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Scaling Up Sustainable Renewable Energy Generation from Municipal Solid Waste in the African Continent: Lessons from eThekwini, South Africa

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Abstract

The three processes of urbanization, industrialization and globalization are positively correlated with municipal solid waste generation and energy consumption in global urban centers. Heavy reliance on fossil fuels in most world cities has contributed not only to global warming and climate change, but also to astronomical increases and volatility in the prices of energy sources. Africa has suffered from energy shortages and climate change as well, for it depends on very limited oil reserves and on finite, toxic coal resources. Thus, the need for innovation in renewable energy generation is more urgent now than ever. Africa is home to many renewable energy sources, ranging from sun and water to municipal solid waste and wind. This article discusses the conversion of waste to energy in the eThekwini municipality, a South African metropolis, and describes prospects for implementing a similar model in other African countries. The study unearths cutting-edge work by the Department of Cleansing and Solid Waste of eThekwini municipality, which has adopted modern municipal solid waste management and treatment systems. For almost a decade now, the municipality has demonstrated the potential for African cities to achieve two primary objectives: first, to generate clean renewable energy sources that contribute to economic development, and second, to reduce urban social and environmental problems resulting from improper waste disposal. The municipality's success also reveals tremendous opportunities to improve waste management, financial investments, technological take-up, and skillsets to support the African green energy revolution.

Keywords: Sustainable renewable energy, municipal solid waste, African, eThekwini, South Africa

1. Introduction

More than half of the world now lives in cities, and it is projected that more than 70% of the global population will have been urbanized by the year 2030 (Sanchez-Rodriguez 2002). Although Africa—with 37% of the urban population—is the least urbanized of the civilized continents, it is currently experiencing the highest rate of urbanization at approximately 4%. Hence, a significant fraction of urban growth in the world today can be attributed to Africa (Cunningham and Cunningham 2008; Jacobsen, Webster et al. 2012; Gumbo 2013). It is important to mention that a few African countries already surpass this level of urbanization. Case in point: There are South African urban centers that already contain about two thirds of their country's population (UN-Habitat 2012). However, urban growth in Africa has yet to slow down, and as Mutanga, Pophiwa, Simelane explain (2013), African cities will continue to experience rapid population growth thanks to processes like rural-urban migration, natural increase, modernization, and globalization. The continent has benefited from advances in production processes and improvements in consumption and standards of living, which have brought to the fore new challenges. It has been widely observed that the growth of urban populations is positively correlated not only with the generation of municipal solid waste in the urban centers of the world but also with energy consumption (Simelane and Mohee 2012). These sentiments have been echoed by Igoni, Ayotamuno, Ogaji, and Probert (2007), who posit that most African urban centers, particularly large and capital cities, are experiencing high urbanization rates that in turn increase the generation of municipal solid waste.

Besides urbanization, processes such as industrialization and globalization similarly trigger the generation of large volumes of municipal solid waste (Achankeng 2003) and result in astronomical rises in energy consumption, which in most cases derives from fossil fuels that contribute to climate change. These related processes bear directly on both the volumes of municipal solid waste (MSW) that are generated in urban centers (Medina 1997) and the amount of energy that is consumed (Zeng , Sun, Huo, Wan and Jing 2010). According to Cointreau (2008), countries in the developing world generate, collect, and dispose of very low volumes of waste as compared to those found within medium- and high-income areas. This scenario is summarized in Table 1.

Table 1: Waste generation per capita, total waste generated, collected and disposed in low, medium and high income worlds.

Level of income	Level of urbanization	Level globalization	Waste generation rate (lbs/person/day)	Total waste generation (Million tons/year	Percentage collected	Percentage disposed
Low income	Lowly urbanized	Lowly globalized	1.3	559	40%	5%
Middle income	Medium urbanized	Medium globalized	1.8	986	60%	30%
High income	Highly urbanized	Highly globalized	3.1	566	100%	100%

Source: Adopted from Cointreau (2008) and Updated

The table shows how high populations in urban areas generate high amounts of waste as compared to low populations (Babayemi and Dauda 2009). For example, China generated more waste than the United States in 2005 because of the former's staggering population (Cointreau 2008). Industrialization and globalization promote economic growth that leads to high standards of living and improved purchasing power, and this is presently the case in transitional economies and the developed world (Medina 2010). As a consquence of stunted economic growth in developing countries, their municipal solid waste is dominated by organic materials and cheap imported materials, in contrast to the developed world, where waste comes mostly in the form of inorganic materials, metals, and glass stemming from highly industrialized economies. The developing world faces serious challenges with collecting and disposing the quantities of waste depicted in table 1.

Closely associated with these formidable challenges is the incessant depletion of non-renewable energy reserves such as coal and the continuous rise and volatility of the prices of oil—the dominant global energy resource at present. All these challenges are a wake-up call that demands innovative strategies to generate sustainable, affordable, secure, reliable, clean, and renewable energy sources from alternative sources like municipal solid waste, water, wind, and sun (Strachan, Wright, Pass, Couth, Pearson 2008). If there is indeed a positive correlation among population concentrations in urban centers, increased demands for energy sources, and huge quantities of generated waste, then said waste should be properly managed and creatively harnessed in service of a sustainable future.

This article focuses specifically on the experiences in MSW conversion to renewable energy, the so-called waste-to-energy (WTE) projects. The study was conducted in the eThekwini municipality, one of the four largest cities in South Africa. The municipality was the first to adopt appropriate technologies to generate much-needed green energy from MSW. The paper goes on to discuss the prospects of establishing similar projects in other African countries with the aim of not only improving energy supply sources but also conserving the urban environment via green energy sources. Challenges that WTE projects commonly must confront in African countries are also highlighted. The article ends by offering recommendations going forward, as the continent steers toward a green revolution agenda.

Adopting the case study approach and applying interview and observation techniques, field data was collected from various stakeholders, including engineers working on the projects, environmentalists, professors, and residents from surrounding urban communities that benefited from the waste-generated energy. Three projects that were either producing electrical energy from waste or generating and burning gas in the eThekwini municipality were all studied. These projects include the Bisasar, Marrianhill, and Buffelsdraai landfill sites. Purposive and snowballing sampling techniques were employed to identify participants in the field work data collection. Random sampling was used to select participants from the neighboring communities in the city that are benefiting from the energy generated and the clean urban environment that results from the extracting and burning of gas from the landfill sites.

2. Conceptual Frameworks on Municipal Solid Waste

Urban centers, particularly in the developing world (e.g., Africa, Asia, and South America), generally lack sound municipal solid waste management. They face serious challenges in the collection, transportation, disposal, and treatment of waste. This results in the indiscriminate dumping of waste at uncontrolled dumpsites and, even worse, on river banks, street corners, passageways, and the backs of buildings (Mazhindu, Gumbo and Gondo 2012). The MSW phenomenon is a consequence of the lifestyle in urban centers, where volumes of waste rise in proportion with population and standards of living. However, cities that lack adequate means of waste collection, transportation, and treatment—and that harbor negative attitudes toward safe disposal—suffer from indiscriminate dumping of waste and decomposition that releases dangerous gases, thereby harming the environment (Johari, Ahmed, Hashim, Alkali and Ramli 2012). A number of factors—such as the lack of access to adequate recycling and waste disposal facilities, the inconvenience of collecting and sorting waste, the discrepancies between intention and action as defined by government policies, and the general lack of trust in local government by residents in developed nations—result in a negative outlook on participation in waste management (O'Connell 2011). Reviewing the barriers to curbside waste recycling by households in the United Kingdom, Jesson and Stone (2009) discovered a wide range of inhibiting behaviors that can be categorized as being related to individuals and households, to information and levels of knowledge, to local situations, and to general attitudes and levels of motivation. These categories are summarized in Table 2.

Table 2: Factors influencing Recycling Behaviors of Households

Household issues / individual behavior	*Information and knowledge*	*Services / local situation*	*Attitudes /motivation*
Inconvenient No time Too much effort involved, too difficult, too much organising, extra work, see it as a hassle, Not a habit, recurrence of old habits, individual forgetfulness, Storage is an issue, storage and handling problems, lack of space to locate bin, shared bins, no space in residence, a lack of storage space, not practical	Lack of information Ignorance about what can be recycled, Low awareness of how to recycle Lack of information from the Council not so concerned about why's wherefores, what's and outcomes Confusion over what services might be available and how to use them	Facilities too far away / inadequate, Physical location, street layout and type Inadequate provision by council, lack of provision Wanted better and more convenient infrastructures for recycling Estate and flat dwellers left out decided or took away bin)	Negative about the Council making money Perceived effectiveness of the activity, Thinks Council throws it away Not bothered, never considered, disinterested in recycling, unrewarded effort I do not want to participate in the scheme Not important enough issues

Source: Adapted from Jesson and Stone (2009) and modified

Municipal authorities have for a long time singlehandedly administered and executed municipal solid waste collection, transportation, treatment, and disposal such that other stakeholders have always considered it to be the duty of government. Generally, the belief tends to be that someone working for the municipality—someone who is employed to keep the city clean—will collect and dispose of waste properly without involving the public, thus framing perceptions of the management of MSW (Tucker and & Speirs 2010). This sentiment has also been observed by Zurbrügg (2002), who posits that ordinary people's attitudes and perceptions about waste management have only recently started to change. Furthermore, as highlighted in Table 2, MSW has generally been considered worthless and hence a waste of time to sort and dispose of. However, in almost all developing countries, communities and individuals have of late been participating in MSW management by informally scavenging and trading in recycled waste. Such efforts require support and partnership between local authorities and the private sector to ameliorate the situation of MSW management (O'Connell 2011; Zurbrügg 2002).

Landfilled municipal solid waste, particularly the organic component, degrades anaerobically productive methane gas that has on average 21 times the potential of polluting the global atmosphere than carbon dioxide (Noor, Yusuf, Abba and Hassan 2013). The MSW growth trend is expected to continue as 4.3 billion people that are likely to be living in urban centers of the world by 2025, will be generating at least 2.2 billion tons of waste (Hoornweg and Bhada-Tata undated).

2.1 Municipal Solid Waste Streams

Municipal Solid Waste (MSW) can generally be defined as rubbish or garbage that comprises leftovers, garden waste, paper, plastic, glass, and metal that are thrown away. Such waste is commonly regarded as worthless. In reality, MSW is a complex and multifaceted phenomenon that is difficult to define and conceptualize—a phenomenon that is more than the sum of its parts (Fobil, Carboo and Armar 2005). MSW can be categorized according to either its components or its sources of generation, which include major streams such as households, commercial activities, and markets, as well as minor contributors such as street sweepings, construction, and demolition debris. Such streams exclude industrial and biomedical waste that is classified as hazardous and infectious, respectively. Households, commercial, and marketplaces generate most of the solid waste in urban centers. At source, MSW sometimes is categorized into dry and wet materials to avoid contamination. The dry components of the municipal solid waste are further categorized as paper, plastics, metal, and glass, while the wet part of the waste includes wood, yard, and food waste materials. The dry waste materials can be categorized further into combustible and non-combustible materials. Countries in the developing world generate MSW that has more biodegradable contents than found within the developed world (Jesson and Stone 2009). It is the organic component of the MSW that is essential in generating renewable energy. Said organic matter can be incinerated or placed into landfills while the non-organic matter can be either recycled and reused or buried underground to promote environmentally healthy urban centers.

2.2 Municipal Solid Waste Management Processes

The maintenance of hygiene and cleanliness in urban communities involves several stages of MSW management. The various processes of managing MSW include collection, transfer, treatment, recycling, resource recovery, and disposal (World Bank/SDC, undated). As part of fulfilling traditional roles and responsibilities of maintaining the cleanliness of their areas of jurisdiction, municipalities have always single handedly collected, transported, treated and disposed MSW (Bartelings and Sterner 1999; Zurbrügg 2002). The complex and integrated processes of managing MSW range from eco-design of production plants to reduce waste at its source to reusing, recycling, and recovery of waste generated. They also included composting, incineration, and landfilling of collected waste from various sources. Disposal at landfill sites can be done directly from sources or from temporary community collection points such as skips, bunkers, standby trailers and open lots (Okot-Okumu 2012). Collection may be done at sources where the MSW is directly disposed of at its final destination, which is normally the landfill sites, or the waste can be gathered at centralised collection points such as skips, bunkers, standby trailers, and open lots before it is transferred to the landfill sites.

2.3 Municipal Solid Waste as a Renewable Energy Source

Energy from waste is renewable in the sense that the major component of MSW is organic matter that is derived from plants and trees, which are themselves renewable resources that form constituent parts of the natural ecosystem (Togo and Kaggwa 2013). The energy is produced by incinerating the waste, or disposing of it in landfills and extracting gas, which is converted to electrical energy. The greenhouse gases (GHGs) that are emitted during the energy-generation process from the waste are recycled in the process helping to reduce greenhouse gases in the atmosphere (Ryu 2010). The gases would have been removed from the atmosphere during the lives of the trees and plants. Therefore, there are no additional or new gases that are released into the air during this cycle. This is much better than the burning of fossil fuels such as coal, which releases carbon dioxide that would have stayed a part of the atmosphere for several centuries. Faced with the daunting challenges of dwindling reserves of coal, which is the most common source of energy, and low oil reserves fetching high and volatile prices, some African countries have started shifting towards adopting and using renewable energy sources. These countries assert they follow a so-called green energy revolution agenda in the continent (Kaggwa and Togo 2013). Indeed, MSW has lately come to be regarded as a resource in Africa, with many countries adopting integrated management practices that emphasise recycling, reusing, and recovery strategies.

3. Case Study of Waste-to-Energy Projects in eThekwini Municipality, South Africa

South Africa is not only a progressive country politically and socially, but also the economic power house in Africa, with a population of about 50 million (OECD 2013; Statistics South Africa 2011). Just like any other developing country, South Africa is facing serious challenges of MSW management in almost all of its urban centers. According to the Department of Environmental Affairs (2012), only 59% of the waste in the country's urban centers is collected. Even the four metropolitan cities Johannesburg, Pretoria, Cape Town and eThekwini face issue with MSW management. The South African government has noted the great challenge that arises from MSW and has in turn put in place legislations, policies, and strategies that seek to alleviate the problem. The Waste Act of 2008 and the National Environmental Management Act of 1998 have been adopted not only to improve MSW management in the country's urban centers, but also to promote innovations in containing the challenge. In response, a sizeable number of cities in the country have adopted innovative solid waste management strategies at varying levels and degrees depending on capacity.

An example of this is the eThekwini municipality, which has embraced innovative technologies to convert solid waste into energy since the turn of the new millennium. This municipality was the first city council not only in South Africa, but also in the continent as a whole, to initiate and implement a landfill gas to electricity project. The eThekwini municipality is located in the Kwazulu Natal province, covering an area of 2297 km^2 and with a total population of about 3 million residents (Department of Cooperative Governance and Traditional Affairs undated). Figure 1 shows the location of eThekwini in South Africa and the landfill sites as well as MSW transfer stations within the municipality.

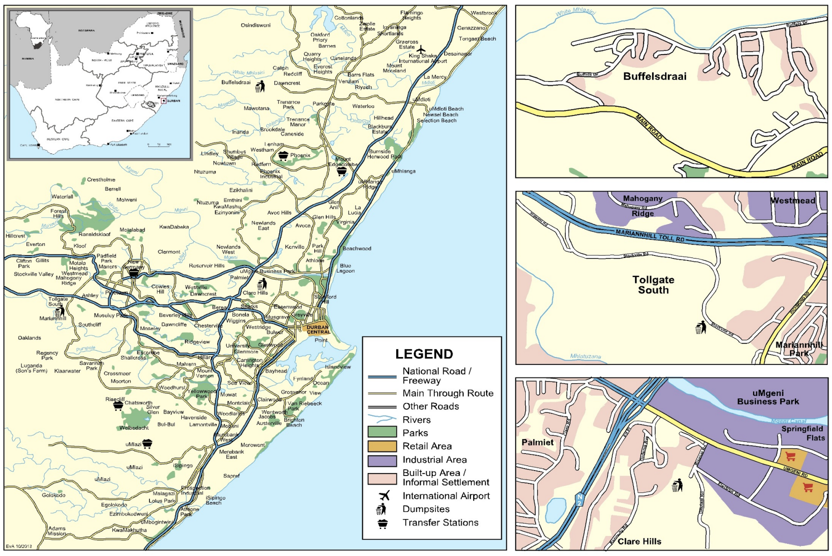

Figure 1: Map of eThekwini Showing Landfill sites and MSW Transfer Stations

The idea to generate energy from MSW by the municipality was mooted in 2002, refined in 2003, and finalized in 2004 when the World Bank agreed to support the project due to its potential reduction of emissions in the atmosphere and actual generation of electricity from waste started in 2006. Although WTE technologies had long been adopted in the developed world, particularly in the United States and Western European countries , the Department of Cleansing and Solid Waste of the eThekwini municipality would adopt the same modern systems three decades later. For almost a decade now, the municipality has demonstrated to the entire continent and the world at large that it is possible for African cities to achieve the twin objectives of generating clean renewable energy sources that contribute to economic development and reducing social and environmental problems associated with improper disposal of waste in an urban context, a common blot on the African city-landscape.

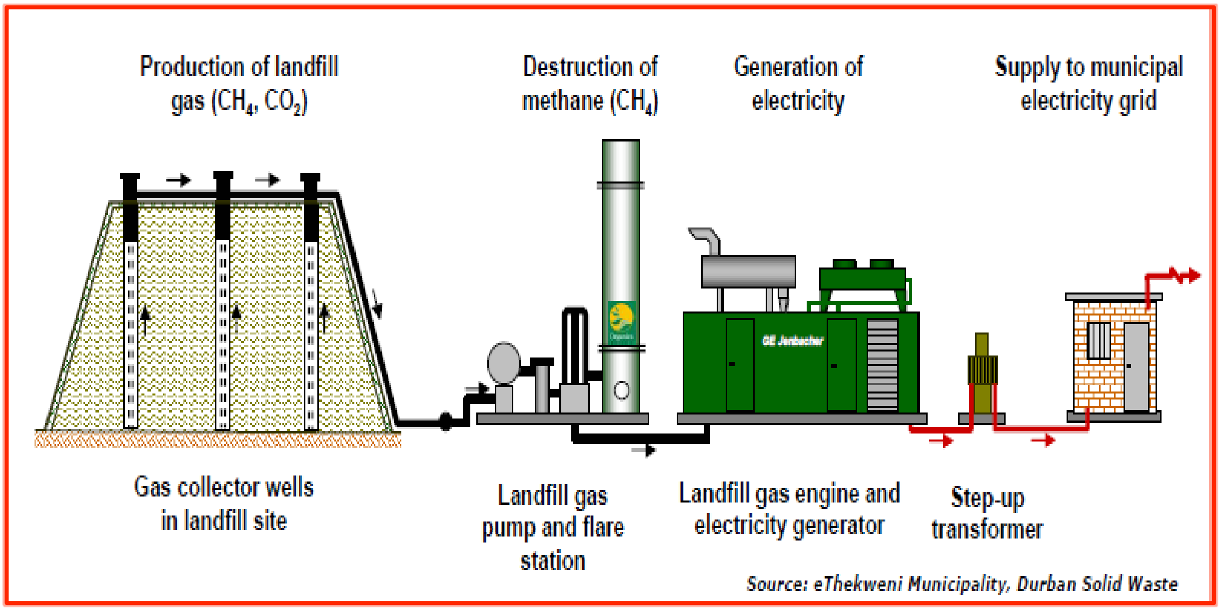

Figure 2: Diagrammatic Representation of Energy Generation from MSW in eThekwini

According to figure 2, gas collector wells that create a vacuum within the decomposing waste are drilled into the mound of landfilled MSW to suck the gas that is later transported along the pipes to the gas pump and flare station. The gas is converted into electrical energy by the turbines and a step-up transformer is used to assist in feeding the electricity of the same voltage into the municipality's grid.

Three projects at La Mercy, Mariannhill, and Bisasar landfill sites were initiated under the Clean Development Mechanism (CDM), a brainchild of the United Nations Framework Convention for Climate Change (UNFCC), formed through the Kyoto Protocol (Strachan LJ, Pass J. undated). Currently the two operational projects are generating a total of 7.5 MW of electricity, which provides power to about 3 500 residents of the municipality, generating a revenue of R48 million through the selling of certified carbon credits and the selling of electricity to the municipality. The projects are also estimated to generate a total of R400 million revenue during its life span.

3.1 Projects Specifications

Initially, the project was supposed to include all three landfill sites that were in existence at the time: La Mercy, Mariannhill and Bisasar. However approval and registration procedures and requirements under the Clean Development Mechanism (CDM) of the United Nations Framework Convention on Climate Change (UNFCCC) in line with the Kyoto Protocol of 2005 were cumbersome, forcing the splitting of the project into two. The Kyoto Protocol encouraged private sector investment in developing countries that reduce emission reductions in greenhouse gas (GHG) to the atmosphere as a way of supporting development in poor counties that lack advanced technologies and necessary funding.

3.1.1 Phase 1: La Mercy and Mariannhill Landfill sites

The study unearthed cutting-edge innovations in the management and treatment of municipal solid waste since the turn of the new millennium. La Mercy started operating as a landfill site in 1980 and was closed in 2006. It is located to the north of the eThekwini municipality, on the rural sugar cane farmlands owned a few kilometres from Shaka international airport. It covered an area of 7.2 ha, had an average depth of 18 m and had contained an estimated 1.1 million m^3 amount of waste. It used to receive 300 tons of waste daily during its operation. The landfill site had 17 vertical wells on both the southern and northern sections that contained older relocated and newly disposed waste respectively. The wells extracted only 183Nm^3/hr. of gas and this could not supply the 0.5MW engine with enough gas for the generation of electricity, hence the project was abandoned and the engine was transferred to the Bisasar road landfill site where there are very high gas levels being extracted. Although leachate pumps had been installed to remove waste water from the wells, the high levels of the leachate and the high amounts of fine sand that had been used to cover the waste before the decommissioning of the landfill site led to blockages to the gas wells, resulting in very low gas levels. After realising that gas flows could not improve the extracted gas levels, the La Mercy landfill site was closed, and it has been rehabilitated into a natural land mass of green grass and forest.

On the other hand, Mariannhill is a sanitary and engineered landfill site that is located on a valley in a peri-urban area of eThekwini municipality. It operates in lined cells that are used to dispose general municipal solid waste, garden refuse, hospital waste, and construction and demolition waste. It started operating in 1997 and covers a total area of 49.5 ha, where the actual landfill covers 18.5 ha and 31 ha act as a buffer zone and are used for conservancy. It has an estimated capacity of 5 m^3 million waste. It receives between 500 and 700 tons of waste per day and is expected to be full and closed by 2022. It has a weighbridge, a material recovery facility (MRF), a sequencing batch reactor for the treatment of leachate, and a registered conservancy area, the first of its kind on the African continent. There is gas extraction and the generation of electricity at the site. It has seventeen vertical wells that extract about 500 Nm^3 per hour and horizontal wells with new cells that were added recently and extract 200 m^3 per hour. In total, the landfill site supplies about 700 m^3/hr and 1 MW of electricity to the engine that was commissioned in 2006. The 1 MW of power is stepped up by a transformer and is fed to the 11KV that is connected to the eThekwini municipality grid. The Marrianhill landfill site has largely contributed to the conservation of the environment within and around the dumpsite as indicated in figure 3.

Figure 3: Leachate treatment plant and the read bed that purifies waste water from the landfill site

The landfill site has a well-run and managed leachate treatment plant that is also supported by a reed bed. The plants process 50m^3 of leachate per day and the excess is directed to waste water. There is also a Plant Rescue Unit (PRUNIT) on Marrianhill landfill site that serves to help conserve the indigenous species and preserve the environment within and around the dumpsite as depicted in figure 4.

Figure 4: The conservancy and plant rescue units (PRUNIT) Besides the primary objective of reducing contamination of land and underground water , the plant treatment also purifies water, which is used to irrigate the plants and trees within the landfill site. Generally, the project has resulted in the reduction of gas emissions in the atmosphere and it has successful reached about 16,000 Carbon Emissions Reductions every year since its inception.

3.1.2 Phase 2: Bisasar Road Landfill Site

The Bisasar Road Landfill Site first used disposable waste in 1980. There is now only one year left until it's retired, although there are plans to extend its life. Bisasar is a deep valley landfill site, situated atop old municipal solid waste and closely located to commercial and residential zones of the municipality. It receives about 3,000 tons of waste per day and about 1 million tons per year. Overall, Bisasar can hold up to 21 million m^3 of waste. Just like the Mariannhill landfill site, it receives different kinds of waste, ranging from from general municipal solid waste, garden refuse, medical, industrial, constructional, and demolition waste. The landfill site has an average depth of 40m and covers an area of 44 ha. In 2007, work to install vertical gas extraction wells, gas collection pipework, and flare systems began. This includes wells and riser pipes that could extract about 2500 Nm^3 and supply 4 MW of electricity. Eleven horizontal wells were also installed to augment the gas extraction of the 48 old and new vertical wells. Thirty-eight leachate pumps were installed, despite the absence of a leachate treatment pump. Initially only 2000 Nm^3 was used to generate 4MW of electricity by the four engines. Each engine generated 1MW, while the remaining 500 Nm3 was flared. More wells were installed in 2009, during which fourteen vertical wells and nine horizontal ones were sunk. Gas extraction increased to 4000 Nm^3, which caused two more engines to be installed and the 0.5 MW engine at La Mercy to be relocated. This brought the total electricity generated at Bisasar landfill alone to 6.5MW. Transformers increased power from 400V to 11KV, and the switch gear was connected the municipal grid. The project has alleviated the burden of electricity shortage in the city and also reduced the amount of GHGs in coal fired power stations. This has resulted in improved air quality in nearby communities. 1 MW of electricity generated provides energy to 500 small houses within the municipality, allowing the Bisasar road project to currently service 3,500 households in the municipality.

The project has also resulted in new local employment opportunities for fourteen skilled personnel at the project's inception stage, thirty-eight semi-skilled and fifty-seven unskilled personnel during construction, and eleven skilled and four unskilled personell as well as one trainee during the operation stage of the project. Three black students who were part of the previously disadvantaged communities were awarded bursaries to study civil engineering at the local university, the University of Kwazulu Natal.

Figure 5: Recycling activities and spraying activities at Bisasar Road landfill site

At the landfill site, there are coordinated and well-managed recycling activities in addition to spraying activities aimed to contain the odors within the landfill site, for the benefit of surrounding communities. The Bisasar landfill site has resulted in the realization of about 218,000 Carbon Emissions Reductions each year since its inception. The project has generated in excess of 6 million carbon credits and reduced the burning of coal by 800,000 tons every year.

By selling the excess certified carbon credits, the project has generated about R48 million and is estimated to generate a total of R400 million total. The project successfully achieved its socio-economic and environmental objectives in fostering sustainabile cities, particularly in the developing world.

4. Prospects of Scaling Up Renewable Energy from Waste

Many literary sources have highlighted the potential in untapped and under-utilized renewable energy sources in the African continent (Hussein, El-Khattam and Abdel-Rahman 2011). There is great potential in increased generation and supply of renewable energy from waste in the African continent. Benefits from converting waste to energy lie in the positive correlation between high population concentrations in urban centers that generates huge quantities of waste, and advancements in technology and production processes that occur as economies grow. Millions of tons of waste, rich in organic content and value, generated in African cities, need to be properly managed and used innovatively in order to contribute to renewable energy production (Abdel-Rahman, and Simelane 2011). Moreover, climatic conditions in Africa, such as heavy rainfall and high temperature are conducive to rapid decomposition of landfilled waste.

In 2006, eThekwini, an African municipality, developed and began operating Buffelsdraai landfill site. The landfill site is 100 hectares large and is expected to last for approximately 70 years. It has a buffer area of 787 hectares that extend for about 800m. It currently receives and processes close to 450 tons of general municipal waste daily, but is expected to receive about 2,000 tons per day when the Bisasar landfill site closes. The landfill is located about 25 km north of the CBD and lies approximately 8 km west of the small town of Verulam. The landfill site is still constructing works more cells and lay pipes for gas and waste water drainage. This landfill site has great potential to generate electricity energy once it becomes fully operational. Other metropolitan cities in South Africa such as Johannesburg, Pretoria and Cape Town have also started WTE projects.

Other African countries have potential to either scale-up existing WTE projects or initiate new ones. For instance, the municipality of Abidjan, in Côte d'Ivoire, has been working since 2009 to generate about 30 MW of electricity from landfill waste. About 200,000 tons of waste is treated anaerobically, where gas is extracted from the landfills and is later converted into electrical energy. In Ghana starting in 2014, WTE projects have already generated about 6 MW of electricity. The landfill site receives 270,000 tons of waste each year and it is expected close by 2044. Starting in 2014, there will be a a further 10-MW WTE project in Accra due to investments by private companies About 1,000 tons of waste will be processed per day. The projects are predicted to generate 100 million USD in revenue per year over 30 years. Other African countries have also generated electrical energy without landfills through incineration and cogeneration of organic waste. Mauritius produces about 87 MW, Kenya 35 MW, Uganda 12 MW, and South Africa about 6 MW from either bagasse or biomass. The WTE initiatives in these African countries have gone a long way towards improving energy security while expanding and widening available choices.

A number of African countries are flaring gas running into several kilotons of carbon dioxide equivalent emissions (kt CO_2-e) from landfills, biomass and bagasse. These materials can be converted into electrical energy if appropriate technologies are adopted. In Dar es Salaam, Tanzania, about 202, 27 kt CO_2-e of landfill gas is flared every year, while in Dakar, Senegal, the number is about 13,132 kt CO_2-e. In South Africa, a total of 23,767 kt CO_2-e is flared every year in Ekurhuleni municipality within the Gauteng province, while about 18,839 kt CO_2-e is burnt every year in various urban centers by the country's EnviroServ landfill gas recovery project. All of these developments represent great potential for energy generation from waste. All that is needed are engines that convert the currently flared gas into energy.

Great prospects and promises also lie in the recent shifts in the policy of various African governments towards increased generation and use of renewable energy as well as the reduction of the fossil fuel use that causes global warming and consequently climate change. It is also hoped that efforts will be made to enforce these policies to regulate productive activities. In some countries, interest has been shown in evaluating the potential of diversifying energy sources through the conversion of waste to energy. This is the case in Nairobi, Kenya, where Kenya Power may investigate possibilities of generating energy from waste at Dandora dumpsite. Such plans will hopefully be converted into tangible action.

5. Challenges with WTE in the African Continent

In most African countries, modern technology is efficient and effective in converting waste to energy, particularly the equipment used to suck gas from landfills, as well as the engines that are used to cool and convert the gas to electricity.

However, these technologies are still lacking due to prohibitive costs (Mudombi 2013; Simalenga 2011). The few projects implemented in the continent suffer critical shortages of experienced and well-trained personnel (El-Khattam W, Hussein and Abdel-Rahman 2011). Appropriate policies that support investments in renewable energy production are also lacking in most African countries, and where they exist, there are serious inconsistencies in their application.

6. Conclusions and Recommendations

Unfortunately, the majority of the African population is not connected to modern energy services. This makes the adoption of technological innovations in generating renewable energy from sources such as waste imperative in the continent. Admittedly, this is a predicament that demands not only immediate and concerted efforts from many stakeholders, but also a complete shift in approaches and techniques of problem solving. In response to demand, a few African countries have recently embraced modern technologies and innovations to affect the generation and supply of renewable energy sources to their populations, and more are on the way. Against the backdrop of dwindling fossil fuels such as coal and the volatility of oil prices, renewable resources are critical to secure future energy supplies and socioeconomic development within the continent. The immediate and long-term energy demands of the ever-exploding populations in African cities need to be met, while simeltaneously ensuring progressive reduction of GHGs, such as methane and carbon dioxide that directly cause global warming and climate change. There is need for a change in behaviour and attitudes so that waste be regarded as a valuable resource. This can only be possible through awareness and sensitization of the general populace to its usefulness. The pursuit of sustainable and clean cities calls for not only a shift in attitude about waste, but also a better and more clear understanding of modern methods of waste management. There is a need for WTE technological uptake and training of personnel to improve the skillset in the continent. Lessons from existing practices in the few African countries such as South Africa and some other previously mentioned countries should provide motivation for the programs and endeavours that are being implemented in other urban centers of the continent. Besides realizing direct benefits of increasing and securing energy sources, scaling up the green revolution in the African continent will also help African countries achieve sustainable socio-economic and environmental development.

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