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# BIOGAS TECHNOLOGY IN SOUTH AFRICA, PROBLEMS, CHALLENGES AND SOLUTIO

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## ABSTRACT

*Biogas is a gas that is produced from the biodegradation of organic materials. It consists mainly of methane and carbon dioxide. The biogas from anaerobic digestion can be a solution to South Africa's energy problems. It can be used for electricity generation, cooking and as transport fuel. There are over 200 biogas digesters scattered across South Africa and the use of biogas is not growing fast in the country irrespective of its benefits in reducing energy related problems such as pollution and energy shortage. This paper reviews biogas technology in South Africa and highlights the problems, challenges and solutions to the expansion of the technology. The research was conducted by surveying biogas digesters installed in the country and measuring the biogas potential from selected digesters. The problems and challenges to biogas technology expansion in the country include; lack of research work on biogas technology, low efficiency of biogas as compared to conventional fuels such as diesel and petrol, cheap electricity cost from coal fired thermal power stations, large amounts of hydrogen sulphides in biogas that can cause corrosion to biogas pipes and internal combustion engines. It was highlighted that biogas digesters to be installed in the country should be sized in accordance with the availability of substrate. In addition, the calorific value of the biogas should be improved so that it can be used to fuel internal combustion engines and generator sets. It was also revealed that community based education on biogas production and its usage need to be initiated so as to reduce biogas digester failures. This would improve biogas technology expansion in the country.*

**Keywords:** South Africa, Biogas technology, Biogas digesters, Biogas, Challenges, Problems, Solutions.

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## Contribution/ Originality

This study has highlighted problems, challenges and solutions to biogas technology expansion in South Africa. The solutions addressed in the paper on problems and challenges to biogas technology expansion would increase the country biogas energy mix, from less than 2% to greater than 15% by 2025, thereby mitigating climate change.

## 1. INTRODUCTION

Biogas is a gas that is produced when any organic matter decomposes under anaerobic conditions (Sibisi and Green, 2005; Walekwa *et al.*, 2009). The gas consists mainly of methane ($CH_4$) and carbon dioxide ($CO_2$). It is about 20% lighter than air and has an ignition temperature in the range of 650-750 °C (Deublein and Steinhauser, 2008). Biogas from anaerobic digestion can be viewed as one of the vehicles to reduce rural poverty and could lead to rural development. The anaerobic digestion produces less greenhouse gases than waste treatment processes such as composting (Walker *et al.*, 2009) and land filling (Lou and Nair, 2009). The biogas technology is appropriate for recovery of energy as it provides renewable energy fertilizer. The methane from biogas is a source of renewable



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energy producing electricity in combined heat and power plants (Clemens *et al*., 2006).The biogas can even be used to complement coal in grid electricity.

Methane is an important component in biogas, as it is a highly flammable gas and can be utilized as fuel for cooking, lighting, water heating, and if the sulphur is removed, it can be used to run biogas-fuelled generators to produce electricity. This gas can be a solution to South Africa's current energy problems. Biogas is an overlooked source of fuel in spite of the excitement surrounding the use of bio-fuels as an alternative source of energy (AGAMA, 2008). As biogas can be stored, the electricity produced can be used at will, especially during peak hours where there is the highest demand of energy and this is not the case with solar and wind that produce electricity only when the sun shines or when the wind blows.

## 2. BIOMASS POTENTIAL IN SOUTH AFRICA

South Africa is endowed with plenty of biomass reserves that are considered as a potential for anaerobic digestion. It is estimated that about 7 million tons of wood with a total amount of energy approximately equal to 86PJ/year is burned for heating and cooking purposes (Davidson *et al*., 2006). However, the over reliance on wood and fossil fuels such as coal, diesel, paraffin and petrol as an energy source remains significantly overwhelming in the country. Biogas is not only one of the most efficient and effective renewable energy possibilities available but also requires less capital investment as compared to other renewable sources like hydropower, solar power and wind power (Rao *et al*., 2010). South Africa lags behind the rest of the world when it comes to use of biogas as a source of energy. Fig. 1 is a Map of biomass potential in South Africa.

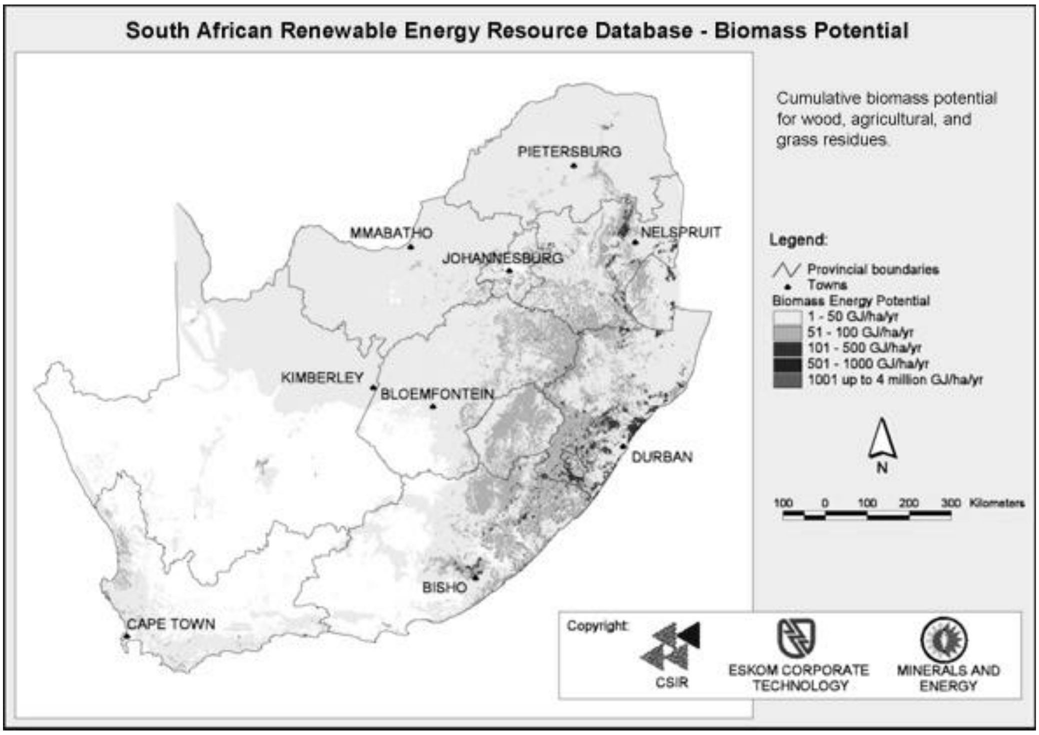


**Fig-1.** Map of biomass potential in South Africa
**Source:** DME (Department of Minerals and Energy) (2001)

Despite biomass resources such as municipal wastes, animal dung and vegetable wastes for anaerobic digestion in South Africa, the dissemination rate of biogas technology in the country is struggling to meet market demand. Nevertheless, there are a number of problems to address especially narrowing down the gap between biogas market demand and supply.

Biogas technology began to appear in South Africa during the 1950s (Amigun and Von Blottnitz, 2010; Mukumba et al., 2012). In the 1970s high fossil fuel prices led many countries to begin to research alternative energy sources, including the use of biogas as a source of energy in rural areas. In the 1990s about five digesters were built around the country, but all digesters ceased to operate within ten years (Greg and Blignaut, 2007). Currently there are approximately 200 biogas digesters in operation in South Africa, of which 90% are of the small scale domestic variety (Tiepelt, 2013). The 200 biogas digesters mainly installed by non-governmental organizations (NGO) are a very small number compared with the vast numbers in both India with 12 million and China with 17 million biogas digesters (DOE, 2015). Germany, as an example, has built 7000 biogas plants over the past 15 years and currently builds a new biogas plant every 8 hours.

The price of electricity in South Africa is still among the lowest in the world (Pegels, 2010). South Africa, historically, has low electricity tariffs that have been very detrimental to the development of renewable energy generation (Winkler, 2005). The South African government has taken steps to enhance energy efficiency and promote renewable energy, however, large-scale effects of renewable energy are still lacking (Pegels, 2010).

## 3. BIO-METHANE PRODUCTION

When $CO_2$ and other impurities are removed from biogas it can be upgraded to bio-methane and injected into the gas grid for use in home and industry. Furthermore, compressed or liquefied, bio-methane can be used as transport fuel. Fig. 2 shows the schematic diagram of bio-methane production.

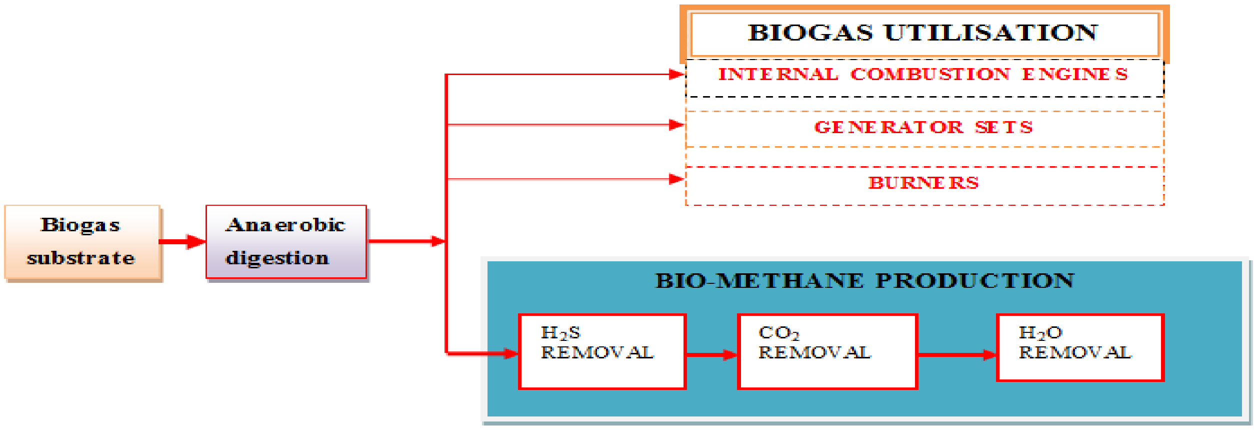


**Fig-2.** Schematic diagram of bio-methane production

**Source:** Author's Computation

The complex conversion of organic matter into methane and carbon dioxide can be divided into four steps, namely, hydrolysis, acidification, acetogenesis and methanogenesis (Nijaguna, 2002; Gerardi, 2003; Leksell, 2005; Parawira *et al.*, 2005; Polprasert, 2005; Boe, 2006; Davidsson, 2007). In a biogas digester, the four processes occur simultaneously.

Therefore, the main aim of the paper is to assess the current status of biogas technology in South Africa and come up with possible solutions to promote its expansion so that the biogas can be used at a large scale for electricity generation and powering engines (diesel and petrol).

## 4. METHODOLOGY

The data was collected from literature, biogas digester site visits, questionnaires sent to biogas installers and vast experience on biogas technology from authors. The observations made during biogas digester site visits were recorded. The data on problems and challenges on biogas technology were collected during installation of some biogas digesters by the authors and from various stakeholders through questionnaires, literature survey and site visits. Qualitative and quantitative data analysis techniques were employed in analysing the data collected.

## 5. BIOGAS COMPANIES IN SOUTH AFRICA

Non-governmental organisations, European governments, Department of Minerals and Energy and climate mitigation agencies provide support for biogas technology in South Africa. The biogas companies in the country include Bio2Watt (Pty) Ltd, Mpfuneko Community Support (MCS) and Netherlands Wild Goose Dutch Development Organisation, Biogas SA and BiogasPro. The fixed dome and balloon digesters are common in the country.

## 6. PROBLEMS AND CHALLENGES OF BIOGAS TECHNOLOGY

### 6.1. High Initial Investment Cost for Constructing Biogas Digesters

Although biogas technology can be a solution to South Africa energy needs especially to people living in rural areas, the designing and installation of digesters require high initial costs. The initial investment cost is one of the major setbacks for the adoption of biogas technology in South Africa irrespective of government support programs in renewable energy technologies. For instance, the installation of a 10 $m^3$ fixed dome digester requires at least R80 000. In addition, labour is required for daily operation, maintenance of the digesters, supervision, feeding, storage and disposal of slurry. The availability of this labour determines if the digester will be fully operational or not. The daily biogas needs increase with family size and consequently the cost will also increase. Certainly, there will be an immediate negative effect on the progress of biogas dissemination, if there are no appropriate measures to tackle those kinds of problem.

### 6.2. Availability of Biogas Substrates

The following biogas substrates are found in the rural areas of South Africa; cow dung, goat dung, sheep dung and donkey dung. The quantity of substrate entering the digesters should be consistent for long term operations. Biogas digesters are installed on the assumption that there is a consistent supply of substrate daily or weekly. Many biogas digesters are failing because of lack of substrate and inconsistent feeding due to unavailability of dung. Dung collection is not easy, together with water to mix with the substrate. In addition, the healthy sustenance of cattle so as to get nutritious cow dung for the biogas production is lacking. To many farmers, the use of other agricultural waste materials such as human excreta, poultry dung, pig dung, donkey dung and garden wastes as substrates for the digesters is lacking. Therefore, many biogas digesters remain under fed resulting in methane production failure.

### 6.3. Limited Research on Biogas Technology

The research work in biogas technology is lacking in South Africa although digesters are being installed in the country. In addition, published work on field biogas digesters and laboratory batch digesters is lacking. There is no available data on the amount of methane produced from installed biogas digesters and ways of improving the methane quality. Sometimes, gathering information on failed digesters is hampered by some procedures. Furthermore, research work on biogas technology by biogas specialists is hampered due to lack of funds and this is negatively impacting on biogas dissemination programmes.

South Africa has different munipalities producing plenty of biogas substrates from human excreta. The munipalities include: City of Tshwane Metropolitan Municipality (Gauteng Province), Maletswai Local Municipality (Eastern Cape), MalutiPhofung Local Municipality (Free State), Umjindi Local Municipality (Mpumalanga), George Local Municipality (Western Cape), Tlokwe Local Municipality (North West), Newcastle Local Municipality (KwaZulu-Natal), Greater Tzaneen Local Municipality (Limpopo) and KharaHais Local Municipality (Northern Cape). The biogas produced in these sewage treatment plants is not utilised due to lack of funding and inadequate research work, but instead, the biogas is burnt in air causing climate change. Fig. 3 shows a photo for a biogas storage tank in North West Province (Tlokwe Local Municipality).

**Fig-3.** 1000 $m^3$ biogas digester for human excreta
**Source:** South Africa Local Government Association (SALGA) (2015)

The biogas from the digester is currently not utilised. Fig. 4 shows a photo of a biogas digester owned by Newcastle Local Municipality (KwaZulu-Natal). The biogas potential from the digester is very low due to the Waste Water Treatment Works (WWTW) utilising anaerobic ponds as a treatment step.

**Fig-4.** Anaerobic digesters being de-sludged.
**Source:** SALGA (2015)

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Fig. 5 shows 3 000 $m^3$ biogas digester for Waste Water Treatment Works (WWTW) owned by Tzaneen Local Municipality (Limpopo Province). The effluent flows from the head of works to the Primary Settling Tanks (PST). Approximately 40% of the sludge from PST is pumped to the digester. The supernatant is pumped to the activated sludge reactor and the humus sludge is pumped to the digesters. Waste Activated Sludge (WAS) and sludge collected by the clarifiers are pumped to the 3000 $m^3$ biogas digester. The digested sludge is dried on the drying beds and then collected by farmers for land application. More research work is required to find ways of utilizing the biogas from the Activated Sewage Treatment Works for the benefit of the people in the province.

**Fig-5.** The 3000 $m^3$ digester at Tzaneen WWTW
**Source:** SALGA (2015)

### 6.4. Biogas Pilot Phase Failure

Many biogas digesters which were built about four decades ago in South Africa as pilot phase digesters are no longer operational and this has disrupted the biogas dissemination campaign. The pilot digesters that were installed were producing biogas mainly for cooking and heating purposes but not for electricity generation or as vehicle fuel. Biogas technology requires some skills, social acceptance and mind set for reliable operation. Up to now, many biogas users in rural communities are ignorant of the advantages of using biogas as a of source energy.

### 6.5. Awareness Program

Education is one of greatest challenges hampering the progress of biogas technology in South Africa. To have a viable and sustainable biogas system, it is important to educate the community on economic, social, health and environmental merits of biogas technology. Rural communities of South Africa need adequate education so that they can appreciate the importance of biogas energy as compared to other sources of energy such as thermal power from coal. In addition, there is no biogas technology education in primary, secondary and tertiary institutions and as a result, many rural communities are ignorant about this new technology on social and economic development and still continue to use firewood when biogas digesters are available.

### 6.6. Inadequate Expertise for Construction and Maintenance

Inadequate expertise for construction and maintenance of biogas digesters is another constraint hindering the dissemination of biogas technology in the country. There are hardly any technical or vocational schools or colleges that train people on how to build biogas digesters and how to maintain the biogas digesters. A number of biogas projects have failed in the country due to inability of proper management as a result of lack of education.

### 6.7. Hydrogen Sulphide and Carbon Dioxide in Biogas

The raw biogas produced from anaerobic digestion contains large amounts of hydrogen sulphide ($H_2S$) and carbon dioxide ($CO_2$). $H_2S$ is a harmful gas that can cause corrosion to biogas pipes, gas stoves and internal combustion engines. The carbon dioxide in biogas lowers the caloric value of biogas when used as fuel since it is not combustible.

### 6.8. Low Efficiency of Biogas

Biogas as a fuel has low efficiency as compared to fuel fossils such as diesel and petrol. The methods to improve its efficiency so as to run internal combustion engines are lacking. Many biogas digesters have been closed due to farmers lacking experience and support from biogas experts to improve the calorific value of biogas. For example, biogas is used in spark ignition engines, it has less power output, less than 20 kW compared to original output of more than 60 kW when petrol is used.

### 6.9. Limited Research on Biogas Technology

There is low application of biogas in the country, mainly for cooking and heating purposes in rural areas. Large applications of biogas such as its use as a fuel for internal combustion engines and for electricity generation are lacking. Using biogas in internal combustion engines started in 1940s but up to now South Africa vehicles are running on fossil fuels and there is no progress that has been made to the engines. It was observed that lack of basic and advanced research in the biogas technology by scientists in the country is one of the factors contributing to poor biogas technology application (Amigun and Von Blottnitz, 2010).

### 4.10. Low ESKOM Electricity Costs

Biogas technology is not an attractive form of energy because of cheap electricity from coal fired power and hydropower stations. The higher the electricity cost from coal, the higher the demand of energy from renewable energy sources such as biogas. The biogas digesters that are installed in the rural communities are producing low biogas that is not enough to be fed into Eskom's national grid. The use of biogas is not growing fast in South Africa irrespective of its benefit in reducing environmental pollution and solving the energy problems. The biogas in South Africa is not as highly advanced as in Germany where it is used to produce green electricity and is fed directly into the grid.

### 6.11. Low Application of Biogas

The quantity of substrates available for a digester determines the digester size. The digesters that are installed to individuals in different rural communities have not been sized according to the availability of substrates. The digesters have the same size irrespective of the availability of the substrates for each family. The digesters should have varying sizes according to substrate availability but this is not the case. These digesters end up being underfed. Generally, a household that has two cows can operate a 4 $m^3$ digester, four cows a 6 $m^3$ digester and six cows a 8 $m^3$digester (Misi, 2001).

## 7. SOME SOLUTIONS TO BIOGAS CHALLENGES AND PROBLEMS

### 7.1. Co-Digestion of Substrates

Many digesters that are installed in rural communities of South Africa use cow dung as a substrate for biogas production. The biogas from cow dung is very low as compared to other wastes. Co-digestion of wastes is not practised, resulting in low biogas yields. The co-digestion of organic wastes involves mixing of various substrates in varying proportions (Mata-Alvarez, 2003). Co-digestion is required to promote ammonia removal during digestion so as to optimise biogas production. The mixing of several wastes has positive effects on anaerobic digestion process because it improves the methane yield, improves stability and achieves a better handling of waste (Mukumba and Makaka, 2015). In addition, such a system is economically more favourable as it combines different streams in one common facility. In the case of the co-digestion of food waste and toilet waste, the low carbon:

nitrogen (C/N) ratio and biodegradability content of the toilet waste are compensated by the high values characterising those two parameters for the food waste. Thus, the major problem of ammonia toxicity due to low C/N ratio is avoided and the low biogas yield due to small content of biodegradable matter is increased. Therefore, co-digestion of wastes improves biogas quality.

### 7.2. Improving the Calorific Value of Biogas

To increase the calorific value for biogas, it should be purified and upgraded so as to remove carbon dioxide, hydrogen sulphide and water vapour. The biogas scrubbing unit will consist of the following sub units, $CO_2$ separation unit, $H_2S$ separation unit and moisture separation unit. Fig. 6 shows a simplified diagram of the biogas scrubbing unit.

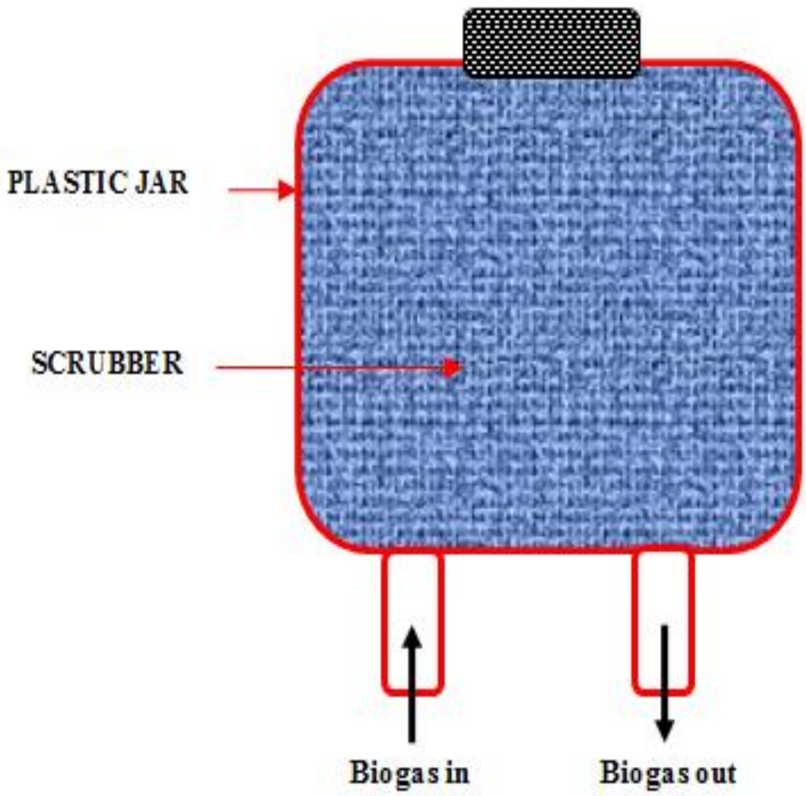


**Fig-6.** Biogas scrubbing unit

**Source:** Author's Computation

The purified biogas from the scrubbing units contains approximately 95% methane compared to biogas coming straight from the biogas digesters fed with cow dung, which contains approximately 55% methane. The biogas, now called bio-methane, with a high heating value can be fed into the national grid for electricity generation and can also be used as a vehicle fuel.

### 7.3. Designing Digesters According to the Availability of Substrates

The biogas digesters to be installed in different communities should be designed according to the availability of substrates for a particular family. Oversized biogas digesters lead to digester failure due to under feeding. The size of the digester is also dependent on retention time and on temperature. The volume of the digester can be calculated from the following equations (Shonhiwa, 2005).

$$V_d = S_d \times R_t \quad \text{(1)}$$

where:
$V_d$ = volume of the digester in cubic meters
$S_d$ = amount of substrate in kilograms
$R_t$ = retention time in days

Therefore,

$$V_d = (B + W)R_t \quad \text{...} 2$$

where:
B = Biomass (kg)
W = Water (litres)
Biogas production is calculated using equation 3.

$$G = V_s \times G_y \quad \text{...} 3$$

where:
$V_s$= weight of feedstock available per day in kilograms
$G_y$ = Gas yield in cubic meters
G = biogas production in cubic meters
Gas production rate is calculated using equation 4.

$$G_p = \frac{G}{V_d} \quad \text{...} 4$$

where:
$G_P$ = gas production rate in cubic metres per day
G = biogas production in cubic metres
$V_d$ = digester volume in cubic meters

### 7.4. Extensive Research Work in Biogas Technology

The government of South Africa is very supportive to biogas expansion in the country. The government should establish centres in each province to train people to be experts on biogas technology. Extensive research work on biogas technology should be done, encompassing the following areas; constraints of biogas technology in South Africa, new biogas designs, model equations for optimum methane yield, techno-economic analysis of rural biogas digesters, prefeasibility and feasibility studies of urban biogas digesters, replacing coal with biomass for heating water for electricity generation, most suitable inoculums to start biogas production and biogas as a fuel to power internal combustion engines. Research work on biomass as a source of energy is still minute in the country. Currently, the country is relying mostly on research work done outside Africa. New knowledge in biogas technology is required, when looking at the country's current energy needs.

### 7.5. Adequate Education on Biogas Users

The government, non-governmental organisations, and biogas installers should provide adequate education to biogas users on feeding and maintenance of biogas digesters to reduce biogas digester failures (Mukumba *et al.*, 2012). Many rural communities using Eskom grid electricity have little appreciation on the importance of biogas as a source of energy, because they have an alternative source of energy. In many rural communities biogas digesters are installed to produce biogas for heating and cooking purposes, but not for electricity generation or as a transport fuel. The biogas installers and biogas specialists through the government support need to give the biogas users adequate education on handling animal wastes, feeding, cleaning the biogas digesters, amount of water to be added to manure and ways of minimising souring of the biogas digesters. It was observed that biogas users perceive that the installation of biogas digesters in rural communities are research based projects not community based projects. Therefore, the biogas users need proper education to feel that the biogas projects are theirs, so as to improve their economic, social and health situations.

## 8. CONCLUSION

South Africa is a blessed country with a lot of biogas substrates. The biogas technology expansion in the country is faced with a number of challenges such as high initial investment cost for constructing biogas digesters, inadequate expertise for construction and maintenance of the biogas digesters, and low efficiency of biogas. It was also observed that limited research work on biogas technology is hampering biogas digester expansions in the country.

It can be concluded that the installed biogas digesters in the country should be sized in accordance with the availability of substrate. In addition, the calorific value of the biogas should be improved by upgrading the biogas to bio-methane so that it could be used to fuel internal combustion engines and generator sets. Furthermore, community based education on biogas production and its usage need to be initiated so as to reduce biogas digester failures. There is a need to fully engage and speed up dissemination of biogas digesters in the country by coming up of new digester designs, providing biogas users with adequate education on biogas usage, maintenance, handling and optimisation of biogas by co-digestion.

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