

# Development of gasification process technology for the production of environmentally friendly and sustainable syngas in Wood Processing Industry

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**Abstract.** One potential bioenergy that has not been explored to its full is the bioenergy potential of wood processing industry waste. The wood processing industry's waste from saw mill wood is an alternative fuel substitute for IDO or MFO which has been widely used in the wood processing industry. The calorific value of saw mill wood waste is around 2,600 -3,400 kcal / kg, because there are many cellulose, sulfur, lignin, water biomass and so on. If the use is burned, it will directly give potential environmental impacts in the form of emission gas pollution in the form of Fly Ash, CO<sub>2</sub>, NO<sub>x</sub> and C<sub>x</sub>H<sub>y</sub>. This method is considered less efficient and gives less value.

This study aims to obtain renewable energy sources by converting sawmill wood solid fuel wood processing industry into clean, sustainable and high-calorie gas fuel (syngas) as well as preventing air pollution. The method used is the development of gasification process technology in the burner vessel fluidized bed reactor with a controlled, low oxygen vertical perforated blade installation, resulting in Syngas. Through the gasification process, saw mill wood waste can be converted into gas that is more flammable with higher calorific value and environmentally friendly (clean energy). Syngas technology will be designed based on the principle of imperfect / oxygen-poor combustion at temperatures of 300 – 500°C, inside the closed vessel, so that the gas formed is CO, H<sub>2</sub> and C<sub>x</sub>H<sub>x</sub> gas.

The output is the development of gasification process technology that produces bioenergy syngas can be used in the substitution of boiler fuel for an environmentally friendly wood drying process.

**Keywords:** process development; syngas; renewable energy; wood processing industry

## 1 Introduction

Indonesia will face up the threat of an energy crisis in 2020-2030. One sector that will be directly affected by the energy crisis is the industrial sector. The industrial sector that has been relying on fossil fuel for its energy sources, must find alternative energy sources. One alternative energy source for industry is a renewable energy source (EBT) from biomass. [1].

Bioenergy that has not been explored to its full potential is the bioenergy potential of wood processing industry waste. Its availability is abundant in Indonesia. The wood processing industry's waste from saw mill wood is one of the alternative biomass fuel sources for IDO or MFO fuel substitutes which are commonly used in wood processing industries [2]. From an economic standpoint, waste from saw mill wood will be much more efficient than IDO or MFO, because of its abundant availability. Saw mill wood

waste includes the most important energy reserves for the wood processing industry.

Currently it has been used directly in the combustion process in Boiler units for the drying process of wood in the oven. The calorific value of waste from saw mill wood is still relatively low around 2,600 to 3,400 kcal / kg. Complaints often occur from the public about the problem of air pollution due to direct wood burning. Black smoke and particulate residual incomplete combustion through the chimney contaminates the surrounding air environment [3].

The calorific value of the low saw mill wood is because there are many cellulose biomass, lignin, water and so on, so if the use is burned directly it will have an impact on the environment which is potential in the form of emission gas pollution including black smoke / Fly Ash, CO<sub>2</sub>, NO<sub>x</sub> and C<sub>x</sub>H<sub>y</sub>. This method is considered less efficient and gives less value. The use of saw mill wood waste as fuel must continue to comply with

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applicable environmental regulations and be increasingly stringent [4]. The use of saw mill wood waste as fuel in the wood processing industry, will be more competitive and more efficient if it is converted into gas syntesis, or other fuels with higher economic value. Two ways considered in this case are liquidation and sublimation (gasification). [5]

Saw mill wood waste combustion is carried out with limited air which requires partial oxidation of hydrocarbons to produce hot gas with the main composition being Hydrogen (H<sub>2</sub>), carbon monoxide (CO), nitrogen (N<sub>2</sub>), CH<sub>4</sub> compounds and other hydrocarbon compounds. Energy potential in the form of gas will be more easily flowed and used as an energy source in other processes, for example for fuel boilers, diesel engines, gas turbines, or processed for other synthetic materials. Its function can replace such as natural gas, so the gas resulting from the gasification of saw mill wood waste is also called syngas (syntetic gas). [6]

When the fuel is burned, chemical energy will be released in the form of heat. Burning occurs when oxygen contained in air reacts with carbon and hydrogen contained in saw mill wood waste and produces CO<sub>2</sub> and H<sub>2</sub>O and heat energy. Under normal conditions, with the right air supply it will convert all chemical energy into heat energy.

If the air supply is reduced, the release of chemical energy will be reduced and then the gas compound will only be formed from this imperfect combustion process (say "half-baked" combustion). This gas compound that is formed consists of H<sub>2</sub>, CO, and CH<sub>4</sub> (methana), which still has the potential of chemical energy that has not been released.

Energy potential in the form of gas will be more easily flowed and used as a source of energy in other processes, for example can replace wood fuel in the boiler unit. The calorific value of gas fuel form will increase to around 6,500-7,400 kcal / kg. Through the gasification process, syngas fuel will be produced with high calorific value, which can increase efficiency in the combustion process. Clean combustion products do not contain particulates / fly ash, are safe and do not pollute the surrounding environment (clean energy). The resulting syngas can be used as a substitute for solid wood fuel in boiler steam generating units in the wood processing industry.

## 2. Methodology

Metode yang digunakan adalah survey dan kajian lapangan ke industri pengolahan kayu di kabupaten Demak dan kabupaten Semarang Provinsi Jawa Tengah- Indonesia, kemudian dilakukan evaluasi dan analisis lapangan. Dilakukan studi pustaka terhadap hasil penelitian yang pernah dilakukan, khususnya mengenai proses produksi pengolahan kayu dan potensi limbah yang dihasilkan serta proses pembentukan syngas. Selanjutnya mekanisme tahapan

reaksi gasifikasi dalam pembentukan syngas pada reaktor gasifikasi dan dibuat analisis potensi bioenergi dengan melakukan inovasi rancangan model reaktor Fluidized Bed yang dilengkapi dengan vertical blade perforator yang digunakan untuk proses gasifikasi *saw mill wood* untuk menghasilkan *syngas* sebagai sumber energi terbarukan dan berkelanjutan yang ramah lingkungan yang dapat digunakan untuk bahan bakar dapur boiler industri pengolahan kayu tersebut.

## 3. Results And Discussion

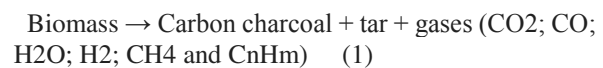
### 3.1 Gasification Process

The gasification process, called pyrolysis, is a decomposition process using heat in the absence of oxygen. This process is the first step that occurs in the combustion process [5]. The residence time and reaction temperature are factors that greatly affect the selectivity of the product.

According to [6] the process of gasification or pyrolysis is one of the processes of conversion of biomass by thermochemistry, to the destruction of organic matter with heat without oxygen to high-calorie energy. Various organic materials from biomass, in destruction will form energy and chemicals. Pyrolysis produces three different products in quantity, namely: charcoal, oil and gas.

According to, [7] pyrolysis is a destructive distillation process of organic matter that takes place when combustion is carried out in a closed vessel with an oxygen-free atmosphere (O<sub>2</sub>). Substances produced from burning organic matter are generally a mixture of tar (C<sub>x</sub>H<sub>y</sub>O), phenol compounds (C<sub>x</sub>H<sub>y</sub>O<sub>z</sub>), methanol (CH<sub>3</sub>OH), acetone (CH<sub>3</sub>COCH<sub>3</sub>), acetic acid (CH<sub>3</sub>COOH), carbon monoxide (CO), carbon dioxide (CO<sub>2</sub>), hydrogen gas (H<sub>2</sub>), methane (CH<sub>4</sub>) and charcoal grains, besides that hydrocarbon oil and solid material in the form of charcoal are also produced.

The process of thermal decomposition of biomass at the pyrolysis stage according to [8] is shown as follows:



[5] said that the pyrolysis process in terms of the process, can be divided into several types:

1. Fast Pyrolysis, which is pyrolysis carried out at high temperature ( $\pm 5000$  C), fast heat transfer rate, has a short residence time vapor ( $<2$  s), produces 75% liquid (25% water), 12% charcoal and gas 13%.
2. Pyrolysis medium, which is pyrolysis carried out at moderate temperatures ( $<5000$  C), moderate heat transfer rate, has a moderate vapor residence time ( $\pm 2$  s), produces 50% liquid (50% water), 25% charcoal and gas 25%.
3. Slow Pyrolysis, which is pyrolysis carried out at low temperatures, slow heat transfer rate, has a long

residence time vapor (> 2 s), produces 30% liquid (70% water), 35% charcoal and 35% gas.

According to [9]. The pyrolysis process involves burning the fuel as a heat source. The exothermic reaction of burning dry leaves causes the temperature to rise so that it can be used as a heat source for pyrolysis. The gases from this combustion will increase the pressure if the volume reaction - reactions that occur during the pyrolysis / gasification process, including:

1. Removal of water at a temperature of 30oC - 170oC;
2. Hemicellulose pyrolysis at a temperature of 170oC - 260oC produces furfural and its derivatives,
3. Cellulose pyrolysis at a temperature of 260oC - 310oC produces carbonyl and carboxyl, as well
4. Pyrolysis of lignin at 310oC - 500oC produces a phenol compound, glucol, siringol together with the homolog.
5. At temperatures greater than 500oC, secondary reactions occur including oxidation, polymerization and condensation [7]

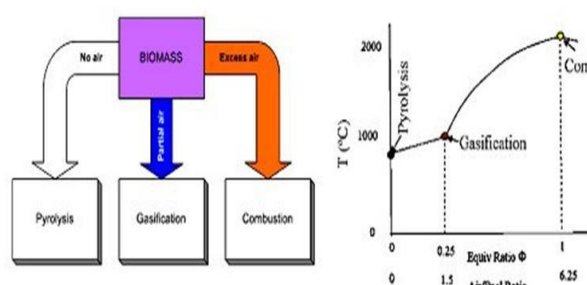


Figure 1. Comparison of air-biomass [10]

According to [10] this biomass conversion process can be done directly or indirectly. Direct conversion can be done with the combustion process, while indirect conversion can be done by pyrolysis and gasification processes. What distinguishes the two from the combustion process is the result of the process and the ratio between the amount of fuel (biomass) and the air used (AFR)

Increased LHV in the combustion process due to increased H<sub>2</sub> and CO<sub>2</sub> content.

According to [8] which has carried out downdraft gasification research with rice husk fuel with two levels of air intake. The results of the temperature characterization of the gasification process using this batch system are as follows:

- Drying at a temperature of 100 ~ 150°C
- Pyrolysis to a temperature of 300°C
- Partial oxidation to a temperature of 960°C
- Reduction at temperatures of 400 - 500 °C

Loss identification based on energy equilibrium shows that there are still losses of up to 20% outside of carbon, ash and heat losses to the environment losses. The thermal efficiency of the gasification reactor reaches 50% in conditions of air heating at 50°C.

Research [12] on coal gasification processes using single or mixed gasifying agents. Air, oxygen, carbon dioxide, and steam are a type of gasifying agent that is often used. . The use of air as a gasifying agent is widely used because it is enough to supply air from the blower so it is cheaper than other gasifying agents. Gasifying agents have an impact on the quality and quantity of syngas. There are four commonly used gasification agents: air, steam, oxygen and air-vapor mixtures. The use of gasifying agent can affect the composition of the gas, tar content, and heating value.

Table 1. Syngas characteristics based on gasifying agent

Gasification Agent	T(°C)	Gas Composition (dry basis)		Yields		
		H <sub>2</sub> (%)	CO(%)	Tar (g/kg)	Gas (Nm <sup>3</sup> /kg)	LHV (MJ/Nm <sup>3</sup> )
Air	780-830	5.0-16.3	9.9-22.4	3.7-61.9	1.25-2.45	3.7-8.4
O <sub>2</sub> - Steam	785-830	13.8-31.7	42.5-52.0	2.2-46	0.86-1.14	10.3-13.5
Steam	750-780	38-56	17-32	60-95	1.3-1.6	12.2-13.8

Source: [12]

The composition of the gas depends on the fuel, gasifying agent, type of gasifier, ER, and type of catalyst. In the gasification process using air as a gasifying agent, syngas contains flammable gas and non flammable gas. Flammable gas consists of gas CO, CH<sub>4</sub>, H<sub>2</sub>, while non-flammable gas consists of N<sub>2</sub> and CO<sub>2</sub> gas. [10]

### 3.2 Wood Processing Industry

The wood processing process is generally carried out through stages starting from the raw material of log logs (sawdust) which is done by sawing to form a wooden board, then drying in an oven using hot steam which is flowed in the pipe as a heater in the oven. Getting out of the oven goes into burning and the assembly to be formed into a product, which then enters the product finishing and packaging unit that is ready to be marketed [13]. At each step the process will produce solid waste in the form of wood and sawdust pieces. This solid waste is used by the relevant industry as fuel for steam generator boiler units. In the process of direct combustion of solid biomass will always form the emission of black smoke that pollutes the environment. This condition is always a problem in the community.

Against the background above, a model of combustion in gas form is designed through a gasification and pyrolysis process in a fluidized bed combustion reactor equipped with a vertical blade perforated, so that syngas is produced which can be used as boiler fuel in

the wood processing industry, so it does not pollute environment and sustainable.

### 3.3 Design of Gacification Reactor Modification

#### a. Flowchart of Syngas Production Process

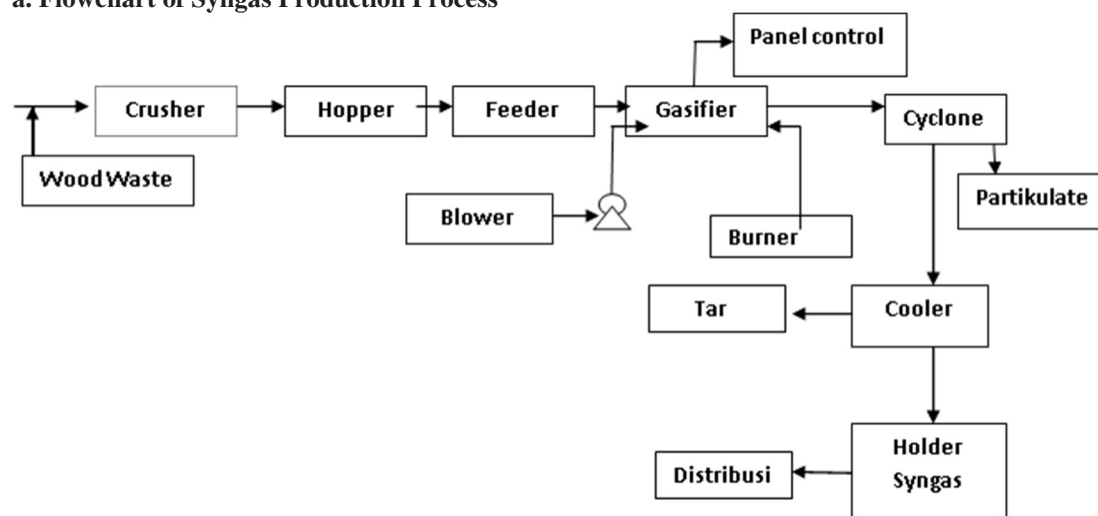
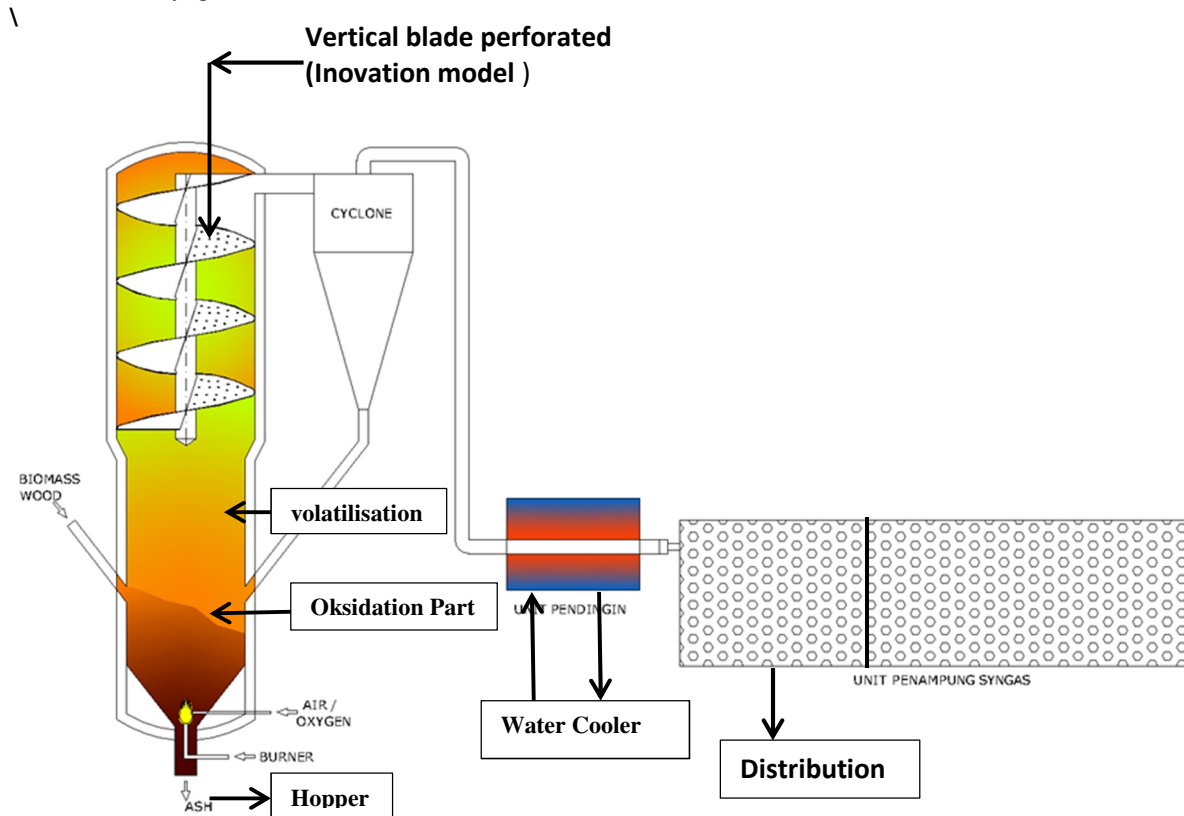


Figure 2. Flowchart of Syngas Production Process from Wood Waste Biomass

**b. Syngas Production Equipment Completeness and its use**

- Crusher : Cutting wood waste with the same size
- Hopper 1 : Collection of wood chips
- Feeder : Feeder enters the burner reactor
- Gasifier : Fluidized Bed modification reactor for Syngas Production
- Burner : Flame maker
- Blower : Oxygen Source
- Cyclone : Particulate separator carried by syngas

- Cooler : Dilutes tar vapor so that it is easily separated from syngas
- Holder : Syngas container / accumulator
- Distributor : Valve divider to Syngas user units
- Control Panel : to control the combustion temperature in the formation of Syngas
- Hopper 2 : Particulate containers that are captured by cyclone.



**Figure 3. Design of unit model of Gasification process equipment (Gasifier Modification)**

**c. Gasification Process Model Design Specifications (Gasifier Modification)**

- Work System: batch
- Gasifier process capacity : 25 kg sawmill per batch, 120 cm high, 75cm OD width
- Sawmill size : <5mm
- Material : cast iron
- As : ss 304 he is 5cm
- Perforated Blade : 12cm wide, he has a 0.5 cm hole
- Isolation : rock wool, 10 cm thick.
- Protective outer metal insulation : aluminum
- Interior innovation : vertical perforated blade, which functions to flatten heat,

accelerate volatility and prevent particulate out of the gasifier

- Blower capacity : 30 Lt / minute
- Control panel : set automatically as desired
- Gasifier buffer : elbow iron 5 cm x 5 cm, 4 mm thick
- Cooling water : circulation of centrifugal pumps, 100Lt / minute
- Tar container : 500 Lt tank
- Hooper : 1m3
- Cyclone type : dry cyclone single stage
- Syngas storage bag : PE vol 5 m3 insulated

## 4. Conclusion

The use of syngas fuel in the wood processing industry means that the government supports the development of an environmentally friendly wood processing industry. The gasification process with this equipment model will get bioenergy syngas renewable energy sources from sawmill wood waste wood processing industry with high calorific value and clean and sustainable energy. Increasing the competitiveness of the national wood processing industry in the international market.

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