel Centre, conducted testing to find the economic value produced stratified downdraft gasification. From the experimental results as shown in **Table 8** and **Table 9** for the generators VA 2500 with 1500 Watt generator load. As for the gasification machine designed 50 kW, biomass to produce electricity needs of about 0.5 kg per kWh of electricity.

**Table 8**. Capacity of biomass vs kWh Production

| No | Biomass kind used on site | Amount of biomass (kg) | Duration (hour) |
|---|---|---|---|
| 1 | Coconut shell | 5. 0 | 2.39 |
| 2 | Candlenut skin | 5.0 | 2.87 |
| 3 | Corn cobs | 5.0 | 1.67 |

**Table 9**. Capacity of biomass vs kWh Production

| No | Biomass kind used on site | kWh production of electricity | Amount of biomass (kg) | The rate of the use of biomass in the production of electricity (kg/kWh) |
|---|---|---|---|---|
| 1 | Coconut shell | 3.59 | 5.0 | 1.4 |
| 2 | Candlenut skin | 4.31 | 5.0 | 1.2 |
| 3 | Corn cobs | 2.51 | 5.0 | 2.0 |

If the price of biomass in sequence starting from coconut shell, pecan shell and corn cob is IDR 550 per kg, IDR 600 per kg, and IDR 505 per kg. And if multiplied by the rate of use of biomass for electricity production in **Table 9**, the obtained value of the Cost of Production in sequence, namely IDR 770 per kWh, IDR 720 per kWh, and IDR 1 010 per kWh. When compared to the cost of production of PT.PLN-Persero in the Province of Gorontalo IDR 2 850 per kWh then electricity are from biomass is much more efficient. It can be concluded that the potential of biomass for power generation in PT.PLN-Persero in Indonesia, specially in Province of Gorontalo should be optimized, because the production cost of electricity can be saved up to IDR 2 000 per kWh.
Potential data biomass overall in Indonesia shown in **Table 10.**

**Table 10**. The Statistic data of biomass potential in Indonesia in the period 2012 - 2013 [14]

| No | Description | Value (MWe) |
|---|---|---|
| 1 | Total potential general | 30183.67 |
| 2 | Total technical potential | 3542.54 |
| 3 | Total optimization potential | 3134.89 |
| 4 | Total benefits at off grid | 689.43 |
| 5 | Total benefits at on grid | 207.3 |

### 3.4. Calculation of GHG emission

The Calculation of greenhouse gases (GHG) emission used software Multiple interface Life Cycle Assessment-JEMAI, data inputs corresponding to real condition in Indonesia are included, such as the use of power plant composition. Japan relies on nuclear energy (34%) as the source of electrical energy while Indonesia uses coal for about 38.5% of total energy source and the calculation includes electricity in Indonesia based on statistic data from PT.PLN in December 2013 [11]. The complete electricity composition used in Indonesia and Japan are shown in **Table 11** and **Table 12**. From the impact assessments of GHG emission, coal power plant releases more emission than nuclear.

The government has targeted renewable energy based by 20% of the total energy source in 2025. If the portion (20%) will substitute biomass, power plant composition will be changed (see **Table 13**). By entering GHG emission value used research by Siregar *et al*., [12] that the GHG emission value of BDF-CJCO throughout its life cycle is 0.689 kg-$CO_2$eq./kg-BDF-CJCO or 0.614 kg-$CO_2$eq./liter-BDF-CJCO, and it’s equal to biomass. The GHG emission value to produce 1 kWh electricity is 0.165 kg-$CO_2$eq. by assuming that SFC (specific fuel consumption) per 1 kWh electricity is 0.27 (normal Diesel Power Plant). This value is lower than fossil fuel, coal, and natural gas, but higher than nuclear, hydropower, and geothermal. The complete results can be seen in **Table 14**. If we compare to diesel fuel, the result of calculation is the potential reduction of value of greenhouse gases emission is about 37 until 67 %.

**Table 11**. National electrical fuel composition (based on statistic data from PT.PLN-Persero)

| A kind of a power plant and a source of fuel | Percentage (%) |
|---|---|
| Hydropower (PLTA) | 7.23 |
| Fossil fuel-HSD | 22.46 |
| Fossil fuel-IDO | 0.03 |
| Fossil fuel-MFO | 6.83 |
| Geothermal (PLTP) | 2.44 |
| Coal | 38.50 |
| Natural Gas | 22.52 |
| Solar power plant | 0.0005 |

**Table 12.** Japan electrical fuel composition (Widiyanto *et al*.,[9])

| A kind of a power plant and a source of fuel | Percentage (%) |
|---|---|
| Hydropower (PLTA) | 9.60 |
| Fossil fuel | 9.20 |
| Nuclear | 34.30 |
| Coal | 18.40 |
| Natural Gas | 26.40 |
| Others | 2.1 |

**Table 13**. The electrical composition in Indonesia

| A kind of a power plant and a source of fuel | Percentage (%) |
|---|---|
| Hydropower (PLTA) | 7.23 |
| Fossil fuel-HSD | 2.46 |
| Fossil fuel-IDO | 0.03 |
| Fossil fuel-MFO | 6.83 |
| Geothermal (PLTP) | 2.44 |
| Coal | 38.50 |
| Natural Gas | 22.52 |
| Solar power plant | 0.0005 |
| Bio Diesel from biomass | 20.00 |

**Table 14.** Impact assessment of GHG emission value of power plant system

| No | A kind of power plant | GHG (kg-$CO_2$eq). |
|---|---|---|
| 1 | Coal | 0.337 |
| 2 | Fossil fuel-IDO | 0.308 |
| 3 | Fossil fuel-HSD | 0.287 |
| 4 | Fossil fuel-MFO | 0.278 |
| 5 | Natural gas | 0.186 |
| 6 | Biomass Power Generation | 0.165 |
| 7 | Nuclear | 0.039 |
| 8 | Hydropower | 0.007 |
| 9 | Geothermal | 0.003 |

## IV. CONCLUSION

Results of machinery stratified downdraft gasification has can be used to run a gas engine with a capacity of 50 kW and can lift loads up to 40 kW or efficiency of 80% for six hours. Best able to burn gas generated at the gas content of CO which amounted to 21.76%, $H_2$ amounted to 13.12%, and 1.12% $CH_4$. Reduction in the value of tar in addition to using activated carbon, also use water trap system (scrubber).

In operation, it is seen that the gas engine operation is unstable, because of the possible supply of gaseous fuel capable fuel produced by the gasifier is unstable, so that the voltage generated is also up and down, of course, this condition will be very damaging to electronic equipment when piped directly to the home community, so it is advisable to make a tank that can accommodate afford fuel gas produced by the gasification process, after a new fit is used to fuel a gas engine, which is expected to be more stable operation. The potential reduction of value of greenhouse gases emission is about 37 until 67 %.

Based on an analysis calculation of financial , a test performance of gasification, and analysis of environmental impact, the use of system gasification can be used on a system a power plant in the isolated area from national electricity company in Indonesia.

## V. ACKNOWLEDGMENT

The author would like to thank the director of PT.Air Surya Radiator as investor to production of machine stratified downdraft gasification for the gas capacity engine is 50 kW and is able to finance the testing results of fuel gas generated.

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