Potentials of Biogas as a Source of Renewable Energy: A Case Study of South Africa

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Abstract One of the fundamental aspects of any economy is the availability and provision of sustainable energy. This is because it forms the central part of social, environmental and economic challenges in any country. Most governments worldwide, are now considering locally accessible, available, and renewable substitute energy options to address the concerns of emissions of greenhouse gases, climate change impacts and the necessity for the provision of cleaner energy. Reliance on fossil fuels for energy provisions is well documented. South Africa thus depends largely on coal as the core energy source contributing about 77%, with 92% production of the total coal consumed on the continent. Biogas, as an alternative is a renewable and sustainable energy source that can offer green energy. Biogas has proven to be a promising, realistic and feasible technology in providing clean and reliable energy. This paper, therefore, aims at presenting the potentials and status of biogas utilization, the technological associated benefits, future prospects and lingering challenges in South Africa.

Keywords: Digesters, firewood, greenhouse gas emissions, South Africa, waste.

1. Introduction

Energy is a fundamental focus of development because it forms the central part of social, environmental and economic challenges in any country. Globally, most governments now look at locally available, renewable and alternative energy options addressing the issues of climate change as well as the need for cleaner energy provision. Fossil fuel combustion contributes greatly to carbon dioxide emissions, which is associated with climate change. Fossil fuel reliance in meeting energy supplies is widely recognized. However, due to concern about climate change, there is a need for the provision of alternative renewable energy

Even with the current low price of oil, the interest in renewable energy technology has not diminished worldwide. This can be attributed to the problem of greenhouse gas emissions and the conventional energy production from fossil fuels that threaten the safety of the environment [1].

The technology of anaerobic digestion to produce biogas as a method of renewable energy utilizes organic waste in numerous forms, in the absence of oxygen leading to the production of flammable gas mixtures of methane and carbon dioxide as well as organic fertilizer and mineralized water [2]. In other words, biogas production takes place through the process of methanogenic bacteria, which in the absence of oxygen, acts on bio- degradable materials in a process referred to as anaerobic digestion. Basically, the process of anaerobic digestion is carried out in almost all organic materials as a substrate in numerous stages. In the digestive system, it occurs in rubbish dumps, septic tanks and marshes [2].

Renewable energy has significant potential to save money in South Africa, as 77% of the nation's electricity is generated from coal, with 85% of the population having access to electricity [3]. The energy crisis of 2008 propelled the government to introduce renewable energy on a larger scale for its energy demand, thereby increasing the diversity of the country's power generation mix, reducing the emissions of carbon dioxide from coal and to mitigate climate change impacts [4].

1.1 The South African Economy

The second largest economy on the continent after Nigeria is South Africa, despite its downgrading by rating agencies. It accounts for 24 percent of the Gross Domestic Product (GDP) in Africa. The country is categorized as an upper-middle-income economy, making it one of such ranked countries on the continent, together with Botswana, Gabon and Mauritius [5]. Crucial to the economy is the energy sector because it relies on large-scale, energy-intensive coal mining industries. The country has been shown to have limited natural gas and oil reserves; thus it uses its large coal deposits to meet most of its energy requirements, principally in the power sector. According to [6], after 1994 which was the end of the apartheid era, the country's economy has rapidly grown and has become one of the most developed in Africa, accounting for 30% of the entire energy consumed on the continent.

The Gross Domestic Product tripled to almost $400 billion, with increased foreign exchange reserves from $3 billion to approximately $50 billion; thereby forming an expanded economy. In 2013, 74% of the country energy consumption primarily came from coal, 22 % came from oil, 3% from natural gas and less 1% came from renewable sources [7]. The agricultural sector contributes 2.6 percent of the country's GDP. This is due to soil aridity, as only 13.5 percent is sustainable in the production of crops, while the high potential land is considered at only 3 percent [8]. Other contributing sectors to the economy include the manufacturing sector, which contributes 11.5 percent to the GDP and the food sector which is the highest employer in the agro sector, contributing 1.4 percent GDP [9].

1.2 Energy consumption status in South Africa

The energy sector of the country describes energy and the production of electricity, its consumption and exportation [10]. In 2017, the country was rated among the top 10 hard coal producers in the world [11]. As in other coal-mining countries, the production of coal and its uses create land fires, Coal Combustion Wastes (CCW), toxic coal and Acid Mine Drainage (AMD). The wastes from combustion comprise of substances that are toxic, such as cadmium, lead, arsenic and chromium. Hundreds of the old coal mines are full of carcinogenic substances such as toluene and benzene, heavy metals and sulfate salts. On the other hand, AMD spreads diseases and sickness, damages aquatic wildlife and contaminates the water used by surrounding communities [12].

Eskom, which is the national power utility, dominates the electricity sector of the country and is owned by the government. It has 27 operative power plants. These generate 95 percent of the entire power in the country and well over 40 percent of total generated electricity on the continent [4]. Furthermore, Eskom is among the ten leading power providers in the world. However, due to lack of government investment, it is unable to keep Eskom production at a maximum due to population and economic growth. Hence, there has been a significant energy shortage, which led to the energy crisis of 2008 [4]. From the total coal consumption, more than half is consumed in the electricity sector, tailed by the petrochemical industries, metallurgical industries, domestic heating and cooking. Due to its reliance on coal, South Africa is one of the continent's leading emitter of carbon dioxide, accounting for 40% of the emissions and positioning the country at number 13th on the list of major emitters in the world [7]. Figure 1 illustrates the different sources.

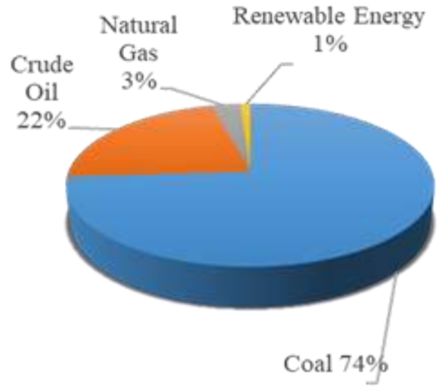

Fig.1: Total primary energy supply in South Africa [7].

Generally, electricity access is perceived as a significant phase in the socio-economic growth of any nation [7]. Regardless of the huge achievements and successes recorded in the electrification plan in South Africa, general access has not been attained [13]. The performance plan of 2013/2014 according to the Department of Energy, showed that the country should have sufficient liquid fuels and electricity supply by 2025 and at least 95 percent of the entire populace having accessing to electricity [4].

Studies conducted in the last two decades indicate a fairly consistent pattern of energy use in South African households [14]. Multiple energy sources are used by households that exhibit greater levels of material shortage to adequately meet their required energy needs [14]. Essentially, this trend has been evident in many households, irrespective of their electrification status and has contradicted the fundamental model of energy ladder and the theories of energy transition. The theories often assume a uni-indicator, straightforward approach from the use of traditional to modern energy once electrical connections are provided to households [14].

A survey by [14] evidently shows the energy patterns that exist in South Africa's electrified and non-electrified households of their dependence on different energy sources to meet their energy needs. This distinctively indicates a considerable pattern and unique energy usage patterns of the country. Figure 2 reveals that households reported that electricity is used both for lighting and cooking or heating. It is however apparent that other sources of energy such as firewood, candles, gas and paraffin are used by at least a fifth of the households to meet their energy needs [14].

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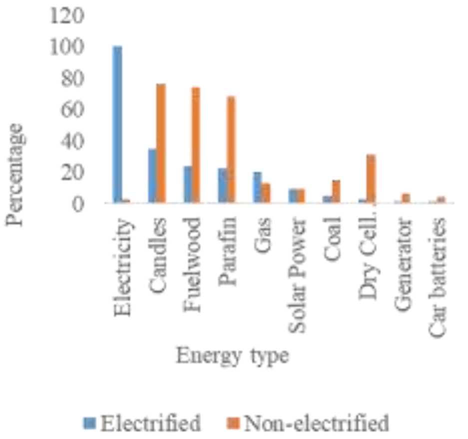


Fig. 2: South African households' energy use, 2014 [4].

2. Biogas Technology Status

2.1 What is biogas?

Biogas is a gas rich in methane that can be generated commercially from waste and other specific produced crops. The yield of biogas from biodigestion depends largely on the type and composition of the substrate, time of retention and the condition of the biodigester. The process of anaerobic digestion requires different bacteria populations and certain environmental conditions, which occur in the digester through hydrolysis, acidogenesis, acetogenesis and methanogenesis, to produce gas [16].

Biogas composition basically depends on the type of substrate. Excreta from humans in terms of biogas contains 65-66% CH4, 32-34% CO_2 by volume and others are H_2S and trace gases. On the other hand, the composition of biogas from a municipal solid waste is 68-72% CH_4, 18-20% CO_2, and 8% H_2S [17]. From different feedstock, the average biogas is presented in Table 1.

Table 1: Average biogas organic composition [16].

Gases	Percentage (%)
Methane (CH_4)	40 - 75
Carbon dioxide (CO_2)	25 - 40
Nitrogen (N)	0.5 –2.5
Oxygen (O)	0.1 - 1
Hydrogen sulphide (H_2S)	0.1 – 0.5
Ammonia (NH_3)	0.1 – 0.5
Carbon monoxide (CO)	0 – 0.1
Hydrogen (H)	1 - 3

2.2. History of biogas and present status in South Africa

There are suggestions that in the 10th century B.C., biogas was used for heating water in Assyria, and that in ancient China, solid waste to anaerobic digestion may have well been applied from the mid-19th century [18]. Digesters were constructed in Exeter, United Kingdom, using sewage sludge in the 1890s to fuel street lamps. The first sewage plant that supplied biogas to the public began operations in 1920, and in 1950, the first large agricultural biogas plant became operational in Germany [18]. However, the spread of the technology increased momentarily in the 1970s due to the exorbitant price of oil, which inspired the use of substitute energy through research. Many Asian countries recorded the fastest growth, followed by Latin American, followed by African nations in the late 1970s and in the early half of the 1980s respectively [19]. Since the beginning of this millennium, particularly from 2007, the numbers of plants has rapidly increased to well over 26.5 million digester plants in China, with an overwhelming majority of 6 to 10m^3 systems in the households. In India, during 1999, there were well over 3 million biogas plants of family size, and at the end of 2007, the government of India had subsidised the construction of almost 4 million family sized biogas plants around the country [20].

In Europe, the first biogas plant was constructed for the treatment of freshwater in Denmark in the 1920s. Initially, the gas was used to heat up the tank, not for the purpose of extracting energy, but rather to reduce and stabilize sludge when the organic matter decomposes in the wastewater, which was a treatment in the product process [21]. Shortly after the Second World War and in the following period, Europe witnessed a substantial growth in the biogas industry, mainly in Germany, France and Britain. Development nearly stopped at the end of the 1950s, owing to the relatively low price of fossil fuels, particularly oil and gas. Nonetheless, the interest was rekindled in the mid-1970s following the 1973 oil crisis [21].

In some African countries, biogas for domestic purposes was introduced around four decades ago, with significant participation in 2008 when awareness of the technology was accelerated by NGOs that promoted and disseminated the technology. Results from the initiatives and national programs showed significant increment in the numbers of installed biogas digesters and technical skills, which was considered a promising take-off of the technology. About 17,000 digesters were installed in nine countries. These were supported by the Netherlands Development Organization (SNV) [19]. The first experimental biogas technology in South Africa was in 1957 which used pig manure [22]. Despite the country's potential in biogas technology, the level of utilization is low with well around 700 functional digesters in operation [23].

The slow adoption of this desirable technology is attributed to lack of incentives, such as feed-in-tariff, elevated cost of installations, reliance on non-renewable energy and earlier low electricity price [24]. Although, these have since changed, particularly due to the continuous hike in the price of electricity by Eskom [23]. The implementation of carbon inducements in the use of green technology and discount schemes, such as the Eskom rebate for renewable energy, has reduced the repayment duration periods for biogas infrastructure and aided the promotion of the technology in South Africa [25].

Biogas technology in South Africa has reported a potential capacity of 2.5 GW of electricity, with a market value of about R10 billion, which can facilitate the creation of thousands of jobs in the country [26]. This and previous decades have witnessed a dramatic rise in the involvement of a number of both government and non – government organizations in biogas-related programmes and initiatives. On the one side, organizations such as the South Africa National Energy Development Institute (SANEDI) and Biogas SA, are more involved in directing, monitoring and conducting innovative research in the technology working together with science councils and academic institutions around the country. On the on the other hand, organizations such as the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) are more into promoting private investment in the renewable energy sector within the country. The first biogas industry association, South Africa Biogas Industry Association (SABIA) was formed around 2014 with the aim of representing the needs of industry stakeholders and promoting biogas technology [27]. The active participation of these organizations has seen tremendous improvement in the innovations of the technology. Community level cooperatives and non-profit organizations are getting involved, notably the Mfuneko Community Support project which provides biogas technology to households in the rural villages in Giyani Municipality. Of note also is the AGAMA Biogas, with a unit capacity of 6000 litres which can produce a minimal amount of 1.9 M^3 of biogas every day. The amount of gas produced is equivalent to 3.5 kWh, 0.8 kg of liquefied petroleum gas or four hours burning time on a single gas plate [28].

At a larger scale, examples include the City of Johannesburg's Northern Waste Water Treatment Works Biogas Plant, with 1.2 MW capacity, and the Novo Energy, which set up a landfill biogas plant to power mini buses in Johannesburg. The Alton landfill biogas plant in Richards Bay sells electricity derived from biogas to BHP Billiton. A recent and impressive example is the Bronkhorstspruit commercial viable biogas plant, with a 4.4 MW capacity. It is one of a kind in the country and presently the biggest biogas plant on the continent. These projects illustrate the imminent magnitude of projects in the future. The project is developed, built and owned by Bio2Watt and it is situated on the Beefcorp premises, which has one of the country largest feedlots. The ideal location of the plant enables the easy movement of the cattle manure used as a substrate and the Beefcorp storm water dam provides sufficient water needed for the operation [29].

2.3 Designs of Biogas Plants used in South Africa

Several types and designs of biogas digesters exist worldwide. However, the designs developed in the last century have mostly been adopted in South Africa. These are categorised into Domestic /Rural digesters and Agricultural / Industrial Digesters [30].

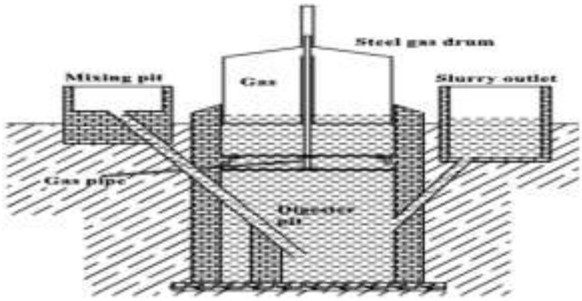
2.3.1 Domestic / Rural Digesters

These digesters, often are small scale digesters, installed in households or small facilities, to generate gas usage. They include the Floating drum digesters, Fixed dome digesters, DIY biobag digesters kit and the Deenbandhu digesters designs.

2.3.1.1 Floating Drum Digesters

Basically, the floating drum digester type is an Indian model which (Figure 3a) comprises of a cylindrical shape, a gasometer, feed and outlet pits [31]. It is made of cement and clay bricks, while the cylinder which can be dome or flat, is prepared with sheets of metal that move up then down when the gas is stored or released. The operational method is continual and sometimes vertical. The space for putridity has a dividing wall and is filled to the ground and expands and holds the slime back over the short way. Provided with stir elements is the steel gas lock while the floating gas lock gathers the gas. It is executed by means of the manual gas movement of lock gas in the periodic annihilation of the swaying layer, as the gas pressure arises at the weight of the gas lock. The Indian design is appropriate for regular materials when using animal excrement, with no intention of building sinking layers [32].

3a



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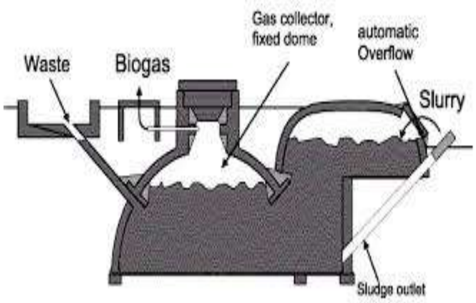

Figure 3a and b: Schematic diagrams of a floating and fixed dome digesters [33].

2.3.1.2 Fixed Dome Digesters

The fixed dome (Chinese model) digester (Figure 3b) comprises a cylindrical body shape and chamber, with two spherical domes, inlet pit, outlet pit and opening for inspection, which also serves as the compensation tank. The structure of the digester is built with cement and bricks and is completely laid underground [34]. The upper part of the chamber stores the gas and when the production of biogas starts, displaced slurry is gathered in the compensation tank. The volume of biogas storage is equal to the volume of the compensation tank [34].

The counterpoise capacity pool needs to be massive, hence the blocked decay substrate can remain absorbed at the peak gas capacity. The gas density is not constant in practice, as it rises with the measure of the gas stored. Therefore, for the gas to be produced regularly, the repository is very important for the gas to swim [32]. Due to the dome digester, which is completely laid underground, the temperature for fermentation should fall under a day due to night changes and simply in the acceptable level in the range of + or – 2ºc. In a household comprising a small family, a mixed concoction of the digester can be installed [32].

2.3.1.3 DIY Biobag Digesters Kit

A Do-it-yourself biobag digester is a Taiwanese model made of soft plastic that is sealed in a tubular structure. They vary in size and thickness (Figure 4). In some countries, especially in the developing world, they are sometimes referred to as tube digesters, bladder digesters, sausage-type digesters and balloon digesters. The design consists of a long cylinder made of durable polyvinyl chloride (PVC), which is resistant to bacteria, and extremely strong and flexible material of polyethylene or red plastic mud [35]). The biobag is designed and developed to solve the problems associated with bricks and mental digesters [36]. It is simple to install with limited training skills required, which makes it ideal for rural households to install themselves. The digester has an inlet and outlet that is water-proof, which ensures the flow of substrate and gravity. The bottom round shape helps the flow of content and excavation from the inlet through the outlet.

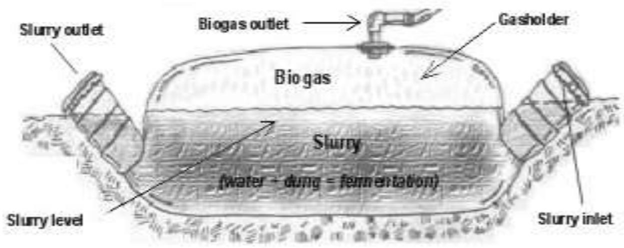

Fig.4: A tube digester [37].

2.3.1.4 Deenbandhu Model Digester

It is a modified design of the floating cover digester. The Deenbandhu (Figure 5) is mostly used in rural villages in South Africa. It is an improved design made to consume less building materials and reduce cost. It is structured with more crack proof materials that reduces the area surface of the biogas plant. Included in the design are two spheres of different diameters that are joined together at the base. At the bottom, the curvature of the digester helps nullify the pressure from the earth with a spherical structural strength which is more than those of the rectangular structures [31].

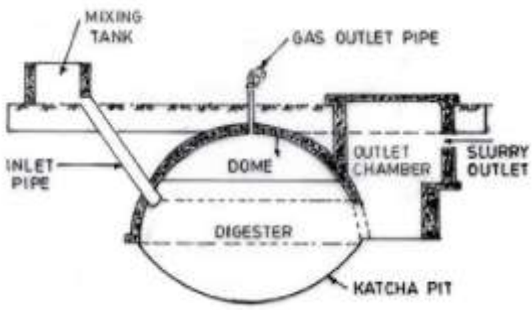

Fig. 5: A Deenbandhu Model Digester [38].

2.4.2 Agricultural / Industrial digesters

These digesters are in the categories of medium to large scale digesters, with a capacity to generate between 25 and 400 kW of electricity. These include the Lagoon digesters, Plug-flow digesters, Complete mix digester and the Up-flow sludge blanket digester [30].

2.4.2.1 Lagoon digesters

The lagoon digester requirements has an advantage of low maintenance for the treatment of waste. This is due to the passive system of design. The biogas is captured under a waterproof cover during manure decomposition. The lagoon acts as a waste treatment system as well as a storage system with two cells [38]. The methane production rate is dependent on temperature variation, with time retention of about 30 to 60 days, depending on the age and size of the lagoon. The digester is typically suitable where a large amount of waste in liquid form is produced, such as in the milk production industry and swine farm. In South Africa, an example of an installed lagoon digester is the 120 kW in the northern part of Pretoria [39].

2.4.2.2 Plug Flow Digester

These type of digesters are reinforced with a long, rectangular heated concrete tank with an impermeable cover when there is flow of manure from one end and flows out at the other. The tank is sometimes U-shaped, and has an entrance and an exit at the same end. The compost is first fed into the mixing pit by allowing the mixture of solid compost with water. As the compost is added, the plug of the new material slowly displaces the older material over the tank in the other end of the digester. Typically, the tank is heated and conserve a mesophilic of 20 and 40 degrees and the volume commonly holds a retention time of 15 to 30 days [40].

2.4.2.3 Complete Mix Digester

The most flexible of all digesters to accommodate varieties of waste is the complete mix digester. Solid waste materials of up 2% to 10% content can be pumped into the digester, which are mixed continuously to avoid separation. The digester is made of round insulated tanks, heated and commonly placed aboveground. The mixing can be achieved through the recirculation of the gas in the presence of anaerobic organisms that are active. The Up-flow anaerobic sludge blanket digester is an example of a complete mix digester. In South Africa, complete mix digesters are typically used in the food processing, fruits, vegetables and abattoirs industries [39].

3. The importance of Biogas as a Source of Renewable Energy

The much-desired revitalisation of sustainable energy in developing countries can be provided by renewable energy such as biogas [41]. It is an option that is less expensive and ideal for low-income groups, with the required inputs because it is relatively affordable, locally available, accessible, and can be managed locally. In large quantities of agricultural, municipal and industrial wastes, anaerobic digestion produced biogas can be used in the generation of electricity and in meeting the heating needs and the residue used as agricultural fertilizer [42]. The digesters are comparatively economical and simple to operate, from small scale to large scale in rural and urban places. In respect of this, many governments and non-governmental organizations have recognized that biogas as renewable energy can play a vital role in augmenting other sources of energy [41].

The use of biogas systems offers multiple benefits. These include, in the course of anaerobic digestion, the fact that organic nitrogen in the compost is converted largely into ammonium, which is a major component in commercial fertilizers [43]. Furthermore, anaerobic digestion can ease offensive odours from encumbered or inappropriately managed manure, which can compromise the air quality and become a nuisance to neighbouring communities. The use of these systems reduces unpleasant odours because the volatile organic acid content, and odour producing compounds are consumed by bacteria in the process of producing biogas [44]. It is pliable energy that is required for several applications. Biogas can also be used lighting and cooking. It is easy and practically effective to use the gas straight in a conventional gas burner, even if it is a low-pressure gas [44]. However, nowadays in several countries, it is used either for combined heat and power generation (CHP) or it is advanced and fed into natural gas grids, in fuel cells or used as vehicle fuel [43].

The technology of biogas production as a method of renewable energy has become a global concern over the past decades. It is a methane-rich gas formed by anaerobic digestion dissolving organic materials, which is different from other renewable energy sources, such as wind, hydro, solar and thermal [45]. The role of biogas in reducing emissions of greenhouse gas and improving the security of energy supply in households, especially where they are having challenges in energy source and supply, is widely acknowledged. Biogas energy has an overwhelming affirmative environmental characteristic, which results in the negative net dispensation of carbon dioxide and very low sulfur content [46]. Thus, the technological use can influence the reduction in emissions of greenhouse gases [47].

A proper, functional system can offer numerous advantages to the users and the society, resulting in environmental protection and resource conservation, with significant impact on the security of energy sustainability and supply [48]. Reliance on fossil fuels impedes the fundamentals of sustainable development because they are unreliable, expensive and exhaustible. Bioenergy not only contributes to the strategy of energy diversification, but is also a replacement for energy significances, making it an important energy source for national and economic security aims [46]. With regards to energy, it is apparent that with time, renewable sources will stimulate a more important role than the conventional sources of energy [49]. In the future, biogas energy will play a significant role in producing green power in the world because it offers opportunities to influence more reorganized systems of electricity production where a plant is designed to meet the needs of the consumers, preventing transmission failures and maximizing adaptability in system use [50]. It also proffers the favourable circumstances to increase power generation diversity and competition in energy generation within the economy [46]. The use of biogas technology provides health benefits in rural areas in compared to the burning of firewood [51].

4. Biogas Energy Sources in South Africa

For an economically feasible biogas program, identified feedstock substrate includes agricultural residues, municipal solid waste, water hyacinth, livestock waste and landfills. The livestock commonly found in South Africa are sheep, goat, cattle, pigs and poultry. A large amount of manure are produced by these animals. The manure acts as a substrate suitable for anaerobic digestion, especially from poultry farming, which is the biggest sector [52]. At the provincial level, the methane potential and electricity production through anaerobic treatment of livestock waste from poultry alone, is summarised in Table 2.

Table 2: Biogas capacity from poultry dropping in South Africa (Source: [54]).

Province	Number of animals	Specific manure production	Total manure production	Specific methane production	Annual biogas production	Annual electricity production	Annual thermal energy production
	heads	Kg/ (head*a)	Mg/a	M^3/Mg_{FM}	M^3/a	MWh/a	MWh/a
Eastern Cape	7 930 017	20	158 600	83	13 163 828	46 073	59 237
Free State	9 736 9 77	20	194 740	83	16 163 383	56 572	72 735
Gauteng	14 636 843	20	292 739	83	24 297 159	85 040	109 337
Kwazulu Natal	19 700 148	20	394 003	83	32 702 246	114 458	147 160
Limpopo	6 256 903	20	125 138	83	10 386 459	36 353	46 739
Mpumalanga	22 590 670	20	451 813	83	37 500 512	131 252	168 752
Northern Cape	210 274	20	4 205	83	349 005	1 222	1 571
North West	30 320 191	20	606 404	83	50 331 517	176 160	226 492
Western Cape	31 305 549	20	626 111	83	51 967 211	181 885	233 852
Total	142 687 572		2 853 751		236 861 370	829 015	1 065 876

From the table, the poultry sector alone could generate an annual thermal electricity of about 1 065 876 MWh/a using the calorific value of biogas of 22.5 MJ/m3, a superficial analysis gives the amount of energy that can be obtained at about 3837153.6 GJ equivalent [15].

5. Potential Benefits of Biogas Utilization in South Africa

5.1 Benefits to the Agricultural sector

The agricultural sector in South Africa economy can be regarded as dual, with a well-built commercial farming and a rurally-based subsistence. The contribution of formal employment by the agricultural sector in South Africa is around 10%, which is comparatively low, compared to other nations on the continent. Farming, however, remains indispensably important to the economy, as well over 638 000 are employed formally in the sector [14].

It is estimated that directly and indirectly, about 8.5 million people depend on the sector for income and employment. The agricultural sector is significant because of its large possibility in creating jobs and it is a strategic focus on the New Growth Path, a governmental plan to create 5 million new jobs by the year 2020. The plans in the program include promoting commercial and small-scale farming [14]. Owing to soil aridity, only 13.5% of the land can sustain the production of crops, with 3% envisaged as promising land [8]. The majority of the households in the rural parts of the country rely on agriculture, using manure as a source of fertilizers [55]. In developing countries, like South Africa, farmers are in dire need of fertilizers in order to maintain crops productivity. Effluent from biogas digesters has been established to be a good fertilizer for farmers, with improved organic content, which can improve agricultural yields [56].

As noted, 74% of the non-electrified households depend on firewood as their energy source for cooking and heating [14]. The exposure to smoke from using firewood can cause infant mortality, eye infection and acute respiratory disorders, resulting from incomplete combustion [57]. Additionally, the issue of deforestation is of great concern, as forests are de-vegetated as a result of fuel wood harvesting [57]. Due to the readily availability of organic waste and it's sustainably low cost, in rural areas of developing countries, biogas has become an increasingly significant source of energy. It is a very appropriate alternative to the use of traditional cooking fuels in the rural communities [58].

The use of biogas can remediate and drastically reduce deforestation, reduce emissions arising from smoke during use of fuel wood, the associated aliments and provide clean and eco-friendly energy.

5.2 Job and employment creation

Although still in its infancy, in a prolonged epoch of time, the biogas industry has a potential testament. This is much embodied in the number of jobs that a thriving biogas industry can create. As of 2016, with 38 commercial projects in operation, the directly employed people was estimated to be 1 700 [25]. With many more constructions of biogas digesters, it is self-evident that the industry is ever-expanding, which will require skilled and unskilled manpower in the industry [25].

An aggregated data using excel input-output model from stakeholders is utilised to determine the employment factor for each phase and type of biogas anaerobic digestion project (small, medium and large). Through feasibility, construction, development, maintenance and operation phases, it indicated a forecasted growth until the year 2030. The developer meaningful job creation outputs in full-time equivalent (FTE) job approximation was calculated over time per project phase and size (See Table 3).

Table 3: Operational Phase [25].

Jobs currently in operation phase in the biogas industry	270 FTE
Conservative job forecast to 2030	59 000 FTE
Optimistic job forecast to 2030	88 000 FTE

Developers have indicated their expected project per 5-year pipeline, which enabled a baseline of project growth to be forecasted until the year 2030. The approximate FTE jobs per project phase and size over time were calculated, and the developer outputs for the meaningful job creation (operation phase) is presented in Table 3.

In relation to a particular industry, jobs are categorised into direct and indirect category, in order to ensure an estimate consistency and to specify job statistics. Direct jobs refer to jobs that are directly involved in the activities of the project and include the phases of development, construction, implementation, maintenance, operation and management [59]. Indirect jobs are those indirectly related to the activities of the project, such as materials acquisition, manufacturing and contracted support, such as banking and legal services [60], while induced jobs are associated with direct and indirect employees spending their earnings in support services such as in food, beverages and accommodation [60].

5.3 Environmental sustainability

Changes in the global climate, the need for rehabilitation and sustainable land use in the mining sector of South Africa are prompting mining industries to reassess their post-mining approach, to ensure that land is left in a good state. End-land use and closures of mines in South Africa are important and have been increasingly imperative in the planning and through the National Environmental Management Act (No 107 of 1998), which require that land should be in an improved state after mining activities.

Biogas development can be used as the base load for electrical power in the mines for fuel and as energy for the on-site beneficiation of minerals. Additionally, it can provide clean and cheap energy that is free of particulate, incomplete combustion and improve soil fertility through slurry. Anaerobic digestion can significantly lower the emissions of greenhouse gas, and solve the problems of sanitation by improving farm hygiene, which can be transformed into energy that could help in mitigating household energy needs. The use of the technology has robust benefits in terms of public health through the provision of cleaner energy, reduction of collecting, harvesting and consumption of fuel wood.

5.4 Reduction of waste disposal costs and landfill diversion.

Currently, in the City of Tshwane alone, there are 15 waste water treatment works (WWTWs) owned and operated by the council and 21 plants privately-owned and operated works that primarily use activated sludge process that has a combined treatment of 495ML/day. The quantities of sludge produced could be decreased through a biogas project thereby solving the issue of sludge and its management. The Rooiwal works, which are the largest WWWTWs process 220ML/day, with plans to upgrade the processing to 300ML/day and could approximately yield an electrical generation of 4MWe through biogas technology [61].

Across the municipality, a total of 3 000 000 tons of waste is currently sent to 8 operating landfills and 10 garden refuse sites, in addition to the large quantity of organic waste purely created by the City's fresh produce market. These wastes can serve as a substrate for biogas production [61]. In addition to these, a public lavatory frequented by at least 2000 individuals per day would generate approximately 60 m^3 of biogas that can run a 10 KVA generating plant for 8 hours a day, with 65 units of power produced [62].

6. Prospects and Challenges

The potential for renewable energy exploitations in South Africa is very high [23] and the country has set a target of 17.8GW of new capacities to install and generate renewable energy by 2030 [61]. Agricultural waste, domestic wastes from schools, prisons, hotels and municipals; food waste from commercial and domestic industries; manure from pig, cattle, chicken, sheep, goat and commercial waste from abattoirs, breweries, plant sewage as well as wine estates, are all potential feedstock for the anaerobic digestion [61].

The South Africa Government has put in place mechanisms to promote renewable energy at all levels, and hence have collaborations with several local and international organizations. These are aimed at strengthening the renewable energy capacity and implementing projects that will fast-track the facilitation of such projects within their areas of jurisdiction. One such project with selected priority due to its number of comparative advantages, is the use of biogas for electricity generation from waste [61].

Load profile is very specific in the South Africa energy demand. The demand levels are during the peak hours of 06h00 to 10h00 and 18h00 to 20h00. This peak is mainly because many households utilise electricity for cooking and heating purposes, as opposed to many developed countries, where gas is used. This can be overcome through the use of the biogas technology. Biogas, has a proven ability to provide power at peak base load and distribute it to grids. It also has high linkages and potential through sustainable rural development job creation; using existing infrastructure for possible (generation) and service (supply); reducing organic waste from municipals in a friendly environmental manner; making a positive impact on municipality expenditures such as electricity generation and greenhouse gas emissions reduction [63].

However, South Africa biogas industry is still facing some challenges that have hindered the stimulation and optimal utilization of the technology. These challenges include the low tariff cost offered (R0, 94c/kWh) compared to solar (R2, 76c/kWh), and wind (R1, 15c/kWh). Another challenge is that the size of the minimum project under the REIPPPP is 1MW whereas, the average biogas size plants falls between 0.3-05 MW, making it difficult to be financially viable [23]. The high initial cost of investment in the construction of biogas digesters is one of the major setbacks particularly for those in the rural parts of the country [63].

The level of awareness and knowledge is still low in the government, public and private sectors [23]. Perhaps, one of the greatest challenges is education about the technology which has hampered its progress. For any sector to buy into the use of the technology, there is a need to educate people on its viability, sustainability as well as the social, environmental and economic merits of the technology [63]. Rural communities that face more energy challenges and relies on fuel wood and other traditional biomass need adequate orientation and education about this desired technology [63]. Another problem is that not all materials and skills available locally, hence the construction of the digesters is slow. Additionally, people are unwilling to share centralized digesters, thus, single household digesters work better but are not as economical in terms of cost. Laws, regulations, expensive legal and license costs for large scale digesters also hinder the proliferation of this technology [27].

Thus, academic institutions should be funded to undertake further research on the technology, while also promoting the technology at primary, secondary schools level, as well as in the technical and vocation schools, to help in the maintenance and monitoring of the projects, while social and cultural conviction such as ethical norms, barriers and stigmatization of the use of the digesters from human and animal waste should be overlooked [64].

7. Conclusion

Biogas is considered a mitigation response to the low level of electrification in rural areas, depletion of forest resources, improving soil quality, waste treatment; increasing agricultural residues, thereby creating sustainable and safe environment. In compliance with safe sanitary and environmental conditions, large to medium households biogas digesters have been installed in some nations. Biogas digesters utilise a variety of feedstock from slaughterhouses, animal dung, manure from chicken and dairy farms; industrial waste and human excreta.

The technology has a significant role to play in the energy needs of South Africa, with adequate spin-off in the social, cultural, economic and technical aspects that should be overcome. It has numerous benefits that have been accrued in developed and some developing nations. In South Africa, the technology can immensely contribute to job creation, ideal waste management option, food security and the production of renewable energy.

Financial incentives and loans, a strong policy framework, adequate education and information dissemination at national, provincial and community levels, will facilitate the improvement, adoption and utilization of the desired biogas technology. NGOs and other stakeholders should be encouraged to offer more assistance in the uptake of the technology. There is a beneficial light in the use of the technology and no uncertainty that it will exponentially lead to its adoption and utilization, which in turn will affect the economic wellbeing and prosperity of South Africa.

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