Urban environmental benefits of Green Energy: A Review of Landfill Gas to Electricity Technologies in eThekwini, South Africa

Abstract

In the quest to ameliorate the negative developments emanating from a heavy reliance on fossil fuels, there has been a surge in the development, adoption and utilisation of renewable energy technologies all over the world. Adopting a case study and phenomenological research design and applying qualitative approaches, this study focuses on the environmental benefits directly emanating from the development, adoption and application of innovative technologies in renewable energy generation and supply. In particular it assesses the experiences of municipal solid waste-to-energy technologies in the eThekwini Metropolitan Municipality, South Africa. The results reveal that the innovative projects have resulted not only in improved municipal solid waste management, but more importantly improved urban environmental conservation. The paper concludes by recommending the scaling up of such innovative projects within South Africa and the adoption and application of these best practices to other African countries.

Key words: renewable energy, landfill gas, environment, climate change, electricity

Introduction and Background

The world's heavy reliance on conventional energy sources that are derived from natural gas, coal and oil, although dependable and effective in the foreseeable future, there are a myriad of serious challenges that warrant a gradual shift to embrace eccentric energy sources. This is the case because global concerns of rapidly depleting amounts, the volatility of prices and the environmental pollution associated with conventional sources of energy have made the search for alternative and cleaner energy technologies very imperative and urgent.

First, conventional energy sources face supply challenges as reserves are depleting for example the extraction of oil and coal is increasingly yielding lesser amounts with every endeavour.[1.2] Meanwhile, the past few decades have witnessed a dramatic change in the world energy scenario, as witnessed by accelerating economic growth in several developing countries, thus placing huge demands on conventional energy sources that are being stretched to new limits. As a result energy consumption in most developing and emerging economies has been growing faster than the generation capacities in the past few decades due to their growing economies[3]. Besides, the prices of conventional energy sources such as oil and gas continue to be volatile thus making planning for energy needs and security a huge challenge and expense[4]. Generally, most African countries in particular have no oil and gas deposit hence they secure oil and other conventional energy sources from other countries leading to swelling import bills that are unmanageable. There are also relentless geopolitical tensions in oil resource rich countries that make energy supply and security problematic particularly in the African continent.

Second, although the conventional energy sources particularly coal and natural gas have been very important and effective in the majority of African economies, they contribute to environmental pollution through the release of Green House Gases (GHG) such as carbon dioxide and methane that lead to global warming that in turn result to the climate change phenomenon[5.6]. These unintended and negative consequences have led to the realization that the heavy reliance and dependence on conventional energy sources for modern civilization are not sustainable[7.8].

Third, in the quest to ameliorate the negative developments emanating from the heavy reliance on fossil fuels, there has been a surge in the promotion of the generation , development, adoption and utilisation of renewable energy sources and technologies[9].[10]. Emerging trends depict an exponential rise in the propagation and diffusion of renewable energy technologies across the whole world, the African continent inclusive. Thus, the adoption and use of renewable energy sources assist in the avoidance of unsustainable practices associated with the predominant use of fossil fuels. There are extensive untapped renewable energy sources in the form of solar, hydro, biomass, wind, and geothermal energy that are uniquely and heterogeneously endowed across the African countries, hence the transition to renewable energy sources in the continent should go on to address environmental issues tremendously.

Consequently, the uptake of green energy technologies and the drive to generate and use renewable energy sources in the African continent has motivated this paper to investigate and highlight the urban environmental benefits that have resulted from the adoption and use of innovative landfill gas to electricity technologies in the eThekwini, one of the eight metropolitan cities in South Africa. The paper extends current discourses on the environmental impacts of renewable energy technologies within African urban communities. Focusing specifically on ways of increasing and diversifying energy sources through the conversion of landfill gas to electricity will also assist in the generation and development of considerable knowledge that inform future developments in municipal waste management in African cities[11.12]. New insights on the processes of formulating and refining institutional frameworks in the development, adoption and implementation of innovative green energy technologies, specifically the innovations associated with the conversion and use of landfill gas to electricity are provided. Surely, the ever rising populations in most African countries and the growing African economies mean increasing and sustained energy demand thus making it necessary to diversify energy supplies and improve energy mix and security. consequently, this can only be achieved through the adoption, use and promotion of green energy sources such as landfill gas to electricity as has already been observed in other studies.

Green Energy Sources

Renewable resources that are part of the natural ecosystem such as wind, hydro, solar, geothermal, and biomass are increasing being exploited to generate green energy. Exploiting these renewable sources of energy re assists in preserving the natural ecosystem. Wind power technology uses wind turbines to convert the kinetic energy of moving wind into mechanical first and then electrical energy[13]. It has become one of the most sustainable renewable energy systems in recent times. Several countries such as China, India, the United Kingdom, Germany, Brazil, Spain, Italy and the United States of America have been increasing the generation of capacity of wind power energy in the last few years[14]. Hydroelectric power is generated through the conversion of the kinetic energy of water moving due to gravity through turbines from higher to lower elevations in sources such as dams and lakes[15]. The technology is well established, flexible, highly advanced and very efficient. The technology is well established, flexible, highly advanced and very efficient in most countries with several efforts to improve the production of electricity through this well tried and tested technology as witnessed by several projects that are being established in countries such as Turkey, India, China and Brazil[16]. Solar power technology generates electricity and heat from sunlight through photovoltaic (PV), concentrating solar power systems (CSPS) and other realted solar thermal systems[17]. The solar technology uses thermal energy from the sun to heat water, heat or cool spaces in homes and businesses[18]. It has been growing in countries such as India, Brazil, Turkey, Germany and China. Countries such as Germany, Italy, China, Brazil and the United States dominate the global solar power technology space. Marine power technology is generated from sources such as tidal range and currents, waves and ocean thermal energy. However, the technology is still at infancy with several research and development efforts in the technology. . Geothermal power technology generates energy from energy stored within rocks, steam and liquid water that are stored within the earth's interior[19]. Hydrothermal is the commonly used form of geothermal energy source, particularly in countries such as the United States of America, Indonesia, Mexico and Philippines.

Municipal solid waste (MSW) that is part of the biomass that can generate energy through a a variety of ways that include combustion, gasification and anaerobic digestion to generate energy or sources of energy[20]. Municipal solid waste is the residue that emanates from everyday activities and that has traditionally been regarded as rubbish or garbage without any value, economically, socially and environmentally[21]. Usually, the amount and types of MSW generated in any society is positively correlated with the levels of economic performance, industrial development and standards of living of communities. Generally, huge amounts and varieties of MSW is associated with highly developed economies [22]. It is estimated that with the continuous increase in the global urbanisation with urban population, projected to reaching

4.3 billion people by 2025, about 2.2 billion tonnes of MSW will be generated from urban settlements[23]. The common sources or streams of MSW include households, commercial and industrial enterprises. The waste is from fresh produce markets, street-sweepings as well as construction and demolition debris[24]. These various components are managed through several processes that include collection, transportation, disposal and treatment. Landfilling organic and biodegradable component of MSW is critical for landfill gas formation [25.26]. The non-organic material can also either be recycled, recovered, reused or buried to conserve the environment[27. 28]. Landfilling represents a cost effective option to dispose of waste in terms of exploitation as the waste is spread into layers, compacted to reduce its volume, and covered by material such as clay or soil, which is applied at the end of each operating day. Anaerobic digestion (AD) is the natural breakdown of organic materials into methane for the generation of electricity. Methane gas produced in landfill is used in an internal combustion engine to drive a generator and make electricity for internal plant use or sold back to the utility[29]. The energy that is generated from MSW is green mainly because its primary source are plants and trees that are renewable resources. The plants and trees would have taken up natural carbon from the atmosphere from during their lives[30]. The stored carbon is only released when the plants and trees decompose when landfilled or when incinerated. It is the same gas that is released and captured and converted into electricity. Consequently, the same greenhouse gases that were removed from the atmosphere during the lives of the plants and trees are released into the air, hence no new or additional gases are released into the air[31], it is the same gases that are recycled. This is different from the processes of burning fossil fuels to generate electricity that releases new and additional carbon dioxide in the atmosphere. Such carbon would have ceased to be part of the atmosphere for centuries.

There are classic examples of landfill gas to electricity projects in developed countries since the early twentieth century. The development of landfill gas to electricity projects has gained momentum over the past four decades due to a number of factors that among others the dwindling fossil fuel resources, the increasing focus on energy security, a greater awareness of the social and environmental hazards of poor waste management and an overwhelming global focus on reducing greenhouse gases. For example there are up to 6000 landfills in the United States and 110 are designated specifically for gas-to-energy processe[32]. The landfills produce methane which is exploited as landfill gas and converted to energy sources. The Puente Hills is a classic example of an extensive United States of America landfill site that produces steam energy that is used to drive steam turbine. These plants generate an approximate of 2,500 megawatts, or about 0.3 percent of total national power generation[33]. The landfill gas-to-energy projects generate enough energy to power 400 000 households daily. Apart from this kind of energy production is said to offset approximately 2 000 000 tonnes of coal per year and significantly reduces greenhouse gas emissions into the atmosphere, thus representing an efficient substitute of natural gas[34.35]. In Europe, there are more than 400 landfill gas to electricity projects and the United Kingdom several projects that generate electrical energy from municipal solid waste.

Several African countries have also joined the band wagon either to generate energy from landfill gas or to flare the gas. These among others include, Côte d'Ivoire, that has estbakished projects at Bingervillle, North of Abidjan to gerenate landfill gas and convert it to electricity. Landfill gas to electricity projects have also been devloepd in Ghana to improve energy availability in Accra the capital city. In Mauritius, Kenya and Uganda efforts have been made to establish and generate energy from MSW. These landfill gas to electricity initiatives in these African cities have not only gone a long way towards improving energy availabity but also the security in terms of energy . There are also African cities such Dar es Salaam in Tanzania, Dakar in Senegal and Ekurhuleni in South Africa and several others that are involved in the flaring of gas thus contributing to the preservation of the environments.

Operationalisation of the Work

This work adopted a phenomelogical case-study design and a qualitative approach to gather and analyse data in order to achieve the aim of the study[36]. An orderly investigation of the management approaches and processes of treating municipal solid waste to generate green energy was applied so as to highlight the environmental benefits of the application of landfill gas to electricity technology in eThekwini municipality[37]. All the landfill sites that capture and convert gas to electricity were identified using a snowballing technique. The key informants that included officials that are directly involved with the collection, transportation, disposal and treatment of MSW within the metropolitan were identified using purposive sampling methods[38]. Also, respondents or informants that are indirectly involved in the landfill gas to electricity projects were interviewed to get details about the benefits of the green energy technologies within the municipality. These included academics at tertiary learning institutions, non-governmental organisations (NGOs), private-sector organisations and representatives of community-based organisations[39]. A combination of both primary and secondary data sets was used to complement each other to highlight the nature of interfaces and praxis in MSW management and treatment. Environmental benefits of the landfill gas to electricity projects were captured through photographic surveys. Content analysis was used analyse gathered data.

Landfill Gas to Electricity Technologies: A Case of eThekwini Metropolitan Municipality

The eThekwini metropolitan municipality pioneered establishments of landfill gas to electricity projects in the African continent. The project was informed by the United Nations Framework Convention on Climate Change (UNFCCC) as a Clean Development Mechanism (CDM) that was aimed at stabilising greenhouse gas (GHG) emissions and concentrations in the atmosphere[40]. Work on the Durban Landfill Gas to electricity project was started in 2002 after the World Bank to offered to support financially, projects that can onctribute to the preservation of the environment as well as lead to sustainable development of local communities. The Bank offered to use the Prototype Carbon Fund (PCF) as seed funding in establishing the project. The fund is orgnaised and manged by the World Bank but in actual fact it is an outcome of a public-private partnership[41] agreement that is made up of six countries that include Canada, Finland, Norway, Sweden, Netherlands and Japan as well as 17 private sector companies that sought to identify projects and secure Certified Emission Reductions (CERs) to be distributed to participants. The CERs are calculated in tonnes of carbon dioxide equivalent (tco_2e). The patrners realised that the Durban landfill gas to electricity project had great potential of extracting and destroying toxic gases that caused odour concerns to surrounding communities. Migrating gas from decomposing MSW causes health problems in local communities, hence the project in particular aimed to meet the environmental conerns at that same time generating electricity from methane a highly calorific clean burning gas. Generally, landfill gas is composed of methane that is between 50% to 60%, whilst carbon dioxide is normally between 50% to 40% and other impurities around 1%. As for the landfill gas to electricity project in eThekwini, landfill gas that is being extracted contains a reasonable amounts of methane (Figure 1).

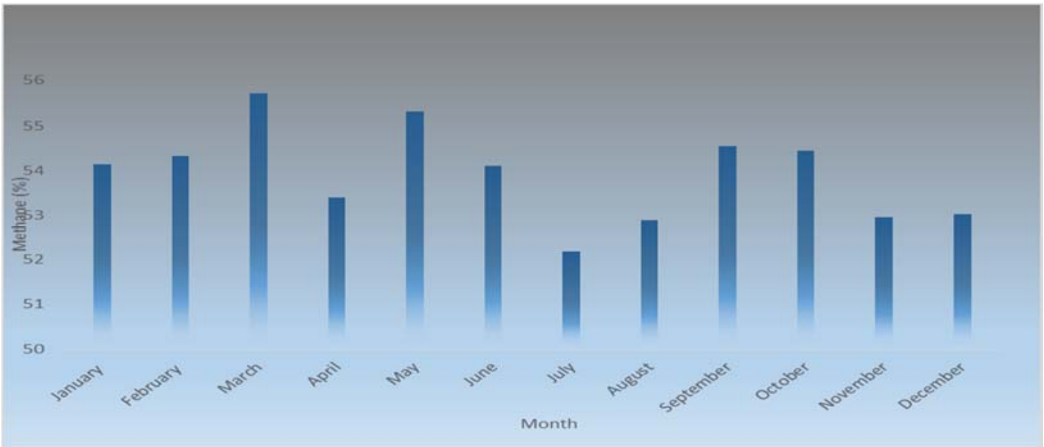

Figure 1 : Methane Gas extracted from Bisasar Landfill Site
Source : Field Studies 2013

The Figure shows that the methane content of the landfill gas is not only reasonable high but also almost constant since the volumes are between 52% and 56% for every month throuhghout the year 2012. It is possible and important to predict the pattern and rate of gas extraction and in general the gas volumes pick up in the first few years and then decreases exponentially over time. The production of gas is a function of a number of factors that include, composition of and density of waste, age of the waste, moisture content of the waste, tepretature within the landfill, availability of nutrients and alkalinity of leachate. Without a strong focus on resolving environmental concerns related to methane and accessing external financial support, the costs of the project was not justifiable and manageable to the municipality. For example, Eskom generated using coal was selling at R0.12/(Kilo Watt) KW whilst the electrical energy generated from landfill gas could only be sold at R0.21/KW hence there was great need for top up for the project to be affordable and feasible. Besides, the landfill gas did not have direct use due to low energy contentd hence it could only be used for electricity generation.

As a result of incorporating social and environmental benefits over and above economic payback, the project met the sustainable development criteria for the allocation of capital funds for the establishment of a two phased project that included three landfill sites La Mercy, Bisasar Road and Mariannhill[42]. The first component of the project was intiated, approved in 2004 and started operating in 2006. It was made up of two landfill sites, La Mercy and Mariannhill that had started receiving MSW in 1980 and 1997 respectively (Table 1). The project aimed at contributing about 7.7 million tonnes of certified emission reductions (CERs), with Bisasar road landfill site realising 5 295 296 tonnes, whilst Marianhill contributed 1 112 568 tonnes and La Mercy realising 488 972 tonnes of CERs.

Table 1: Characteristics of Landfill Sites in eThekwini

Name of Landfill site	Size of Landfill	Year of Commission	Gas	Electricity	Leachate
La Mercy	7.2 Ha	1980	No	No	No
Marrianhill	18.5 Ha	1997	Yes	Yes	Yes
Bisasar Road	44 Ha	1980	Yes	Yes	No
Buffelsdraai	100 Ha	2006	No	No	Yes

Source: Field Studies 2013

La Mercy was later decommissioned as it proved to be uneconomic and the engine was moved to Bisasar Road landfill site that us more efficient. The second phase was the Bisasar Road

Landfill Site that was commissioned in 1980 and holds of waste. The municipality commissioned Buffelsdraai landfill site in 2006. The site is relatively well-engineered site has a very long lifespan of over 70 years. There are also additional construction works to expand the landfill site and improve its operations through the installation of more cells and laying pipes for gas and leachate and waste water drainage. Although this landfill site has not yet started to capture gas and generate electricity, it has great potential to generate high volumes of electricity energy in the near future.

Landfill Gas to Electricity Technologies in eThekwini

The eThekwini landfill gas to electricity project is capital intensive. In total, the capital cost to set up the project amounted to R114 million with an annual operating cost of R 12 million. The finance was provided by the Department of Trade and Industry through its critical infrastructure programme (CPI) and the Department of Minerals and Energy helped to finance the projects. A loan was secured from the French Development Bank to finance this innovative project.

Jenbacher Engines

The major component of the total capital investment in the landfill gas to electricity project was the purchase of engines. Jenbacher 320 cylinder spark ignition engines were purcahsed for the project; The engines drive generators to produce electricity that is fed into the local distribution network. The power that is generated is stepped up by transformers and is fed to the 11KV that is connected to the eThekwini municipality electrical grid. Marianhill has an engine that generates about 1Mega Watt (MWh) of electricity per hour, whilst the Bisasar road landfill site has a total engine capacity of 6.5MWh of electricity. The two landfill gas to electricity sites generate a combined amount of about 7,5 MWh of electricity, which provides power to about 3 500 residents of the municipality. The project as a whole is estimated to generate a total revenue of of R400 million from selling electricity and carbon credits during its life. Figure 2 below shows the net production of electricity at the Bisasar road landfill site during the year 2012.

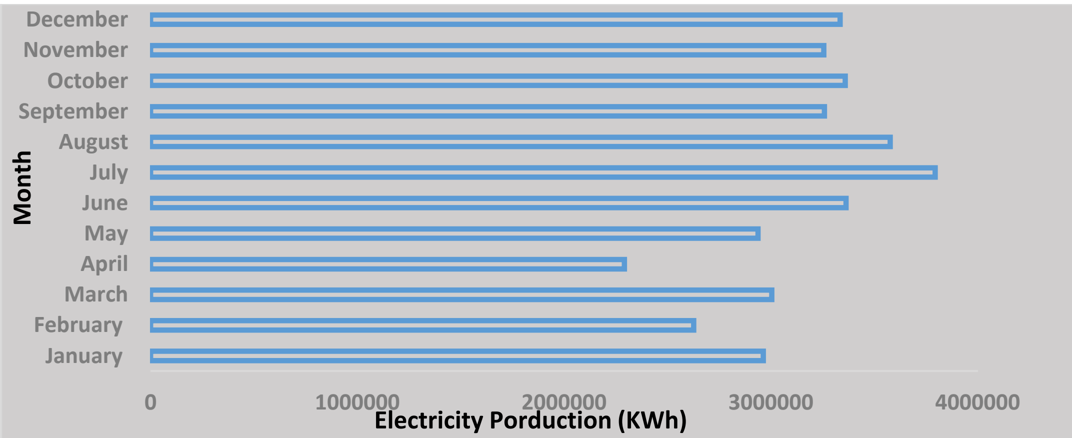

Figure 2 : Net Electricity Production during the year 2012
Source : Field Studies 2013

The Figure shows that the Bisasar road landfill site alone generated between 2.5 million (Kilo Watt per Hour) KWh and 4 million KWh every month throughout the year 2012. The generated electricity is stepped up by transformers to increase power from 400V to 11(Kilo Volts)KV and thereafter it is fed into the municipal grid.

Extraction Wells

The project draws out gas from landfill sites through a system of wells and risers that were installed at the landfill sites. Vertical and horizontal gas abstraction wells that are drilled in the waste mass are used to sxtract gas. As for vertical wells, a single well is placed per hactere of landfill surface whilst horizontal wells are placed 50 and 200 feet apart. The Bisasar road landfill site has 77 vertical and horizontal extraction wells apiece, whilst Marianhill has 13 vertical and 6 horizonatl extraction wells. Figure 3 below shows the volume of gas that was extracted from the Bisasar road landfill site monthly during the 2012 production year.

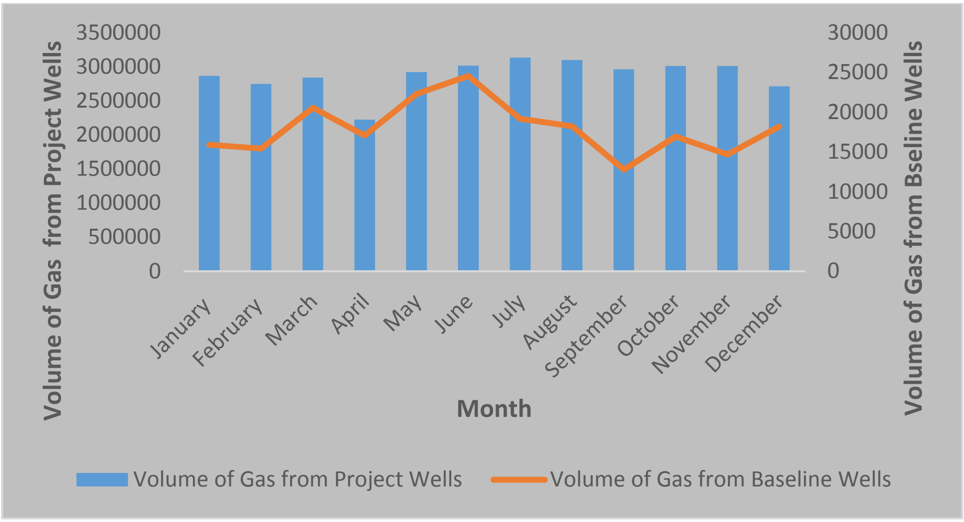

Figure 3 : Volume of Gas Extracted from Bisasar Road in 2012
Source : Field Studies 2013

The Figure shows that baseline wells realise low amounts of gas compared to project wells. Whilst the project wells extracted gas volumes of between 2.7 million (Normal Cubic Metres) Nm^3 and 3.2 million Nm^3 during the 12 months of 2012, the volumes of gas realised by baseline wells were between 15 000 Nm^3 and 25 000 Nm^3 during the same period. This evinces that project wells realise more gas than the baseline ones and this explains the project is doing very well in terms of gas extractions from the landfill site.

Gas Extraction Plant/Blower, Pipes and flare units

The technology also uses gas collection and transportation pipes. They collect and transport gas from wells to the extraction plant. At the extraction plant, gas is converted into electricity. The gas extraction plant is commonly known as the blower. The blower creates lower pressure inside the wells than in the landfill as a result it sucks the gas from landfill into the well. After extrcating the gas from landfill it is taken to the extraction plant and then transmitted to generation engines or flare unit.

Flaring Machines

The landfill gas to electricity projects have flare units that are installed at bothe landfill sites. They burn excess gas that can not be converted into electricity at 1000 Nm^3. Figure 4 shows that between 900 000 Nm3 and 1 300 000 Nm3 of landfill gas at Bisasar road was flared using the appropriate technologies to avoid the chocking of jenbacher engines due to excess gas.

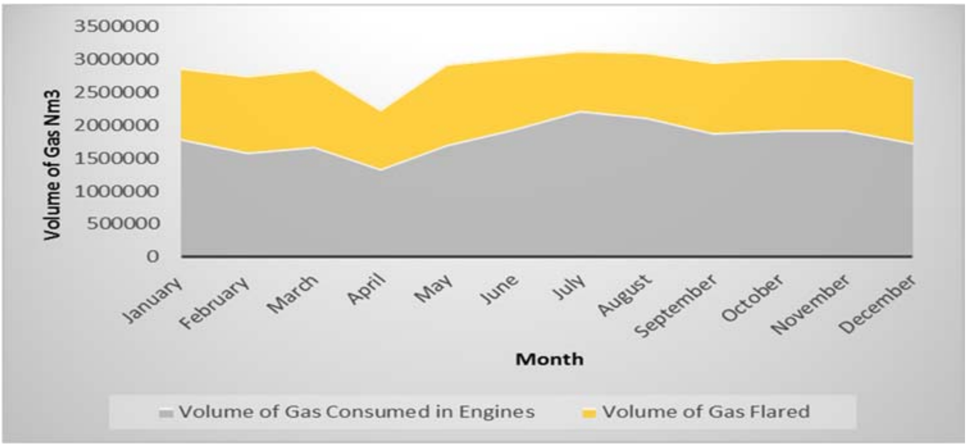

Figure 4 : Combusted and Flared Gas at Bisasar Road Landfill Site in 2012
Source : Field Studies 2013

Also, between 1 700 000 Nm3 and 2 300 000 Nm3 of gas is consumed in engines. This shows that the project is achieving great fete in the destruction of poisonous methane gas, carbon dioxide and other impurities.

Urban environmental benefits of Landfill gas to electricity project in eThekwini

The innovative green energy technologies employed to exploit landfill gas have resulted in at least four benefits that are; (i) reduced carbon levels, (ii) preservation of underground water sources, (iii)conservation of plants and trees, and (iv) the general cleanliness of land surfaces (Figure 5).

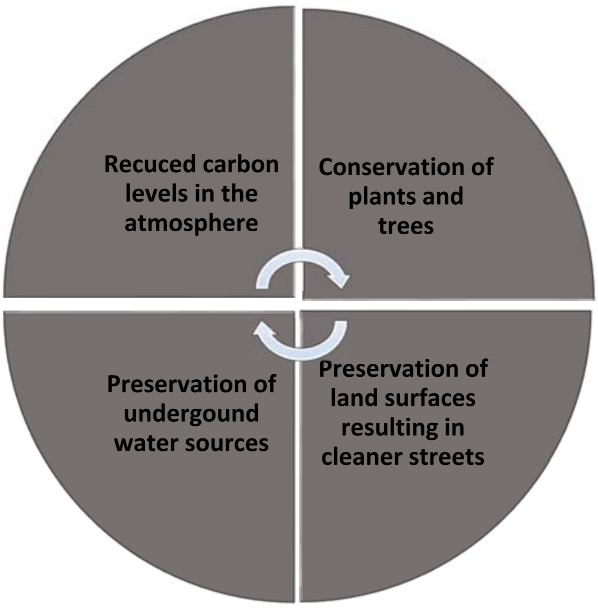

Figure 5 : Urban Environemental Benefits of landfill gas to electricity Projects in eThekwini
Source: Field Studies

1. *Reduced carbon emissions* – The landfill gas to electricity projects in the eThekwini metropolitan municipality have resulted in the capture of methane gas from the decomposing biodegradable municipal solid waste. Methane gas (CH_4) has 21 times the global warming potential of carbon dioxide (CO_2). The two gases are the some of the biggest components of GHG. Figure 6 shows the carbon emissions that were reduced during the year 2012 at Bisasar road landfill site.

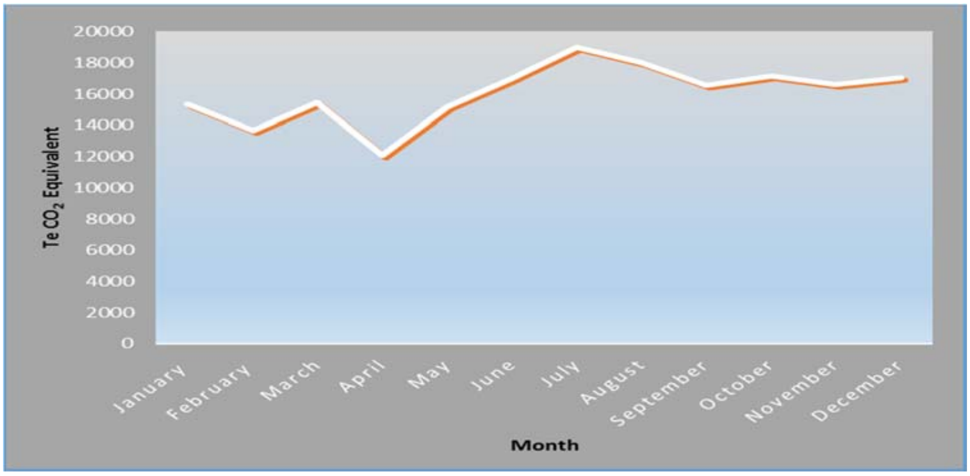

Figure 6 : Carbon Emission Reductions for 12 months during 2012 at Bisasar Road
Source : Field Studies

The table shows that the carbon emissions of between 1 200 Te Co equivalent and 1900 Te Co equivalent for the 12 months of the year 2012 were realised. Overall, the burning and conversion of gas into electricity in the projects directly resulted in the realisation of over 200 000 carbon emissions reductions every year and a cumulative figure of over 6 million carbon credits since its inception. Indirectly, the landfill gas to electricity projects assisted in reducing the burning of coal by 800,000 tons every year, consequently helping reduce GHG emissions that are resident in the municipality's traditional electricity supplies. The project has generated more than R48 million through the selling of certified carbon credits to date.

2. Preservation of water sources – The landfill gas to electricity projects have well-functioning leachate treatments, In particular, Marrianhill and Buffelsdraai. The purification of waste water from the dirty and contaminated state to clean and clear state before it seeps into the ground as indicated in Figure 6 , helps to reduce the contamination of surface and underground water sources. Recycling water and using it to irrigate plants and trees within the landfill sites also helps to save fresh water from rivers and dams.

3. Preservation of plant and trees – The highly engineered and sanitary landfill sites have also resulted in the preservation not only of the natural plants and trees within the landfill sites but also of the surrounding environments. At the three landfill sites that are operational, there are great efforts to conserve the natural environment. The conservancy and plant rescue unit (PRUNIT) not only conserve the natural vegetative environments but also preserves indigenous plant and tree species. The waste water that is treated is used to irrigate plants and trees within the landfill sites, thus maintaining the flora within and around the landfill sites. The reclamation of landfilled areas and the subsidence and settling of disposed municipal solid waste assists in maintaining the environment as it was before disposal of waste commenced. Marrianhill has a material recovery facility (MRF), a sequencing batch reactor for the treatment of leachate and a registered conservancy area. About 50m^3 of leachate that is processed and cleaned per day is used for various purposes for example watering within the reed bed and Plant Rescue Unit (PRUNIT).

4. Cleanliness of land surfaces and infrastructure preservation – The landfill gas to electricity projects have resulted in cleaner land surfaces particularly at the source of municipal solid waste generation which are in most cases are suburbs, commercial enterprises, city streets and markets. The projects have encouraged the collection, transportation, disposal and treatment of large volumes of municipal solid waste. The landfill gas to electricity projects also encouraged the separation of municipal solid waste at the source and the recycling of materials on the landfill sites without incurring any costs thus ensuring the cleanliness of the urban areas.

Challenges of the Landfill Gas to Electricity Technologies

The landfill gas to electricity projects in eThekwini metropolitan municipality have resulted in huge achievements in terms of the environmental benefits. However, realising the benefits of capturing landfill gas and converting it to electricity demanded a lot of resources that included finances, highly trained and experienced personnel, and specialised machinery and equipment[43]. This makes the costs of acquiring landfill gas to electricity technologies are very prohibitive not unaffordable without external support particularly in developing countries with their characteristict lack of financial capital[44] to initiate such projects. Machinery and equipment are in most cases made and assembled in developed countries. Developing countries have to import these in the midst of chronic of foreign currency deficits. Even the spare parts that are needed to keep the machines running are imported and in most cases very difficult to secure, making the maintenance of the engines very expensive. It is common knowledge that there is a serious shortage of skilled and experienced engineers from mechanical, electrical, civil and environmental engineers in many developing countries[45].

Adding to these challenges is the fact that although such projects are initiated under the clean development mechanism arrangements, there is a general lack of support from international institutions and partners in the developed world when it comes to payment for carbon credits[46]. There are also challenges with attitudes and behaviours that are still not supportive in separating municipal solid waste particularly at the different sources such as households, institutions, markets and commercial enterprises[47].

Conclusions and Recommendations

Green energy generation in the African continent in general and South Africa in particular, has several benefits especial in the preservation of the environment. This is important against a background of rising global temperatures causing climate change, as direct result of greenhouse gases emissions such as methane and carbon dioxide a direct result of the overreliance of fossil fuels like coal. Green energy production, particularly from landfill gas and promotes the sustainable and cleaner cities particularly in African countries that have always struggled with inadequate, inappropriate and inefficient municipal solid waste management[48]. Embracing these innovative technologies not only assists inimproving the diversification of energy supply but also promote cleaner and sustainable urban centres. It is however, disappointing to note that these innovative technologies are very expensive to acquire and use. This suggest a need to develop partnerships and strengthen collaborations between developing countries and developed countries, international institutions and private sector companies globally[49]. This may increase and improve the adoption of these innovative technologies. Locally, there is need to develop home grown solutions to energy challenges of the African continent. There is also a challenge with attitudes of the general public in urban communities that do not view MSW as valuable assests that can be harnessed to produce green energy[50]. There is therefore need to concientise and sensitise the general urban public to encourage them to change their attitudes and beliefs about the value and usefulness of municipal solid waste. Some of the initiatives and interventions may include training technical experts within o technology recipient countries as part of efforts to to reduce the costs of operating the projects[51]. Preferable this could be complimented by developing local technologies that suit the local environments. This would help to reduce the high costs of acquiring the technologies from abroad.

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