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## Producer gas production of Indonesian biomass in fixed-bed downdraft gasifier as an alternative fuels for internal combustion engines

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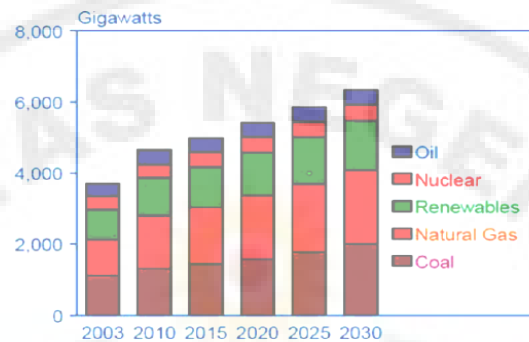
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**Abstract**-downdraft biomass gasification reactors, coupled with reciprocating internal combustion engines (ICE) are a viable technology for small scale heat and power generation. The direct use of producer gas as fuel substitution in an ICE could be of great interest since Indonesia has significant land area in different forest types that could be used to produce bioenergy and convert forest materials to bioenergy for use in energy production and the versatility of this engine. This paper will look into the aspect of biomass energie as a contributor to energy mix in Indonesia. This work also contains information gathered from numerous previews study on the downdraft gasifier based on experimental or simulation study on the ability of producer gas as fuels for internal combustion engines application. All data will be used to complement the preliminary work on biomass gasification using downdraft to produce producer gas and its application to engines.

### 1. Introduction

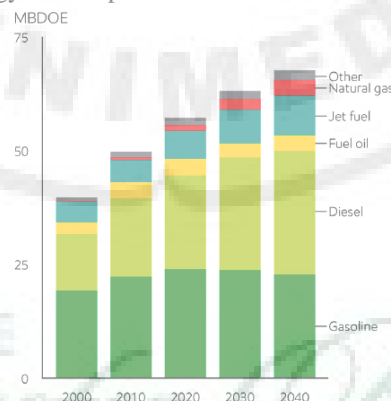
Until today, approximately the most of the world electricity is generated from coal, natural gas, nuclear, and oil. The coal and natural gas play important roles in producing world electricity. However, with the limitation of resource and green house effect, renewable energy source becomes the third popular generation route as energy sources as can be seen in Fig.1. Renewable energy is the energy derived from natural processes that do not involve the consumption of exhaustible resources such as fossil fuels. The exploration for stable energy supplies from various energy alternative resources is important, because most energy resources currently depend on fossil fuels, which are of finite availability. From a technical point of view, the large use of renewable energy sourcess or alternative fuels can also directly donate to improvements in engine performance and polution characteristics. Biomass is one of the alternative energy sourcess and most plentiful organic materials on the earth, which is produced by photosynthesis process in green plant in the presence of sunlight.





**Figure 1.** Predicted world electricity generation capacity from 2003 to 2030 [1]

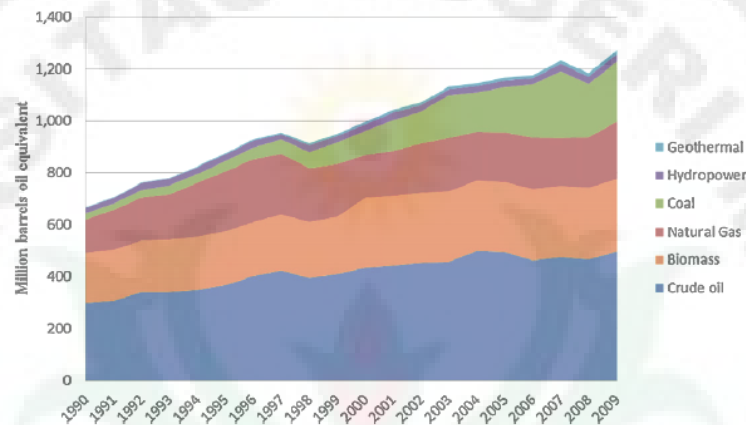
Indonesia has great potential renewable energy resources such as biomass that could be used for further applications. The biomass can be proceed through a gasification process where high temperature and airfuel ratios play important roles. Gasification involve thermo-chemical process for converting a solid fuel into a mixture of combustible gases that can be used for heat and power applications. Downdraft gasifier is one the reactor types that could be used to convert solid fuel. Numerous study on investigation of a downdraft biomass gasifer has been carried out using biomass under various operating conditions. The main advantage of downdraft reactor compare to fluidised bed is the lower tar concentration in the producer gas, which is very important for the durability of the engines and downstream devices. The downdraft gasifier however has some disadvantages suchas limited implementation to small capacities that means difficult to scale-up, lower heating value compared to fluidised bed especially internaly circulating fluidised bed on optimum operation condition ( $6.79 \text{ MJ/m}^3$ ) [2]. The largest downdraft gasifiers which exist have the power output in the range from 1.5 MWt to 5 MWt. Similar to world electricity energy, the energy demand in the transportation sector also keeps increasing in the near term where the ratio of biofuel to the total amount of fuel is also expected to increase. Fig.2 shows the fuel consumption needed for world global transportation until year 2040. Gasoline and diesel fuel still the biggest contributor to the world energy of transportation.



**Figure 2.** World global transportation deman by fuel [3]

In Indonesia, dynamic changes in the energy sector were happened in 1998 that was called **economis crisis** periode. Facing such an unfavorable situation, the government of Indonesia prioritizes on energy

supply securities by diversification of energy resources. Biomass renewable energy is one of the contributor to energy mix of the other resources such as crude oil, natural gas, coal and renewable energies as shown in Fig. 3. It can be seen that total primary energy supply had increased steadily over the past 19 years. It is estimated to reach about 1270.9 Mboe in 2009 which is more than 200% increase from 1990.



**Figure 3.** Primary Indonesian energy supply by fuel type in [4]

Nowdays, the energy mix in Indonesia is dominated by petroleum from numerous companies, however almost all the companies reported a drop in the production as shown in Table 1. In this article, it was assumed that gasoline would be substituted by an equal volume of bioenergy due to energy production and the versatility of the engines. In year 2005, Indonesia needs 17.480 billion litre of gasoline to fuel the transportation devices as shown in Table 2.

**Table 1.** Indonesian primary energy share 2003-2004 [5]

Company	2003	2004	Change (%)
Caltex <sup>a</sup>	506.9	507.0	0.0
Total	81.1	81.8	0.8
CNOOC	94.9	81.5	-14.2
Unocal <sup>a</sup>	53.9	55.7	3.3
Exspan	66.4	54.0	-18.6
Pertamina	43.6	48.4	10.9
Conoco Philips	51.4	44.1	-14.2
Petrochima	40.5	36.6	-9.7
BP	38.8	31.3	-19.4
BumiSiakPusako	32	30.0	-6.2
Vico	32.3	28.8	-10.8
ExxonMobil	25.4	21.2	-16.5
Others	79.6	74.1	-6.9

<sup>a</sup> Changed to Chevron after merger.

**Table 2.** Fuel consumption for transportation in Indonesia by 2005 (in billion litre) [6]

Fuel type	Transportation	Industry	Household	Electricity	Total
Gasoline	17.480	-	-	-	17.480
Kerosene	-	0.091	11.295	-	11.386

Diesel	12.1322	8.506	-	6.832	27.470
Diesel oil	0.072	0.807	-	0.016	0.895
Fuel oil	0.281	2.392	-	2.155	4.828
Total	29.965	11.796	11.295	9.003	62.059

## 2. Potential of biomass as an energy source in Indonesia

Biomass is natural energy source, mostly coming from agriculture crops and residues, forest waste, commodities of plantation, and animal waste. In Indonesia biomass is available in the form of agricultural residues, forestry residues and animal residues. According to [7], estimated total energy that can be obtained from agricultural residues and forestry residues is to be 614 and 141 million GJ/year, respectively. However, utilization of biomass instead of energy sources is suspected to be driving the destruction of forests in Indonesia and create conflict of land use for food or for biomass.

Biomass is the only one of the renewable energy, which can be used to produce three kinds of fuel, liquid, solid and gas fuels. Some of early works on biomass energy conversion in Indonesia are discussed by Refs. The country's total biomass production was around 146.7 million tons per year, equivalent to 470 GJ/y and mostly used by rural areas and small industries to provide energy for cooking, heat and electricity. Biomass energy source in the country can be obtained from palm oil residues, rice residues, rubber wood, palm oil residues, sugar residues, etc. As presented in Table 3. Rice residues have the biggest energy potential about 150 GJ/year, followed by rubber wood, sugar residues, and palm oil residues with energy potential 120 GJ/year, 78 GJ/year, and 67 GJ/year, respectively. The rest are from agricultural wastes and residues from any other agriculture activities such as logging residues, coconut residues, sawn timber residues and plywood and veneer residues with potential energy smaller than 20 GJ/year. Indonesia was known as the largest palm oil producer in the world after overtaking Malaysia in 2006. The country produce 21.6 million tons of palm oil, rise 3.8% from 2009. One of the factors leading to higher production is the expansion of palm oil plantation area by 6.7% to 5.73 million hectare in 2010.

**Table 3.** Major biomass energy potential as energy sources in Indonesia [8]

Biomass	Main region	Production (Milion/year)	Technical energy potential (GJ/year)	Remarks
Rubber wood	Sumatera, Kalimantan, Java	41 (replanting)	120	Small log<10 cm medium and big logs are used as fire wood in brick and roof tile industry
Logging residues	Sumatera, Kalimantan	45	19	
Sawn timber residues	Sumatera, Kalimantan	13	13	Residues of the factory often used as fire wood by local communities, residue available for free
Plywood and veneer production residues	Kalimantan, Sumatra, Java, Irian Jaya, Maluku	Bagasse: 10 Cane tops: 4 Cane leaf: 9.6	16	Bagasse is generally used in sugar factories (90%), The use of cane leaf and tops need to be investigated
Sugar residues	Java, Sumatra, Sulawesi,	Bagasse: 10 Cane tops: 4	78	Bagasse is generally used in sugar factories

Rice residues	Kalimantan, Bali/Nusa Tenggara	Cane leaf: 9.6	150	(90%), The use of cane leaf and tops need to be investigated Stalk and straw are generated at the field and generally burnt, in some areas used for feeding or raw material for paper industry Husks often burnt uncontrolled
	Java, Sumatra, Sulawesi, Kalimantan, Bali/Nusa, Tenggara	Husk: 12 Bran: 2.5 Stalk: 2 Straw: 49		
Coconut residues	Sumatra, Java, Sulawesi	Husk: 12 Bran: 2.5 Stalk: 2	7	Residues are used generated decentralized and usually left on the plantation field. Largely used as Firewood and for production charcoal
Palm oil residues	Sumatra, new areas: Kalimantan, Sulawesi, Maluku, Nusa Tenggara, Irian Jaya	Empty fruit Bunches: 3.4 Fibers: 3.6 Palm shells: 1.2	67	Palm cells and fiber are common fuel source, EFB are generally incinerated

### 3. *Downdraft fixed-bed gasifier*

Fixed bed gasifiers system is the most common technology used for solid biomass conversion. During gasification process, biomass as feedstock are subjected to different reaction zones (drying, pyrolysis, gasification, and combustion). There are many types of fixed bed gasifiers with diverse arrangements. The fixed bed gasifier can also be classified according to the ways the air as the gasifying agent come into the gasifier such as updraft, downdraft, cross draft gasifier. The downdraft application is limited to small capacities. According to [9], the largest downdraft gasifiers which exist have the power output in the range from 1.5 MWt to 5 MWt. The most commercially fixed bed gasifier that used until now is downdraft gasifier, whilst atmospheric downdraft gasifier is an attractive for small-scale application. Table 4 below shows the data of energy content which called heating value from biomass diverse by using fixed bed reactor as the gasifier.

**Table 4.** Energy content from types of biomass by using fixed bed reactor as the gasifier. [10]

No	Gasifier Type	Biomass Used	Low Heating Value (MJ/Nm <sup>3</sup> )
1	Fixed bed downdraft	Wood chips	4,7
2	Downdraft double air stage	Eucaliptus wood	4,6
3	Downdraft gasifier	Sawdust and Sunflower seed	5,6
4	Fixed-bed Twin Fired	Wood chip	5,8
5	Two stage downdraft	Wood chip	6,0
6	Downdraft Gasifier	Olive kernel	4,46
7	Dual fired downdraft	Wood	5,3

8	Downdraft gasifier	Rice husk	5,6
9	Downdraft	Wood chips	5,1
10	Downdraft gasifier	Wood chips	5,52
11	Downdraft gasifier	Wood chips	4,6

#### 4. Syngas for engine application

Internal combustion engines as well as spark-ignition (SI) and compression-ignition (CI) are machines that convert heat produced from fuels combustion into mechanical useful work. The combustion process is one of the most important energy conversion methods where the chemical energy of fuel (producer gas) is directly converted into heat. During the last years, the effect of producer gas, a low-heating value fuels on the engines, (either spark-ignition or compression ignition one) has been intensively studied. There is about 40 % of combustible gases which mainly consists of carbon monoxide (CO), hydrogen (H<sub>2</sub>) and some methane (CH<sub>4</sub>) is produced since gasification process occurred, and the rest are non-combustible and consists mainly of nitrogen (N<sub>2</sub>), carbon dioxide (CO<sub>2</sub>) and water vapour (H<sub>2</sub>O). The are also condensable gas include such as tar, acids and dust which called impurities that could be affected engines operational. Usually, the main problem of gasifier system design is to generate a producer gas with a high proportion of combustible components and a minimum of impurities. Spark ignition engines, normally operated with fuel oil, usually petrol or kerosene, but it can also be run on producer gas alone. Diesel engines can be changed and fuelled by producer gas by lowering the compression ratio and the installation of a spark ignition system. Dual fuel mode is another possibility to run a normal unconverted diesel engine in, whereby the engine draws anything between 0 and 90 % of its power output from producer gas, the remaining diesel oil being necessary for ignition of the combustible gas/air mixture. The advantage of the latter system lies in its flexibility: in case of malfunctioning of the gasifier or lack of biomass fuel, an immediate change to full diesel operation is generally possible. However, not all types of diesel engines can be converted to the above mode of operation. Compression ratios of ante-chamber and turbulence chamber diesel engines are too high for satisfactory dual fuel operation and use of producer gas in those engines leads to knocking caused by too high pressures combined with delayed ignition.

#### 5. Relevant work of syngas application on engines

Numerous of the research on the application of low-heating value gaseous fuels in engines has been studied so far through both modelling and experimental way. Martinez et al. [11] concluded that low energy density of the producer gas/air mixture and the engine's low volumetric efficiency causes power de-rating. However, according to [12] the way to increase the maximum brake torque (MBT) is by simultaneously retarding spark timing and increasing compression ratio. Sahoo et al. [13] reports the ignition characteristic of producer gas in order to render its long-term use feasible. According to literatures, the engine power de-rating when using producer gas can be as great as 70% [14]. The reason for this decrease is the low calorific value of the producer gas, which rarely exceeds 6–7 MJ/Nm<sup>3</sup> [15]. Another phenomenon related to the use of producer gas in engines, especially spark-ignited ones, is the combustion cyclic variability, which can be quantified by the coefficient of variation (ratio of standard deviation to the mean value) of the maximum combustion pressure or the indicated mean effective pressure (IMEP). The stability of engine operation, as well as the misfire and knocking tendencies, when using producer gas as fuel, have also been studied, using the coefficient of variation of the mean effective pressure [16]. Szwaja et al. [17] studied a SI engine which operates on sewage sludge producer gas mixed with methane in various proportions. The results shows that the coefficient of variation of IMEP was greater than 5%, which is considered unacceptable for power production engines. Similar results are reported by Orbaiz et al, who used four different fuels [18]. By using dry wood as the feedstock [16] also studied the effect of compression ratio and percentage of opened air inlet valve on break power of Honda

Model GX-120-four strokes-spark ignited engine, they used compression ratio of 7.5:1 and 9.3:1 and percentage of opened air inlet valve of 30% and 75%. They found that the brake power of compression ratio at 9.3:1 with 75% of opened air inlet valve was 1,443.6 Watts at 3,800 rpm showed the highest break engine power. Through intake flow of gas modification, the influence of swirl on the performance, emissions and combustion in a constant speed Spark Ignition (SI) engine has been studied experimentally by numerous researcher. A single cylinder diesel engine was also modified to operate as a biogas operated spark ignition engine [19]. They tested engine at 1500 rpm at throttle opening of 25% and 100% at various equivalence ratios. Their tests covered a range of equivalence ratios from rich to lean operating limits and also at an optimum compression ratio of 13:1 with normal and masked intake valve to enhance swirl [19]

## 6. Conclusion


Through literature study, a downdraft biomass gasifier can be used to generated producer gas instead of fluidised bed that can be applied to fuel an internal combustion engines. Minimum calorific value of producer gas needed is above 3 MJ/m<sup>3</sup>. Considering the relative success of the studies performed in this work, it seems interesting to consider the use of biomass materials to produce syngas for engines. This preliminary work covers potential alternative fuels for automotive engine application for both spark ignition (SI) and compression ignition.

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