8. Waste to Energy

8.1 Overview

When electricity or heat is generated from a waste source it is utilizing waste-to-energy (WtE) technology, thus reducing the amount of waste that would otherwise go into landfill, or reducing the amount of methane being released into the atmosphere from landfill and sewerage sites. It is necessary to consider the possibilities that WtE technologies present, not only from their energy generation potential, but also from their potential to reduce greenhouse gases.

A number of WtE technologies exist worldwide, with the most prevalent being landfill gas, wastewater gas, incineration and gasification. These will be examined in more detail below.

It is important to remember that the most sustainable way to deal with waste is to eliminate it entirely. Reducing the amount of waste generated, reusing discarded items, and recycling and composting are fundamental principles in achieving zero waste. Municipalities should strive to achieve this goal.

Landfill Gas

When organic waste decomposes without the presence of oxygen, anaerobic fermentation slowly produces landfill gas. Landfill gas contains 40-60% methane, with the remainder being mostly carbon dioxide. Methane is 23 times more potent than carbon dioxide when it comes to its properties as a greenhouse gas, making it a key climate change gas to address. Burning methane produces energy, carbon dioxide and water. This is a very useful outcome as besides being an energy source, the hugely potent methane is replaced by the considerably less potent CO_2. For this reason landfill gas projects are potentially very lucrative CDM projects.

A landfill gas electricity generator at La Mercy landfill site, eThekwini

Landfill gas energy facilities capture the methane and combust it for energy. It can be used to produce electricity, or used directly for cooking and for space and water heating. When concentrated and compressed, it can also be used as a vehicle fuel source.

Wastewater Gas

The theory behind anaerobic digestion of wastewater is very similar to that of landfill gas in that waste is decomposed without the presence of oxygen to produce a gaseous mixture of methane and carbon dioxide. The volume and mass of wastewater sludges are reduced by anaerobic digestion, as is the emission of volatile organic compounds and odours into the atmosphere. Similar to landfill gas facilities, anaerobic digestion of wastewater produces a biogas of 60% methane and 40% carbon dioxide that can be used for energy production. This biogas can be used to generate heat and electricity or it can be used as a vehicle fuel.

Incineration

Incineration involves the combustion of organic materials into incinerator bottom ash, flue gases, particulates, and heat, which can be used to generate electricity. It is both a landfill reduction method, reducing the volume of waste by 95-96%, and a WtE technology.

The heat produced upon incineration can be used to generate steam which can then be used to drive a turbine in order to produce electricity. 500 kWh of electricity can be generated per ton of municipal waste.

Gasification / Pyrolysis

Just about any organic material, such as biomass, wood and plastic waste, can be converted into a gas mixture of carbon monoxide and hydrogen by gasification and pyrolysis.

Unlike incineration, gasification does not produce energy from waste through direct combustion. Waste, steam, and oxygen are fed into a gasifier where heat and pressure break apart the chemical bonds of the waste to form synthesis gas (syngas). It allows the breakdown of hydrocarbons into the gaseous mixture by carefully controlling the amount of oxygen available.

Syngas may be used directly in internal combustion engines or to make products that substitute for natural gas, chemicals, fertilisers, transportation fuels and hydrogen. Pollutants are removed from syngas before it is combusted, so that it does not produce the high levels of emissions associated with other combustion technologies.

Like gasification, pyrolysis also turns waste into energy by heating under controlled conditions, but involves thermal degradation in the complete absence of air. Pyrolysis produces char, pyrolysis oil, and syngas, all of which can be used as fuels.

8.2 The Case

All of the WtE technologies generate energy from products that would otherwise not be used. South Africa disposes almost all of its waste into landfills. There is a constant need for waste disposal, resulting in an equally constant energy generation potential.

By providing an alternative to fossil fuelled power stations, WtE plants reduce the emissions these plants would otherwise produce, and reduce the levels of methane being generated at the waste site. In addition to reduced emissions, these technologies reduce other adverse impacts related to coal-fired electricity production, such as coal mining and transportation. WtE technologies can help meet renewable energy targets within cities and can help to diversify energy profiles.

Currently in South Africa, and specifically from a City perspective, primary focus has been on landfill gas generation sites. For the rest of this chapter, landfill gas will receive more attention than the other technologies, as it is deemed to be the most feasible in the current climate.

Landfill gas

Using landfill gas to generate energy and reduce greenhouse gas emissions has been financially viable in South Africa to date, provided suitable carbon funding is sourced. This has been proved at eThekwini where several landfill sites currently capture methane and burn it for electricity. The cost to generate electricity from landfill gas depends primarily on the size of the generating unit, which can range from a 500 kW unit to a 4 MW unit. Data generated from a 2004 DME report on landfill gas potential gives a range of production costs from 17 to 30c/kWh (See tables below). Given inflationary increases of 8%, this figure is more likely to be around 25 to 44c/kWh for 2009.

Landfill Gas cost per kWh (DME, 2004)

Category Name		Annual Production Output (GWh)	Static Financial Cost (R/kWh)
1	Micro	191	0.30
2	Small	160	0.19
3	Medium	215	0.18
4	Large	32	0.17
	TOTAL	598	

The following tables outline the capital costs as well as the operation and maintenance costs of the various plant sizes, ranging from 500kW to 4MW.

Landfill gas capital cost (DME, 2004)

Category Name	Category 1 Micro	Category 2 Small	Category 3 Medium	Category 4 Large
Building	110,255	–	–	–
Civil	982,925	1,632,735	2,286,280	2,858,099
Mechanical Machinery	3,691,574	6,137,612	8,525,751	10,784,794
Electrical Machinery	1,328,894	2,219,003	3,112,681	3,949,145
Other	1,089,652	1,392,110	1,683,526	1,951,202
Total Capital Cost	7,203,300	11,381,460	15,608,238	19,543,240

Landfill gas operating and maintenance cost (DME, 2004)

Category Name	Category 1 Micro	Category 2 Small	Category 3 Medium	Category 4 Large
Consumable Inputs	412,300	1,276,577	1,914,866	2,553,155
Staff				
-Skilled	37,500	37,500	37,500	37,500
-Semi-skilled	12,500	12,500	25,000	12,500
-Unskilled	12,000	24,000	36,000	48,000
Annual Maintenance	216,099	341,444	468,247	586,297
Total Operational Costs	278,099	415,444	566,747	684,297

Eskom currently sells electricity to municipalities at approximately 18c/kWh. Based on the landfill gas electricity production cast figure of 25-44c/kWh, it is clear that to make the project feasible, additional funding sources need to be present. This is where traditionally carbon funding has played a role.

However, in 2009 an alternative financing source has been made available to potential landfill gas projects. NERSA's renewable feed in tariff (REFIT) stipulates that electricity generated by landfill gas projects will be bought at 90c/kWh. Therefore, with the REFIT, no carbon funding needs be sourced to make the project viable, which means a far less onerous and complicated process to implement a landfill gas project. It is anticipated that this tariff structure will accelerate the building of landfill gas generation sites around the country.

The technology to generate electricity from landfill gas is mature, and expertise to implement the technology in South Africa exists. With the highly attractive REFIT being provided, there is a very strong case for all viable landfill sites to be set up as a landfill gas electricity generation site.

Wastewater Gas

Anaerobic digestion is a waste treatment process that powers itself. CO_2 emissions can be reduced by 16% when it is used to treat sewage waste rather than using conventional sewage treatment techniques. In addition to producing energy, anaerobic digestion can also produce quality soil conditioner to fertilize land. The conditioner is a result of the solid and liquid residue called digestate that is produced throughout the process. If the digestate is clean enough, it can also be used for land reclamation and landfill restoration.

Current costings for wastewater gas facilities place them higher than landfill gas projects. Also given that no REFIT is available for them, it is unlikely that cities will focus on this area in the short term.

Incineration

Incineration reduces mass and volume of landfill, lightening the load of landfill management in cities. There has been concern around the health ramifications of incineration, but significant advances in emission control have occurred and strict regulations have been initiated internationally concerning dioxin and furan emissions (both of which are highly toxic substances). By diverting municipal solid waste, incineration avoids the release of methane into the atmosphere. In addition to methane, for every ton of municipal solid waste that gets incinerated, approximately one ton of CO_2 is prevented from being released into the atmosphere. It is estimated that 2000 tonnes of waste have an electricity potential of 1050 MWh.

Gasification / Pyrolysis

Gasification and pyrolysis are extremely efficient ways of using biomass to produce energy, both being more efficient than incineration. They are flexible technologies where existing gas-fuelled devices (ovens, furnaces, boilers, etc.) can be retrofitted with gasifiers and syngas can directly replace fossil fuels. Gasification is able to generate energy in engines and gas turbines, which is cheaper and more efficient than the steam process used in incineration.

Municipal solid waste can be reduced by as much as 75% through this process, reducing to the same degree the amount of potential emissions the waste would have created in a landfill. The process of sorting and preparing the solid waste (autoclaving) for pyrolysis is well established and the technological expertise is available in South Africa.

8.3 Potential for rollout

Landfill Gas

The Economic and Financial Calculations and Modeling for the Renewable Energy Strategy Formulation document (DME, 2004) from the DME identified 57 feasible landfill to energy sites ranging from micro (650 kW Capacity) up to Large (4000 kW Capacity) in South Africa that are estimated to produce 43 million m^3 of methane gas per year and are planned to ultimately deliver 830GWh of electricity per year. For the full DME report go to www.cityenergy.org.za/resources/renewable-energy

If all the proposed landfill to energy sites are implemented, the following savings will occur:

Additional renewable energy added to the grid/year	830GWh
CO_2 reduction from offset coal fired electricity/year	830 000T
CO_2e reduction from burning methane	1 928 550T
Total CO_2e reduction/year	2 758 550T

Given that the renewable energy feed in tariff (REFIT) will be made available to landfill gas projects, making them more than financially viable, there should be a large scale rollout of these projects in the short term.

Such projects are employment creators, currently a key national issue.

Wastewater Gas

The total potential for wastewater gas in South Africa is not clear – estimates vary from 36 MWh (1.13 PJ) per annum for electricity generation and 96 MWh (3.0 PJ) for heating purposes (DME, DANCED, 2001) to 800GWh per annum (Holm et al, 2008).

Currently there is limited focus on sewage gas methane production in the country. This is partly because landfill methane is considered a more feasible option in terms of institutional and technical capacity, and financial viability (including CDM carbon revenue generation). Municipalities therefore tend to focus on this option. It is however recognized as one of the options that will be exploited in the medium-term to promote the renewable energy profile of cities.

Gasification / Pyrolysis

More than 140 gasification plants are in operation around the world, and the worldwide capacity is projected to grow 70% by 2015. Although high capital costs are associated with gasification power plants, there is the potential for operating costs to be significantly lower than those of conventional processes or coal-fired plants. Gasification plants are more efficient, require less pollution control equipment and are able to generate a variety of energy products.

South Africa does have expertise in this process, and construction of these plants using local skills is possible.

8.4 Barriers to implementation and efforts to resolve these

Onerous project planning process: To date the establishment of a landfill gas project has required the onerous process of registering the project for carbon financing, lengthy EIAs and local government approval processes. This coupled with Municipal Finance Management Act constraints has led most cities to hold back on landfill gas project development.

Effort to resolve

The renewable energy feed in tariff (REFIT) will now make landfill gas projects financially feasible which will negate the need for carbon financing, and make city approval processes for projects less problematic. If cities can see a clear and simple financial case for the intervention, it should pave the way for increased implementation.

Economy: Most WtE facilities have high capital costs and require technical expertise for maintenance, requiring long contract periods to recover initial investment costs. It is likely that other forms of WtE technologies will only become implemented on a mass scale if they are also included in the REFIT.

Efforts to resolve

WtE plants can access carbon funding to make them more financially feasible. Landfill gas now qualifies for a REFIT, making it financially viable even without carbon funding.

Toxicity: Despite advances in emission control and government regulations, public perception is that anything requiring combustion still produces significant emissions. Where incineration is concerned there is a debate over whether it is possible to convert thousands of tons of trash into nothing and achieve zero emissions, but this is unresolved. Incineration produces particles containing toxic metals, dioxins, and furans that are so small that they can evade pollution control devices. Incineration also produces a highly toxic fly ash that must be safely disposed of; leading to transportation and residential health concerns. Gasification and pyrolysis on the other hand are cleaner processes and do not pose toxicity threats.

Effort to resolve

This does not pose an immediate threat as incineration is not currently a priority for Cities.

Sustainability: The real sustainable solution is zero waste. Waste has a lighter impact on climate change and has more economic value when it is reused, recycled or composted than when it is converted to energy. When materials are recycled, three to five times more energy is conserved than is generated by incineration. Intensive recycling and composting programs are needed, but these may be hindered where WtE streams are implemented.

Effort to resolve

With the focus on already established landfill sites, this is not an immediate concern, but could become so in the future as more WtE sites are established.

8.5 How to go about implementation

Landfill Gas Projects

As landfills are City owned, a landfill gas project should be predominantly a City Council driven process. Landfill sites have a substantial potential for income generation through a carbon offset project (methane flaring and green electricity generation), in addition to the savings from electricity generation. It is therefore an attractive prospect for City Councils to consider if the business case is made. In order for the City to participate in the process though, certain guarantees have to be in place, to ensure that public money will not be put at risk. A willing buyer for the carbon credits has to be sourced, and the project has to be approved by the Designated National Authority (DNA) as a valid carbon offset project. Negotiations in this area are critical as a first phase of the project, and should be done at a high level – preferably mayoral - to ensure city buy in.

For first hand experience in this process, the eThekwini landfill gas projects are the most useful information source – see the case study in the next section.

However, with the onset of the Renewable Energy Feed in Tariff (REFIT), it is unlikely that carbon will be required to make landfill gas projects feasible in the future (see Making the Case earlier in this chapter). The process to qualify a project for the REFIT is not available yet, but this should be the priority in any landfill gas project planning process.

Once secured, the city will have to go through the necessary internal assessment and approval processes to determine who will plan, construct and operate the landfill gas site. These City processes are well established and should not present too many obstacles, given that

- the project will not place a financial burden on the taxpayer, and is in fact financially viable
- with the REFIT in place there are very low financial risks associated with the project
- employment will be created in the City
- CO_2e emission levels will be reduced in the City, supporting local and national targets
- the energy security of the city will be enhanced
- a source of renewable energy will be added to the grid, supporting local and national targets

Other WtE Technologies

It is unlikely that Cities will pursue other WtE technologies in the short term, given the viability of landfill gas projects and support for these from the REFIT. However, should the REFIT be made available to these technologies, it is anticipated that they too will enjoy mass implementation in the country. These WtE technologies will most likely be exploited in the medium term by cities in order to promote their renewable energy profiles.

8.6 Case studies

Case Study: Landfill Gas to Electricity Project – eThekwini

In March 2007, Africa's first landfill gas to electricity project was launched; aiming to enhance landfill gas collection and use it to generate electricity for export to the municipal grid in Durban.

Landfill gas is collected at the Bisasar Road, Mariannhill and La Mercy landfill sites in Durban. The Mariannhill landfill site had received 850 000 tonnes of waste by 2004 and will continue accepting waste until 2024. The La Mercy landfill site is an old landfill that will soon be closed; having received over 1 million tonnes of waste to date. Combined, the Mariannhill and La Mercy landfill sites have the potential to generate up to 2 MW of electricity. The Bisasar Road landfill site is the busiest landfill in Africa accepting 3500 to 5500 tonnes of municipal sewage waste daily and will continue to accept waste for another ten years. It has the potential to generate up to 10MW of electricity through collection, combustion and landfill gas. The final wells will be installed in approximately 2016.

With the annual estimation of emission reductions beginning in 2006, it is estimated that a total of 480 000 tonnes of CO_2 will be reduced at the three locations by 2013. There are also significant positive effects on local air and groundwater quality and safety. Emissions related to fossil fuel electricity generation are reduced by displacing electricity from these sources, as are those related to the transport and mining of fossil fuels. The amount of landfill gas in the atmosphere is reduced, thus reducing the risk of dangerous methane concentrations. This is particularly significant for the Mariannhill landfill site, as it is located close to residential areas. There has also been the economic benefit of additional employment, providing skilled jobs for the operation and maintenance of equipment at the landfill and at the power generation units.

Overview of project

eThekwini landfill gas project makes use of methane extracted from city landfill sites for the generation of electricity. The project is registered with the Cleaner Development Mechanism (CDM) and generates income from the sale of carbon credits through:

i) The process of flaring – burning methane to produce CO_2 (methane is approximately 23 times more potent a greenhouse gas than CO_2)

ii) Offset of coal generated electricity through the use of methane powered generators for electricity (reduction in electricity use from coal fired power stations)

Without the CDM funding, the project would not have been viable. In fact, the generation of electricity is secondary when compared to the CDM credit income from the flaring process.

Three landfill sites were targeted – Marianhill (1MW generator - installed), La Mercy (750kW generator – installed) and Bisasar (two 4MW generators installed, first commissioned in early 2008).

The project is expected to have reduced greenhouse gas emissions by 7.8 million tonnes by 2021. Once fully operational, the project will also have the capacity to generate a total of 10MW of electricity.

Drivers for the project

Prototype Carbon Fund (PCF)/World Bank: Offer to buy CDM carbon credits from eThekwini Municipality through a landfill gas project

eThekwini Cleansing and Solid Waste Department: Cleansing and Solid waste Department drove the project through the many administrative hurdles (CDM registration to verification, EIA positive Record of Decision). By all accounts, the project would not have succeeded without their championing the project.

eThekwini Electricity Dept: Driving the process for the installation and commissioning of electricity generators on landfill sites and linking the generators to the electricity grid.

City Involvement in the Process

This is predominantly a City Council driven project. Landfill sites are City Council owned and the potential for income generation through a carbon offset project (methane flaring and green electricity generation) is substantial, not to mention the additional savings from generating their own electricity. It is therefore an attractive prospect for City Councils to consider if the business case is made. In order for the City to participate in the process though, certain guarantees had to be in place, to ensure that public money would not be put at risk. A willing buyer for the credits had to be sourced, and the project had to be approved by the Designated National Authority (DNA) as a valid carbon offset project.

All this required an internal driver, and the Champion of this process, Lindsay Strachan from the Cleansing and Solid Waste Department, coordinated this. High level buy in was sought from the outset. The mayor (Mr Mlaba) was involved directly in negotiations with the World Bank around the sale of carbon credits generated by the project. Once the MOU agreement was signed, and conditional approval for the project from the DNA was given, the project was presented to Council and it was approved.

Reasons why project took so long to reach implementation

This project took four and a quarter years to get from first contact to start of construction. Several barriers had to be overcome to reach this point.

1. *Negotiations leading up to MOU between eThekwini and World Bank – 9 months*
2. *Emissions reductions purchase agreement (ERPA) with World Bank – 1 year*
3. *EIA process – 1 year*
4. *Tendering to contract award process – 1 year*

The table below provides a full breakdown of the project's progress with associated timelines

First contact with PCF/World Bank - November 2001
Letter to the Mayor of from PCF/World Bank – May 2002
Ken Newcombe (PCF) – Mayor Mlaba meeting at WSSD 2002 – August 2002
Letter from DNA of Conditional Approval for CDM project – November 2002
MOU between eThekwini and PCF – February 2003
Report to full Council and EXCO on Project – June 2003
Council Approval – July 2003
Commence EIA's – July 2003
Adhoc Approval for funds – October 2003
ERPA Signing (Conditional to EIA's) – June 2004
ROD's for Mariannhill and La Mercy ("Component One") – July 2004
Appeal against "Component One" by a Mr Childs – August 2004
Appeal response to Minister of DAEA for "Component One" – September 2004
ROD Bisasar ("Component Two") – October 2004
Started construction …. "Component One" - January 2006
Final Revised ROD for "Component Two" (Bisasar) - August 2006
CDM Registration of Component 1 (Mariannhill & La Mercy) - November 2006
Commissioning of Mariannhill & La Mercy Flares & Gens - Nov~Dec 2006
Initial Verification of Component 1 – January 2007
"Component Two" (Bisasar) Start Construction – March 2007
Delivery of 1st CER's ("Component One") – May 2007

Replicability

Landfill gas projects are replicable for cities around the country. They are made economically feasible either through CDM funding (like this project) or through the Renewable Energy Feed in Tariff.

Important lessons learnt

1. Internal communication and buy in at the highest level was key to getting the project implemented. A strong financial, environmental and social case was made for the project.

2. A project champion with good management and communication skills ensured that the correct processes were put in place and the necessary agreements and approvals obtained. This driver within the City is crucial for the success of such intensive city centred projects

Case Study: World's largest WtE plant in SA

The world's largest WtE conversion plant, a R28 million facility, was opened in July 2008 in the Gauteng province of South Africa by Prestige Thermal.

Prestige Thermal has been at the forefront of WtE technologies for more than six years and this has led to the development of a specialized autoclaving technology that converts solid waste into clean gas through pyrolysis. An autoclave is a pressurized chamber that aids in the chemical decomposition of organic materials by heating in the absence of oxygen. Autoclaving municipal solid waste conditions the material and aids in its downstream separation. This new technology allows the conversion of many different types of materials and was specially designed for "black bag" general waste.

The biogas that results from the pyrolysis can be used in electricity generating turbines to produce 3 MWh of electrical energy from 3 tonnes of municipal solid waste. It also supplements the steam needed for the autoclaving process.

Case Study: Athlone Sewage Plant

A feasibility study was recently completed which looked into refurbishing and upgrading the sewage gas to energy facility at the Athlone sewage plant in Cape Town.

Based on gas produced from waste water works worldwide, and the average flow at Athlone, it is expected that 10,000 m3/d of biogas with a methane (CH_4) content of 65% will be produced (once the digesters are refurbished). One cubic metre of biogas at 65% CH_4 should generate about 2 kWhe (assuming 30% efficiency) and one cubic metre per day can cook daily meals for 4 people. Therefore the gas produced by the digesters at Athlone could replace the kerosene boilers that heat the digesters and still cook daily meals for about 20,000 people or fuel an electricity generator of 830 kWe to supply about 6.9 GWhe/a (including downtime).

Description	**Heating and Cooking Gas**	**Electrical Generation**
Refurbished biogas generation at AWWTW	10,000m3/d	10,000m3/d
Capacity	1500 households	830kW Generator
CAPEX	R5 million (pressurisation, distribution, CDM but ex EIA costs or refurb)	R14 million (scrubbing and generator, CDM but ex EIA costs or refurb)
OPEX (mainly digester)	R100,000 pa	R200,000 pa
CDM Revenue	R3.8 million pa	R4.5 million pa
Simple payback (ex energy sales or loan costs)	1.4 years	3.3 years