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Reviewing The Potential of Internal Combustion Engines for Biogas-Based Power Generation

Engr Adulrauf Baba Dauda[1], Nura Abdullahi Haladu[2], Atiku Salisu[3] , Muhd Bura Garba[4]
Department of Mechanical Engineering [1,3]
Department of Science Laboratory Technology [2,4],
Hussaini Adamu Federal Polytechnic, Kazaure, Jigawa State

Abstract: *The goal of this paper is to review previous research on the production of electricity from biogas containing methane (CH_4) by using an internal combustion (IC) engine equipped with a gas carburetor (Model I120 B). The biogas is combusted to generate electric power; the output is measured from current (I) and voltage (V), while frequency is tracked using a digital counter. As energy costs continue to rise and new small-scale generation technologies emerge, small consumers and mid-sized businesses are increasingly encouraged to explore alternative energy sources. Our review indicates that biogas offers a viable pathway to producing greener energy that does not contribute to global warming. This method not only supports long-term sustainable energy strategies but also enhances waste management. It is essential for stakeholders to raise public awareness about the role of internal combustion engines in converting waste into power, thereby reducing environmental impact.*
Keywords: *internal combustion engine, gas carburetor, biogas, anaerobic digestion, electrical power generation.*

I. Introduction

The rising energy costs and the advent of small-scale generation technologies have driven small consumers and medium-sized enterprises to consider alternative energy sources. In this context, internal combustion engines (ICEs) have emerged as promising tools for biogas-based power generation. Biogas, a combustible gas derived from the anaerobic digestion of organic waste, presents a renewable energy source for electricity and heat generation. Using biogas in ICEs can lessen dependence on fossil fuels, mitigate greenhouse gas emissions, and support sustainable waste management practices (Jovović, Velimirović, & Yaman, 2025).
ICEs primarily operate in dual fuel mode when utilizing biogas; a small quantity of ignition gas is injected alongside biogas to facilitate ignition (Simon, 2022). As demonstrated in various studies (Vasan et al., 2024), the combustion of biogas in ICEs is feasible for electricity production. The process entails feeding biogas into an ICE via a gas carburetor where it combusts to generate mechanical energy, which is further converted into electricity by a generator. This electricity can power homes and businesses or be supplied to the grid, providing a reliable and renewable energy source (Strielkowski, Civín, Tarkhanova, Tvaronavičienė, & Petrenko, 2021).

Figure 1 internal combustion engine. (Bansude, 2019)

Only in dual fuel mode do I.C. engines run on biogas. Together with the biogas, a tiny quantity of ignition gas is pumped to help the biogas ignite (Prasad, Sheetal, Venkatramanan, Kumar, & Kannojia, 2019)

External combustion engine:

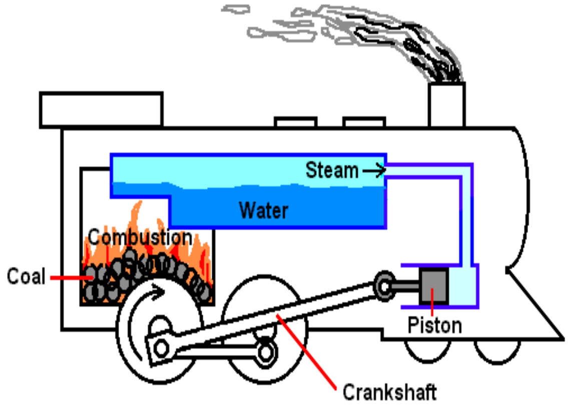

Figure 2. External combustion engine (Bansude, 2019).

Here, the boiler outside the engine produces the working medium, or steam, which is then permitted to enter the cylinder to drive the piston and do mechanical work (Bansude, 2019).

In contrast to stirring motors, biogas serves as the working medium and, according to Aksha Joshi et al. (2020), it is similarly burned outside, heating the stirring motor via a heat exchanger. As a result, the gas in the stirring motor expands, moving the engine's mechanism. Electricity is produced using the resultant labor. However, they are characterized by low efficiency and are somewhat costly.

Internal combustion motors, either as gas or diesel motors, are now the standard technology in the majority of commercially operated biogas power plants because their use is restricted to a few extremely specific applications.

Techniques for Natural Gas Engine Injection NG can be injected into the engine cylinder in four different ways (Hofny, Ghazaly, Shmroukh, & Abouelsoud). Gas mixer/carburetor injection is the first type; single point injection is the second; multipoint injection is the third; and direct injection is the fourth. Figure 3 is an illustration of the four NG injection-techniques.

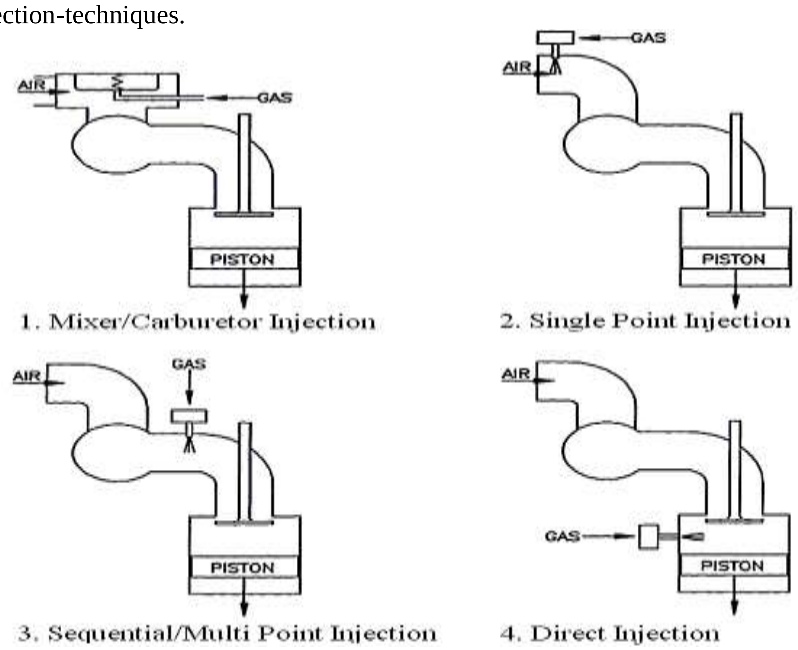

Figure 3, Injection method gas engine (Rosli *et al*, 1997).

According to Rosli et al. (1997), an electronically controlled gaseous fuel metering system or a mechanical gaseous fuel mixer or carburetor can be used to mix the fuel (Prasad et al., 2019). Prior to the air flow splitting in the intake manifold, this method aims to create a uniform blend of fuel and air. The air-fuel ratio can vary significantly from cylinder to cylinder if a homogeneous mixture is not achieved at this stage.

An air-fuel ratio of 5.71 m3 per m3 of 60% methane biogas must be met for the biogas to completely burn (Brian, 2009).

Upstream of the gasoline carburetor, Jawurek (1985) connected a Beam model I 120 B "gas carburetor" to the engine's air intake. The unit consists of a venturi with feed holes drilled through the throat region that allowed biogas fuel to be drawn at a flow rate roughly proportionate to the air intake rate while it was provided at ambient pressure (Wang, 2022). A needle valve in the gas inlet port controls the strength of the mixture. A step-switchable resistance box was used to dissipate the alternator's electrical output; frequency was measured on a digital timer; and power output was calculated using measurements of voltage and current.

Additionally, Horizontal pipes that link each well to a single well station led the biogas as it was pumped from vertical wells (perforated pipework in bulk of trash) (E. Karapidakis, Tsave, Soupios, & Katsigiannis, 2010). The electric power station's major horizontal network rounds up and transmits biogas from well stations. There, biogas is fed into the generator unit for combustion and the generation of energy after passing through the proper dehumidification and elaboration equipment (such as a freeze). Additionally, when the generator is not running, the facility has a flare for burning the biogas. In figure 4, the generative process is displayed.

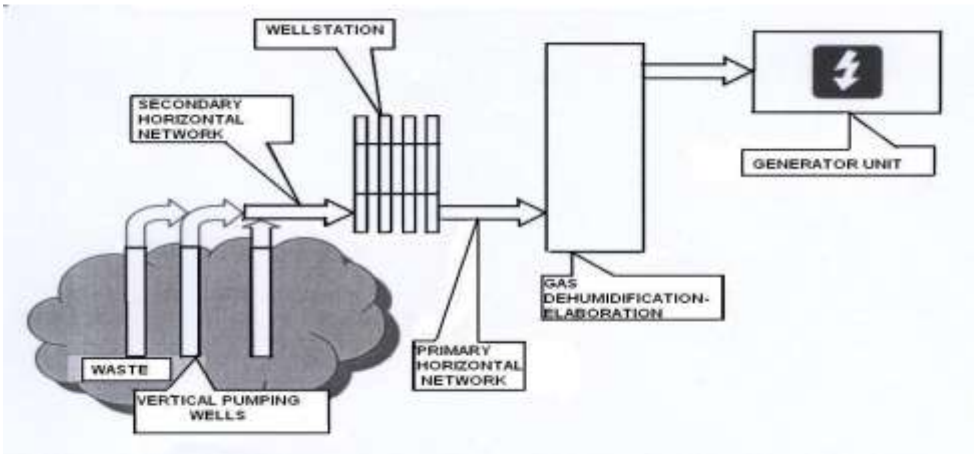

Figure 4. Generative procedure (Karapidakis, 2014).

The generating unit uses biogas, which is burned to provide electricity. Given that electric generator power is 1262 kW, the availability of those plants (average 94%) results in biogas counts up to 10,391.8 MWh/year.

Accordingly, power generation system consisting of a synchronous generator and an internal combustion engine (ICN) (spark ignition engine) was used (Monroy, Romero, & Henao, 2023). In order to allow biogas to burn in the combustion chamber and for the engine to generate a torque that rotates the synchronous generator, they integrated a low pressure gas carburetor into the ICN. Because of its functionality and contact with the biogas generation and purification system, the low pressure cab was designed to assure safety.

In conclusion, based on the literature now accessible, it can be said that using biogas to power an internal combustion engine produces electricity in a way that is more environmentally friendly and does not contribute to global warming. When combined, they can aid in waste management and offer a sustainable long-term strategy for economic growth and energy self-sufficiency.

II. Types of Combustion Engines and Their Efficiency

In addition to ICEs, external combustion engines are also relevant in this discussion. These engines utilize a boiler to produce steam, which enters the cylinder to drive the piston and perform mechanical work (Tech). Biogas can serve as the working medium, and as observed by (Chauhan & Joshi, 2024), it is combusted externally, heating the engine through a heat exchanger. However, external combustion engines are generally characterized by low efficiency and higher costs (Dahham, Wei, & Pan, 2022).

Currently, ICEs, whether operating on natural gas or diesel, dominate in commercially run biogas power plants. Various techniques exist for injecting natural gas into engine cylinders, including gas mixer/carburetor injection, single-point injection, multi-point injection, and direct injection (Li et al., 2021). To achieve complete combustion, a specific air-fuel ratio must be maintained, typically around 5.71 m^3 of biogas per m^3 for biogas that contains 60% methane (Akram, 2012). Jawurek (1985) describes the connection of a Beam model I120 B gas carburetor to the engine's air intake, which facilitates the proportional flow of biogas according to the air intake rate (Xu et al., 2025).

The biogas, once extracted and processed through necessary dehumidification and refining equipment, is transported through horizontal pipes connecting multiple wells to a singular well station (Paglini, Gandiglio, & Lanzini, 2022). The generator unit combusts this treated biogas to produce electricity, with an average availability of 94% resulting in an annual output of approximately 10,391.8 MWh from a 1262 kW electric generator (D. E. Karapidakis & Tsave, 2006).

To generate power efficiently, a synchronous generator coupled with an internal combustion engine is typically utilized (Monroy Jaramillo, Ramírez Alzate, Romero Piedrahita, & Mejía Hernández, 2024). The implementation of a low-pressure gas carburetor ensures safe operation as biogas is combusted within the combustion chamber, producing torque that drives the synchronous generator. In conclusion, current literature supports that utilizing biogas to power internal combustion engines provides an environmentally friendly method for electricity generation, as it minimizes contributions to global warming. When integrated into waste management systems, this technology not only offers a pathway towards sustainable economic development but also promotes energy self-sufficiency (van der Kam, Lagomarsino, Parra, & Hahnel).

III. Suggestions for Improvement

To effectively tackle electric power shortages, it is recommended that governments establish commercial-scale biogas facilities aimed at producing bio-fertilizer while generating electricity. The implementation of pretreatment methods can also enhance the efficiency of commercial biogas plants. Proper utilization of animal waste for biogas production should be encouraged, and farmers must be educated on the benefits of biogas to reduce reliance on non-renewable energy sources. By providing cleaner energy, biogas contributes to ecosystem stability and a greener planet.

Furthermore, to significantly augment the installed capacity of electricity generation in regions like Nigeria, government agencies should advocate for the broad adoption of this technology within the power sector. It is critical to raise awareness among stakeholders about the cost-effective and readily available internal combustion engines that convert waste into electricity, thus aiding in environmental waste reduction.

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