A Review on Biogas, its Application as a Dual-Fuel on Diesel Engines for Power Generation

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Abstract**—** Rising global challenges of energy generation, sustainability, cost, environmental concerns among others have triggered immense research on alternative energy sources and technologies in the recent past. Such previous works includes research into use of biogas as a substitute fuel in diesel engines.

This paper focuses on how biogas is generated from solid waste and among other uses, is used for power generation, electrical energy is generated from biogas and diesel, using dual fuel (DF) generator. DF applications are considered to lower cost of operating automobile engines and power generators. Furthermore this paper focuses on reviewing alternative fuels techniques focusing on bio-gas properties and local potential, then on how to run internal combustion engines on biogas fuel, previous applications, their availability and costs. The paper also illustrates methods for modification of ordinary engine to run on dual fuel, considering their applications, performance and cost implication.

The findings of this work are of great importance in developing a local mechanism that uses diesel as a pilot fuel and biogas as substitute fuel. The findings also will help in identification of an appropriate fuel regulation tool and in adapting the generation plant for a beneficial use. This is to provide affordable alternative source of electrical power to institutions, municipalities or in remote rural localities.

Keywords**—** Biogas; Diesel engine, Dual-fuel, Power generation.

I. Introduction

THIS To provide solution to the problem of solid waste and sewage disposal and to curb rising challenges of power generation, a resource recovery scheme is applied. Such a scheme may be to convert the waste to useful products. When the scheme is applied to produce electrical power, it is then referred to as Waste to Electricity Energy (WTEE) [1].This has been applied in some countries and has seen municipal and industrial waste converted into low-cost renewable energy; a potential technology with diverse environmental benefits. This paper reviews the general techniques of waste to energy conversion with interest on locally available waste materials. World use of bio-fuels has been on increase in the recent years as shown on the figure below

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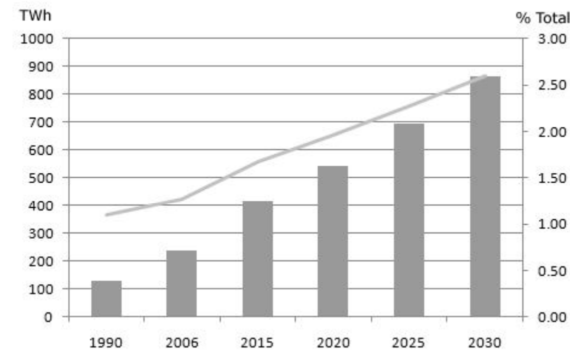
Table 1 World Electricity in Terawatts from Biomass (World Energy Outlook 2008)



This is stimulated by rising in awareness for need of environmental friendly fuels and rising cost of fossil fuels [2]. Dual fuel engines are built in such a way to run on two fuels in this case biogas and diesel [3]. There are several ways of making this happen which can be applied locally; some are as this review shows.

II. Waste to Energy

Due to diverse nature of municipal waste in terms of physical and chemical composition, there is need to classify the waste and hence apply appropriate conversion methodology [4].For dry waste materials such as agricultural by products, energy conversion is Marjory by thermal conversion techniques such as gasification and pyrolysis. Wet waste materials are converted to energy through use of biochemical processes such as fermentation and anaerobic digestion. The above methods are also classified as primary waste to energy conversion techniques.

III. Bio-fuels from Anaerobic Digestion

From wet waste materials, bio-fuel can be obtained through a biochemical process called anaerobic digestion where a group of bacteria is used to decompose organic matter in the absence of oxygen to produce biogas. This process and can be applied to waste materials of diverse nature including industrial, waste municipal solid waste , livestock and food processing wastes and human sewage. The growth in the use of bio-fuels has been facilitated by their ability to be used as blends with conventional fuels in existing engines, where ethanol is blended with gasoline and bio-diesel is blended with conventional diesel fuel [5].

The flow chart below shows how biogas is generated from anaerobic digestion until utilization for power generation.

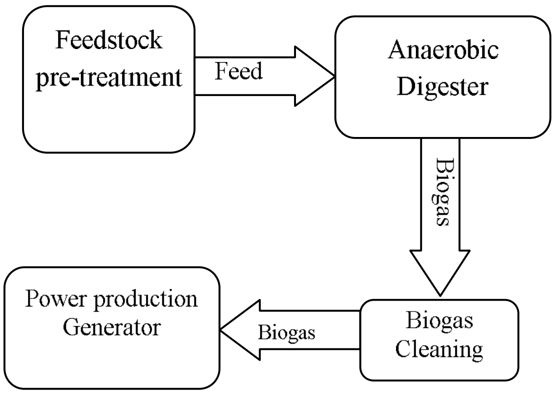


Figure 1 Biogas Production Sequence

The composition of the biogas produced is mainly methane and minor percentage of carbon dioxide and other gasses. Due to corrosion problems, biogas needs to be cleaned before being used in engines. This cleaning incorporates Hydrogen Sulphide (H_2S) removal and removal of dust, water, halogenated hydrocarbons and siloxanes [6].

IV. Secondary energy conversion techniques

Once waste materials have been converted to bio-fuels, there exist several technologies of converting it to final form of energy. Depending on the final product such as bio-diesel it can be used directly in the place of fossil fuel. Biogas can be converted for final use for cooking and lighting. It is a safe and clean-burning gas, producing little carbon monoxide and no smoke [7].Research in has seen biogas being used to produce electricity in hybrid plants [8]. In this case power generated from biogas plant is used to substitute power from wind generator in a distributed power system (DPS) to supply remote, off-grid communities where the costs of connection to the long-distance transmission or distribution grid are too high.

V. Biogas and energy

Biogas originates from bacteria in the process of bio-degradation of organic material under anaerobic (without air) conditions [9]. The natural generation of biogas is an important part of the biogeochemical carbon cycle. Methanogens (methane producing bacteria) are the last link in a chain of micro-organisms which degrade organic material and return the decomposition products to the environment. In this process biogas is generated.

Biogas is a mixture of gases that is composed chiefly of [10]:

- Methane (CH_4): 40-70 vol.%
- Carbon dioxide (CO_2): 30-60 vol.%
- Other gases: 1-5 vol.% including
- Hydrogen (H_2): 0-1 vol.%
- Hydrogen sulfide (H_2S): 0-3 vol.%

Biogas is a fuel that fits well in a sustainable society such as Sweden, where the gas is produced and is used for local heat- and electricity production or supplied as vehicle fuel [11]. In order to evaluate the suitability of a particular source of biogas, its composition and calorific value are first determined since different sources of biogas give different calorific values [1]. The calorific value of biogas is about 6kWh/m^3. Biogas utilization has positive effect on environment, once combusted, its main component methane-with higher green house potential than carbon dioxide (CO_2) –is converted to CO which has less environmental effect.

A. Application

Internal combustion engines have been fuelled by biogas from municipal digester systems for more than 40 years with varying degrees of success [12]. Biogas produced from digesters can be used for two basic purposes. It can be burned directly for cooking and lighting or indirectly for lighting to generate electricity or motive power. As a result, it can be used to replace wood for cooking and diesel fuel for power generation as shown in the figure 2 below.

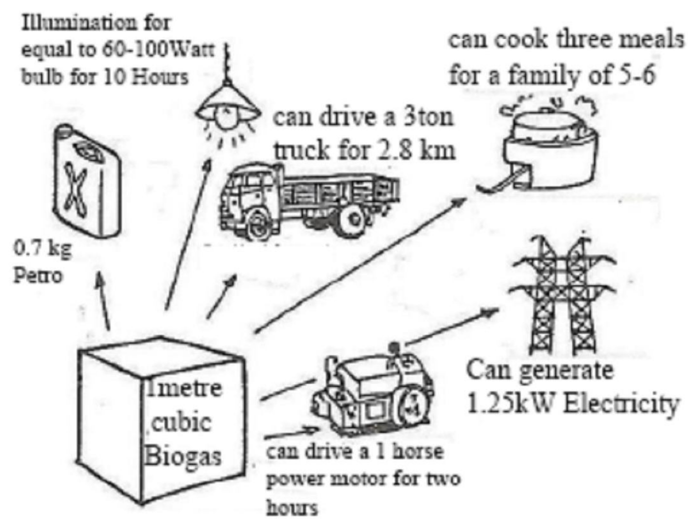


Figure 2 Energy Equivalence of One Cubic Meter of Biogas

Generally in application a litre of Gasoline is equivalent to 1.3m^3 -1.9m^3 of biogas (with 55% methane & 45% Carbon dioxide) and a litre of Diesel is equivalent to 1.5m^3 -2.5m^3 of biogas [13].

In recent years, this application has been extended to agricultural and industrial systems for a variety of power requirements. Such as

- cogeneration
- pumps,
- fans and blowers,

- •elevators and conveyors,
- •heat pumps and air conditioners
- •automobiles
- •industrial applications

B. Cost Advantage

Economic implication of use of biogas cannot be directly quantified since unlike fossil fuels, biogas is not sold in the local market and doesn't have a standard market price. The cost of biogas thence is an approximation based on cost of installation of the digester and arising maintenance expenses over time [13]. The result of practical use proves that biogas is more economical to use than fossil fuels.

VI. Biogas in Kenya

SI Kenya has a high potential of biogas owing to its readily available agricultural by product and municipal waste. However use of some of agricultural wastes from food crop plant such as maize, rice and wheat by products as a feedstock for biogas digesters is not encouraged due to their implications on food security [14].Locally, biogas has previously been used for cooking and heating. Though in other countries biogas has been used for power generation, this has not been used as often in Kenya. In a wider sense, there is unlimited use of bio-fuels locally as use of firewood and related forms of energy is classified as bio-fuel. Use of 'refined bio-fuel' has been on increase locally though affected by natural calamities and local policies. On the global scene, developed countries such as Japan, European Union and United States have new policies to promote production and usage of locally produced bio-fuels as blends to fossil fuels [5].

In evaluating the power generation potential of Biogas, parameters of the raw materials are first evaluated including availability (weather seasonal or throughout) biogas content in (m3 per ton) and Methane content (m3 per ton). For most of locally available raw materials, the parameters are as shown in the table below [14].

Table 2 Biogas Potential

SOURCE	BIOGAS CONTENT (M^3/TON)	METHANE % IN BIOGAS
Sisal waste water	475	84
Pineapple waste water	375	75
Slaughterhouse waste	340	69
Daily waste water	367	80
Chicken manure	435	63
Vegetable waste	525	55
Municipal sewage	398	64
Tea waste	358	55
Coffee pulp	390	63
Cut flower waste	360	55
Pig manure	525	55

Municipal solid waste (MSW) forms an easy source of biogas; it is discarded from residence, commercial establishments, institutions, and industries and varies with the source. On average the composition of the waste is as shown on the table below [15]

Table 3 MSW Composition

CONSTITUENT	WEIGHT (%)
Paper	37.8
Plastic	4.6
Rubber & Leather	2.2
Textiles	3.3
Wood	3.0
Food waste	14.2
Yard Waste	14.6
Glass and ceramic	9.0
Metals	8.2
Miscellaneous	3.1
Total	100

From table3 above, it is clear that a reasonable percentage is biodegradable hence can be used to produce biogas, though challenges arise where the waste is mixed up. Presence of synthetic matter in the waste may slow down anaerobic digestion and cause the waste to be gratuitously bulky hence difficult to handle. This can be improved further where waste is separated at source. Implementation of the policy on classifying and separating waste may help in refining waste for energy production.

Application of biogas as an alternative electric power source in remote villages has been successful on several occasions in developing countries; this is where there is a communal digester for several families since biogas production on small scale for a single family may prove uneconomical [15]. Further installation of dual fuel adjustments for a small power generator is not economically realistic.

VII. Units Dual fuel engines

Dual-Fuel engines are engines modified to operate simultaneously on two fuels, in most cases natural gas and diesel fuel. Here, diesel fuel is used to ignite the mixture while the majority of the fuel burned is natural gas. This allows retention of the diesel efficiency while burning cheap and clean natural gas. Research has shown promising results of dual fuel engines having the combination of diesel and natural gas [16], similar engine performance can be obtained through use of biogas since it can be upgrades to natural gas quality through purification. Economic analyses also show that conversion of engine to dual fuel to use biogas is justifiable and applicable in automobile engines, marine vessels and diesel power generation systems [3].

The dual fuel engine utilizes a lean-burn combustion process when operating on biogas. Here the gas is mixed with air before the intake valve during the air intake period, after the compression phase the gas air mixture is ignited by amount of diesel [17]. This diesel is pressurized and fed into the cylinders. Combustion is fast and after the working phase the exhaust gas valve is opened and the cylinder is emptied in the exhaust gasses. In the event of a gas supply interruption, the engine transfers from gas to fuel oil operation instantaneously and automatically. Utilization of biogas in diesel engines has some extra benefits over petrol engines since they operate on dual fuel mode with biogas and can be switched over to diesel only mode at any load without interfering with engine operations [18].

VIII. Conversion techniques

Diverse methods have been applied to make diesel engine operate on dual fuel mode, some manufacturers have come up with readymade engines operating on dual fuel mode while others have developed control system for fuel injection and regulation [19]. One such innovation is an engine modification design to make a normal diesel engine operate on gaseous fuels. Diesel fuel has a high energy density - the amount of energy per unit of volume - that allows it to power engines for a longer period of time than standard gasoline [20].

Lead generator manufacturers have come up with several methods of injecting biogas into the engine with minor modifications [21], they include:-.

A. Low Pressure Injected Gas (LPIG)

Where gas is introduced using port injection, so it mixes with combustion air just before it enters the cylinder. This is done under moderate pressure and requires injectors at each cylinder, a gas compressor and a multiple line fuel delivery. This adds substantial cost to this type of engine.

B. High Pressure Injected Gas (HPIG)

Here gas is delivered directly into the combustion chamber under extremely high pressures. This is necessary since the natural gas is injected when the cylinder pressure is very high - at the end of the compression stroke and after diesel fuel has been injected to initiate combustion. A separate high pressure natural gas injectors, pumps and fuel delivery lines system drive a large price premium for these engine systems.

C. Combustion Gas Integration

Here the gas is introduced with intake combustion air just prior to the turbocharger as shown in figure 3 below. Since a single, low pressure delivery system is used, additional engine component costs are minimized. Advanced microprocessor, sensor and actuator technologies can now economically provide the precision and response necessary to control the system. The most economical means is Combustion Gas Integration.

Experiments have also shown that there is also a minimum amount of diesel necessary for good operation of the engine; at low loads it is best to use about three times as mush diesel as gas [22,19]. As load increases, it is important to increase the amount of gas so that at full load the gas used is about three times diesel used. This is possible through valve and control system design that increases the biogas 16 times faster than diesel. More recent designs come with governing circuit that evaluates the speed and automatically regulates the fuel ratio.

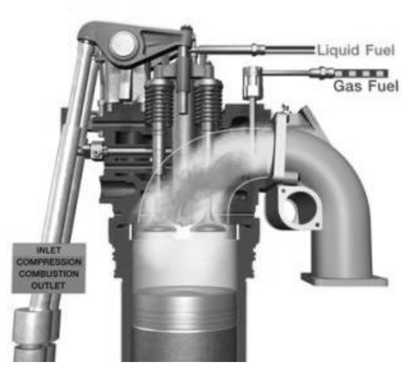


Figure 3 Engine Modifications.

IX. Application of dual-fuel engine for power generation

Generally diesel engines are used locally as emergency units in institutions and rarely as standalone units in remote rural areas. Research by Energetech shows power production using dual fuel is more economical than on diesel alone [23]. This is arrived at after comparing cost per kWh from utility company and cost from dual fuel engine. To determine the cost of power from the plant, the following are considered; - cost of biogas digester set-up, cost of generating gas, cost of diesel generator, and cost of generator maintenance.

X. Conclusion

From this analytical work, it is evident that there is a great potential of biogas generation and use in Kenya. So, by applying the reviewed methodologies for utilization it is therefore possible to develop a local mechanism that uses biogas to provide electrical power in remote locations or in standby generators for cities and municipalities. The work then opens the eyes of relevant stakeholders and poses a motivation to local researchers, engineers, investors and leaders of institutions to embrace this and explore further possibilities with biogas dual fuel engines.

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