Developing Family-Size Biogas-Fueled Electric Generator

By Agus Haryanto; Sugeng Triyono and Udin Hasanudin

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Developing Family-Size Biogas-Fueled Electric Generator

Agus Haryanto[*,1], Sugeng Triyono[1], and Udin Hasanudin[2]
[1]Department of Agricultural and Biosystem Engineering, Faculty of Agriculture
University of Lampung, Jl. Soemantri Brojonegoro No.1 Bandar Lampung 35145, Indonesia.
[2]Department of Agro-Industrial Technology, Faculty of Agriculture
University of Lampung, Jl. Soemantri Brojonegoro No.1 Bandar Lampung 35145, Indonesia.
Email: agus.haryanto@fp.unila.ac.id[*]

Abstract

Recently, electrification ratio in Indonesia has reached 84%. This means that there are still 16% (around 40 million peoples or 8 to 10 million household) have no access to national electricity grid (PLN). Most of these peoples live in isolated areas and remote islands that have not been facilitated by power grid (off grid). Family size power generation fueled by biogas can be a suitable solution for these areas. This paper discusses potential to develop small scale electricity generation using biogas produced from anaerobic digestion of cowdung. Results show that a family size anaerobic biogas digester with 6 heads of cows is able to serve 750W power generator engine operating for 4 hours per day. Therefore this technology is attractive to be developed to powering isolated areas with no access to PLN grid.

Keywords: *biogas, cowdung, electricity, remote areas.*

1. INTRODUCTION

Indonesia is covered by many small islands that are remote and out of national electric grid (PLN). By September 2014, electrification ratio in Indonesia has reached 84.3% in (PT. PLN, 2015). This number is still lower as compared to other ASEAN countries such as Malaysia (99.4%), Singapore (100%), Thailand (99.3%), the Philippines (89.7), or Vietnam (97.3%) (Power in Indonesia, 2015). The implication of this condition is that there are still around 16% of Indonesian people (about 40 million) who do not have access to the electricity. These people are living in remote and sparsely populated areas or small islands. Most of the unelectrified household (HH) live in and currently uneconomical to be reached by PLN.

Considering each unelectrified HH requires electricity supply of 450 VA at peak load (the lowest of existing power rate from PLN's grid) and all power plants to supply them operate at maximum 80% of their name plate capacity, then it will require approximately 5,6 MW new additional capacity to power up just the HHs in remote areas. The actual power capacity will be larger than just to cover the HH demand, likely reach 7–8 GW capacity due to increasing economic activity and other infrastructures, such as: schools, telecommunications, health clinic, village administration and police station, as well as other rural economic and retail activities.

Some communities have generated their own electricity using small diesel- or gasoline-generators. However, this option is expensive. At non subsidy diesel fuel price of 9.400 IDR/L and gasoline 8.600 IDR/L, and engine efficiency of 30%, then the cost of electricity is around 3,100 IDR/kwh (for diesel generator) and 2,900 IDR/kwh (for gasoline generator) just to cover fuel consumption. This is much expensive as compared to current electricity price of 1,509.38 IDR/kwh for R1-TR connection type (www.pln.co.id). In more remote areas the electricity price using diesel generators will likely be much higher due to fuel transportation cost.

Remote and sparsely populated areas will be best powered up by locally available renewable energy using economically efficient and proven technology, such as: biomass and hydro power, or biogas plant. Biogas can be one of the reliable solutions to generate electricity in remote areas. Raw materials or substrates for biogas can be developed locally and cheaply such as cow dung and agricultural wastes. In less developed countries, the biogas produced from renewable sources is the right option and could play a major role in meeting both energy and environmental problems (Kabir *et al*., 2013). Based on a thorough parametric analysis, Chandra *et al*. (2012) concluded that the production of methane (biogas) from lignocellulosic biomass agricultural waste is more economically and environmentally advantageous and is the utilization of biomass in a sustainable way to produce energy.

Application of family-sized biogas in Indonesia has a renewed attention since 2009 through a program popularly called BIRU (Biogas Rumah). By the end of 2014, the program a total of 14,110 domestic digesters (BIRU, 2015).

Small-scale electricity generation using biogas fuel can be one of the most suitable ways to overcome the electricity shortage problem for people in remote areas. Small generators (about 1 kW capacity) run on gasoline has been more and more applied in suburban areas by small shops, households or offices to cope up with the frequent power black outage. The generator can be operated completely using biogas to overcome electricity scarcity in remote areas. Vaghmashi *et al*. (2014) concluded that compressed biogas is having good potential to replace petrol. Ayade and Latey (2016) recently reported that blending biogas with petrol at a ratio of 60% petrol and 40% biogas (B40) resulted in the increase of thermal efficiency of the engine up to around 37% as compared to around 26% of engine with neat petrol. Ehsan and Naznin (2005) reported their work on power generation using small engine (1.5 kW) running with 100% biogas. Even though the brake specific fuel consumption (BSFC) using biogas was comparatively high but peak efficiency was comparable to that of engine using petrol.

Spark ignited gasoline engines may be converted to operate on biogas by changing the carburettor to one that operates on gaseous fuels. The conversion of SI engines to gas fuelling is a simple matter, requiring only the fitting of a simple gas-fuel adaptor and, possibly, hardened valves and valve seats (Jawurek *et al*., 1987). Recently, it was reported a simple conversion of gasoline-fueled single cylinder four stroke engines to run the electric generator using biogas without changing the compression ratio of original spark ignition engine. The engine run stable and was able to generate electricity using 100% biogas (Surata *et al*., 2014). Biogas treatment, however, may be necessary depending on the type of engine used. Electric generation using ignition engine requires that biogas must be cleaned so that the hydrogen sulfide (H_2S) content reaches less than 100 ppm (McKinsey-Zicari, 2003).

This paper discusses a prospect for developing family sized power generation using biogas, especially to electrify remote and sparsely populated areas.

2. MATERIALS AND METHOD

2.1. Biogas Consumption of Engine

Biogas consumed by power generator engine was evaluated by testing a 750W generator engine using pretreated biogas. The pretreatment was intended to reduce H_2S content to a level accepted by the internal spark engine. Pretreatment was conducted using locally fabricated compost. After pretreatment, the biogas has CH_4 content of 56.48% (calorific value of 20.23 MJ/N m^3) and H_2S content of 75 ppm. The engine testing was performed by varying the load from 100 to 700 W and was replicated 3 times for each load. Each experiment unit was run for 10 minutes. Parameter to be analyzed including biogas consumption, power production, and thermal efficiency. Power is equal to electric voltage (V) multiplied by electric current (I). Thermal efficiency (η_{th}) is calculated from:

$$\eta_{th} = V.I/(BC \times HV) \quad (1)$$

where BC is biogas consumption (L/s) and HV is heating value of biogas (MJ/L).

2.2. Biogas Production Potential

Biogas production potential from a family sized biogas digester was evaluated by measuring biogas yield of biogas digesters located in Pesawaran Indah village, District of Pesawaran, Lampung Province (Figure 1). The digesters were constructed in 2010 using concrete with fixed dome type and capacity of 6 m^3. Biogas yield was calculated by pressure difference measured using simple U-tube water manometer for a given period. Biogas composition was analyzed using a gas chromatograph (Shimadzu GC2014) with TCD detector and zinc carbon column.

Figure 1. Fixed dome biogas digester and simple water manometer.

3. RESULTS AND DISCUSSION

3.1. Biogas Consumption

Table 1 showed power generator engine performance using 100% biogas. The results showed that at load of 100 to 700 W, biogas consumption (BC) ranged from 400.8 to 434.4 L/h with an average value of 415 L/h.

A more useful parameter is the specific biogas consumption (SBC) which is fuel flow rate per unit power output. It measures how efficiently an engine converts the fuel to produce useful work. Our results showed that SBC decreased with load and ranged from 5.05 L/Wh at a load of 100 W (13.3%) to 1.07 L/Wh at a load of 600 W (80%).

Table 1. Performance of 750W power generator engine using 100% biogas

Load (W)	BC (L/h)	Power out (W)	SBC (L/Wh)	η_{th} (%)
100	400.8	80	5.05	6
200	413.6	177	2.35	14
300	386.4	207	1.98	17
400	407.6	286	1.42	23
500	426.8	284	1.50	21
600	437.6	408	1.07	30
700	434.4	379	1.15	28

Thermal efficiency (η_{TH}) increased with the load from 6% at a load of 100W to 30% at 600W. At a load of 600 W, thermal efficiency was maximum (30%) with SBC of 6.88 L/Wh. This meant that the engine produce the best performance at load closes to the maximum capacity.

It was also noted that biogas utilization as fuel for generator set showed a good performance during the test, which reached a total of 210 minutes.

3.2. Biogas Potential

Table 2 showed biogas yield of two biogas digester estimated by pressure difference of a U-tube manometer (indicated by difference of water column). Digesters with 5 to 6 heads of cow were capable of producing biogas at rate of 1582 L/day or 280 L/day per head of cow. Pathak *et al.* (2009) calculated that 2200 m^3/year (6 m^3/day) biogas can be produced from a family-sized digester with four cattle. Therefore, our result is much lower than the theoretical potential that can be improved through a better operation and management.

Table 2. Biogas yield of family size digester

Digester	Number of cow (head)	Biogas yield (L/day)	Biogas yield (L/head/day)
1	6	2164	360.7
2	5	1000	200.0
Average		1582	280.3

Biogas composition was presented in Table 3. The composition indicated that biogas has a fairly good quality and easy to burn. Using low heating value of 191.76 kcal/m³ or 35.82 MJ/Nm³ for methane (, the biogas has a calorific value of 20.23 MJ/N m³. With an average CH_4 content of 51.4%, fixed dome family size digester produced biogas with energy value of 29.14 MJ/day. By taking low heating value (LHV) for gasoline as much as 44 MJ/kg or 32 MJ/l, the produced biogas is equivalent to 0.91 L of gasoline/day.

Table 2. Biogas composition

Digester	Composition		
	CH_4	CO_2	N_2
1	54.14	34.90	10.95
2	48.71	32.72	18.56
Average	51.42	33.81	14.76

Based on previous data on biogas consumption, it can be showed that biogas produced from a family digester with 5 to 6 heads of cow will be able to fuel 750W generator set for around 4 hours a day. Assuming that electricity consumption of a simple family is primarily for lighting about 4 hours a day (6:00 to 10:00 PM), it can be concluded that a family digester with 5-6 heads of cow is able to shine a single family.

4. CONCLUSION

The power generator can be well operated using 100% biogas with methane content of 56.48%. Biogas consumption of 750W power generator engine ranged from 400.8 to 434.4 L/h. A family size anaerobic biogas digester with 5-6 heads of cow is able to serve 750W genset operating for 4 hour per day. More research is required to study technical issues like the effect of biogas fuel on the engine performance as well as carbon deposit at the piston for much longer running time.

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