Overview

When electricity, gas or heat is generated from a waste source it is utilising waste-to-energy (WtE) technology. In addition to energy/heat generation potential, these processes may also reduce waste that would otherwise go into a landfill and help close the nutrient loop through better sludge management; they also reduce the amount of methane released into the atmosphere from landfill or wastewater treatment sites, thus mitigating climate change.

It is important to remember that the most sustainable path is one of ZERO waste. Reducing the amount of waste generated, reuse of discarded items and recycling and composting are fundamental principles in a ZERO waste approach. Municipalities should strive to achieve this goal ahead of pursuing waste for energy purposes.

A number of WtE technologies exist, with the most relevant for municipalities being that of biogas digestion at landfill and wastewater sites. Biogas digestion at landfill and wastewater treatment sites, based on mature technologies, is now taking place at within the larger metros. Located on municipally owned sites with municipally-controlled energy feedstocks, and with important waste management improvements to be gained through such projects, these are typically municipally driven. Both of these technologies are developed in detail below.

It is unlikely that Cities will pursue other WtE technologies, such as incineration and pyrolysis/gasification in the short term, given the viability of landfill gas and wastewater biogas projects and support for these from the national renewable energy Independent Power Producer Program (REIPPPP). However, should the REIPPPP 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. A brief overview of these technologies is provided at the end of the Waste to Energy chapter.

Private sector investment in WtE, particularly in the agricultural waste sectors (crop produce and animal waste), is growing in South Africa. This is of interest to municipalities as it may offer waste management opportunities.

Landfill gas (LFG) is released when anaerobic bacteria decompose organic waste at landfill sites. A landfill acts as an anaerobic digester producing gases composed of 50 – 60% methane (CH\textsubscript{4}), 40 – 50% carbon dioxide (CO\textsubscript{2}) and a small percentage of volatile organic compounds. Formation of methane and CO\textsubscript{2} commences about six months after depositing the landfill material. The evolution of gas reaches a maximum at about 20 years, then declines over the course of decades.

Methane has a global warming potential 21 times as high as that of carbon dioxide. Instead of escaping into the air, LFG can be captured, converted and used as an energy source. CH\textsubscript{4} is a high energy clean burning gas and is suitable for generating electricity or for direct use as a combustible fuel.

The basic idea behind the technology is that landfills are covered (e.g. by a layer of earth) and LFG is extracted from the landfills using a series of wells and a blower/flare (or vacuum) system. This system directs the collected gas to a central point where it can be processed and treated depending upon the ultimate use for the gas.

From this point, the gas can be flared (to dispose of flammable constituents safely, control odour and mitigate climate change through conversion of methane to carbon dioxide), used to generate electricity, or used directly for space and water heating. It can also be upgraded, concentrated and compressed, to pipeline-quality gas where the gas may be used directly or processed into an alternative vehicle fuel.
Municipal Initiatives

A LFG to energy project thus has two major technical components, often completed as two separate phases of the project:

- **Phase 1:** Gas collection and flaring: this involves the installation of a pipe network drilled into the landfill, the laying of vertical and horizontal gas wells, gas collector pipework, high temperature gas flares and continuous gas monitoring system. Results from the gas monitoring will facilitate best sizing of the electricity generation unit.

- **Phase 2:** Gas conversion to electricity or direct use for energy or thermal purposes. Detailed feasibility needs to be done on the best use (greatest financial, economic and social benefit) of the gas. If electricity is to be produced, the captured gas is fed to a modular electricity generation plant, very often a gas engine in a container. The generator combusts the methane to produce electricity. Excess gas, and all gas collected during periods when electricity is not produced, is flared.

For a large modern landfill, useable LFG may be generated for between 15 and 30 years. However, biogas composition can vary significantly across locations as it depends on factors such as climatic, industrial and agricultural production characteristics and waste management practices.

Several options are available for converting LFG to energy. Below are descriptions of some of the typical project types. Experience from the pioneering landfill to electricity sites in the eThekwini municipality indicate that direct use of the gas may prove to be the most economical.
Electricity Generation

The harvested gas is burnt in spark ignition gas engines which drive generators to produce electricity. Although a variety of technologies can be used for the electricity generation, the vast majority of projects use internal combustion engines. Any surplus gas is flared via flare units. The LFG generators have an anticipated life of 10 – 15 years depending on operational conditions, fuel quality (in the form of LFG), and the maintenance regime adopted.

Direct Use

The harvested gas can be used directly in a boiler, dryer, kiln, greenhouse, or other thermal applications, offsetting the use of another fuel. Current industries using LFG include auto manufacturing, chemical production, food processing, pharmaceuticals, cement and brick manufacturing, wastewater treatment, consumer electronics and products, paper and steel production, and prisons and hospitals.

Cogeneration

Cogeneration, also known as combined heat and power or CHP, projects use LFG to generate both electricity and thermal energy, usually in the form of steam or hot water. Several cogeneration projects have been installed at industrial operations, using engines or turbines. The efficiency gains of capturing the thermal energy in addition to electricity generation can make these projects very attractive.
Municipal Initiatives

Alternative Fuels

Production of alternative fuels from LFG is an emerging area. LFG has been successfully delivered to natural gas pipeline systems as high and medium energy intensity fuel. LFG is also being used to produce the equivalent of compressed natural gas (CNG) for use in vehicles.

Figure 3: The Simmer and Jack landfill site, Ekurhuleni municipality: gas flare and 1MW electricity generation engine and water and gas monitor boreholes

Figure 4: Mariannhill, eThekwini Municipality, 1MW engine and LFG flare; Bisaser Road, eThekwini Municipality, 6.5MW engine and LFG flare station
Implementation

Landfill sites, with powerful greenhouse gas emissions, offer an important opportunity to reduce GHG emissions in line with national goals and targets. At a local level, municipalities need to manage the emissions from their landfill sites in order to comply with air quality licensing thresholds and improve the safety and quality of life of local residents who live nearby to the landfill sites. A landfill gas extraction to energy project can provide opportunities to achieve these goals, while also producing energy and offsetting electricity costs to the municipality. Benefits of landfill gas conversion to electricity:

- A substantial GHG emissions reduction impact: GHG emissions are reduced through conversion of methane to water and CO₂ (which has a lower global warming potential than methane) and through displacing energy produced from fossil fuel combustion.
- Improved site management as escaping gas impairs the working of the landfill
- Improved groundwater quality as the management of the site could relatively easily be combined with leachate collection and disposal action.
- Improved local air quality, safety and reduction in odour for neighbouring communities.
- Economic stimulant and job creation: the process of designing, constructing and operating LFG capture plants creates jobs associated with such activities: engineers, construction firms, equipment vendors, and utilities or distributors; local spend on drilling, piping, construction and operational personnel.
If we do nothing differently, methane emissions from municipal solid waste are expected to increase globally by around 19% above 1990 levels by the year 2050. This increase could largely take place in developing countries (US EPA, 2005).

Potential for rollout

The technology to generate electricity from landfill gas is mature and expertise to implement the technology in South Africa exists. With the potential for inclusion within the REIPPPP, along with the rapidly closing gap between the unit cost for landfill gas to electricity and average Eskom Megaflex tariffs, there is a very strong case for all viable landfill sites to be set up as landfill gas to energy generation sites.

Ekurhuleni Metropolitan Municipality, the City of Johannesburg and eThekwini Metropolitan Municipality have all three developed landfill gas to electricity projects. The projects were developed over two decades: eThekwini initiated exploration in 1994, Ekurhuleni in 2005 and the projects in Johannesburg are still in construction phase. Over this period of time, the regulation applicable to municipalities has changed, the electricity sector in South Africa has been transformed and most importantly, an impressive amount of knowledge, capacity and skills have been developed, within municipalities but also for the manufacturers, suppliers and service providers involved in the projects, from the designing phase to operation and maintenance.

In total, a capacity of 8.5 MW is currently installed in municipal landfills, 18.6 are being built and a further 4 are at planning stage. This should add up to a total of about 30 MW of installed capacity across the 3 municipalities. While this is small compared to the needs of the country, it is electricity generated as a base load, close to the consumption area, which decreases transmission losses and at a price which can be controlled over time. These 30 MW installed could in theory power 37,000 households (at an average consumption of 500 kW/month).

According to a 2004 DME study, Economic and Financial Calculations and Modelling for the Renewable Energy Strategy Formulation document, 57 feasible landfill sites, currently producing some 43 million m³ of methane gas per year, were identified across the country. Potential electricity generation capacity from the sites (ranging from micro/650 kW capacity to large/4 000 kW capacity) could contribute the following:

<table>
<thead>
<tr>
<th>Renewable energy capacity</th>
<th>75 MW *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual renewable energy into the grid</td>
<td>830 GWh</td>
</tr>
<tr>
<td>CO₂ reduction from offset fossil fuel electricity</td>
<td>830 000 tons</td>
</tr>
<tr>
<td>CO₂e reduction from burning methane</td>
<td>1 928 550 tons</td>
</tr>
</tbody>
</table>

As landfill sites are municipal-owned, a landfill gas to energy project needs to be driven by the municipality.
Costs and financial viability

The financial viability of a landfill gas to energy project is complex to assess because:

- There is a very significant difference between the financial and economic costs of a landfill gas to energy project. This is to do with the emissions offsets that are possible to achieve within such a project. Conventionally the financial viability would be assessed through comparing the cost of producing energy from the landfill gas vs the cost of the equivalent grid electricity available. However in a landfill gas to energy project there is the added component of the value of the gas management and emissions displaced. In this instance a project’s viability must look at the cost of the landfill gas energy as compared to the displaced fossil fuel energy plus the value of the reduced methane emissions. Where such offsets have a financial value (such as through carbon credits, or avoided carbon tax) this can enormously facilitate the viability of a project, where not, the project may not be financially viable.

- In addition the municipality would need to assess the important, but often un-costed/non-financial benefits for the municipality: air quality standards adherence, climate mitigation targets and integrated waste management. Where gas capture infrastructure is installed as part of waste management and thus “off” the energy project balance sheet, the financial viability of the energy production element will be greatly enhanced.

Landfill gas to energy projects are relatively new in South Africa and investment costs and returns are still fairly variable. The City of Johannesburg development of the Robinson Deep Landfill to energy project was considered financially viable at the REIPPPP tariff rate of 1.00 ZAR/KWh, but not at the Eskom Mega Flex rate, which was – at the time of project development – R0.53/KWh (in 2014/5). With Eskom Megaflex at an average rate of R0.85 (2016) however, this gap may well be closing rapidly; the Robinson Deep developers believed that a minimum rate of R0.71 was required for viability.

The following table provides a simple payback analysis for LFG to electricity projects (no inflation, discount, interest, electricity price increases have been used). The figures are purely indicative as all costs drawn on have been in ZAR at the time of the investment (not constant ZAR).

Table 1: Simple payback analysis for LFG to electricity projects

<table>
<thead>
<tr>
<th></th>
<th>REIPPPP Feed in Tariff (FIT) unit rate (2015)</th>
<th>Eskom Avg Mega flex unit rate (2016)</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average output per MW installed</td>
<td>7 095 600</td>
<td>7 095 600</td>
<td>KWh/year</td>
</tr>
<tr>
<td>Average capacity/load factor experienced in SA projects</td>
<td>81</td>
<td>81</td>
<td>%</td>
</tr>
<tr>
<td>Anticipated/global average capacity factor</td>
<td>92</td>
<td>92</td>
<td>%</td>
</tr>
<tr>
<td>Tariff for landfill gas</td>
<td>1</td>
<td>0.85</td>
<td>ZAR/KWh</td>
</tr>
<tr>
<td>Annual income/MW installed</td>
<td>7 095 600</td>
<td>6 031 260</td>
<td>ZAR/MW</td>
</tr>
<tr>
<td>Annual income minus op costs</td>
<td>4 967 600</td>
<td>3 903 260</td>
<td>ZAR/MW</td>
</tr>
<tr>
<td>Revenue over 15 year lifespan (12 - 20 years avg lifespan)</td>
<td>106 434 000</td>
<td>90 468 900</td>
<td>ZAR/MW</td>
</tr>
<tr>
<td>Capital cost/MW (estimated avg. including wells)</td>
<td>19 300 000</td>
<td>19 300 000</td>
<td>ZAR/MW</td>
</tr>
<tr>
<td>Operational costs per year (figure indicative)</td>
<td>2 128 000</td>
<td>2 128 000</td>
<td>ZAR/MW</td>
</tr>
<tr>
<td>Operational costs (over 15 years)</td>
<td>31 920 000</td>
<td>31 920 000</td>
<td>ZAR/MW</td>
</tr>
<tr>
<td>Revenue minus costs (over 15 years)</td>
<td>55 214 000</td>
<td>39 249 900</td>
<td>ZAR/MW</td>
</tr>
<tr>
<td>Revenue minus costs (average annual)</td>
<td>3 680 933</td>
<td>2 616 593</td>
<td>ZAR/MW</td>
</tr>
<tr>
<td>Payback/break even – number of years</td>
<td>3.89</td>
<td>4.94</td>
<td>Years</td>
</tr>
</tbody>
</table>

Given the likely increase in Eskom prices over the next 15 – 20 years, LFG projects offer a stable source of electricity at a stable price and would be in the best interests of a municipality to pursue.

**Financing opportunities for LFG to electricity projects**

The following financing opportunities can be explored:

**Municipal budget:**

Given that LFG to electricity (or energy) projects may offer reasonable ROI and relatively short payback periods it is worth exploring whether the municipality could undertake its own investment in the project. Ekurhuleni Municipality went this route, with budget allocated to the project through the annual CAPEX budget process.

**The national Renewable Energy Independent Power Producers Program (REIPPPP):**

South Africa has a target of 17 800 MW of renewable energy by 2030 under the Integrated Resources Plan (2010-2030). The Minister of Energy has to date determined a total of 13 225 MW to be procured through the RE Independent Power Producer Procurement Program (REIPPPP), launched in 2011. Landfill gas to electricity is an approved technology within the program, with a capacity allocation of 25 MW. In addition, landfill gas may qualify within the Small Projects IPP category, to which an additional 400MW has been allocated (each project may have a minimum and maximum contracted capacity of between 1 MW and 5 MW). The maximum tariff a bidder may bid is set out in each Bid Window Request for Proposals. This was set at R1.00/KWh for landfill gas to energy in the Bid Window 3 (2014). Although this provides a critical source of funding for projects, it must be noted that allocations for landfill are limited and not all projects may qualify within the program. The tender process is complex and requires the dedicated time of experienced project developers. The City of Johannesburg ultimately used this route to fund their LFG to electricity project (developed as a Public Private Partnership – PPP – between the City and a private developer).

**Carbon finance:**

As noted, landfill projects have sizeable carbon ‘credits’ (or offsets) associated with them – from the conversion of methane gas to CO2, and the offset of fossil fuel electricity production. However, to date the route of carbon financing has proved...
costly, inefficient and unproductive for South African landfill gas to energy projects. Unless the price of carbon is very good, the costs of verification may often be significantly more than the value of the credits themselves.

Registering a Carbon Credits or Cleaner Development Mechanisms (CDM) project with the UNFCCC Executive Board is a lengthy process and involves a substantial range of stakeholders, adding to project complexity. Emissions reduction monitoring is onerous and gas emissions data needs to be collected every few seconds using rigorous monitoring methods and expensive software packages. The data requires in depth analysis to explain irregularities for verification purposes and ongoing engagement with external verification teams.

CDM projects can also only be registered where a case can be made for “additionality”. This means that the project must be able to demonstrate that it would not have been able to be implemented without the additional carbon monies. As South Africa’s electricity prices increase to close to cost comparable with LFG to electricity prices, this may become a challenge. A further concern is that this additionality clause will deter government from implementing regulations for air quality management that would require landfill site management to bring in gas capture and flaring processes as this may inhibit CDM funding. However, carbon offset markets into the future might still mean that LFG to electricity projects can attract carbon credit finance.

Establishing project feasibility: determining the gas and electricity potential and undertaking a detailed feasibility assessment

It is necessary to have a reasonable idea of the gas yield in order to design the appropriate gas extraction schemes. The gas yield and the lifespan of the yield may limit the economic viability of the use of the gas.

Methane gas can only be harvested where landfills have been well developed and managed. Poorly designed and managed landfills will have leaked substantial amounts of gas, and the site may not have viable concentrations of gas for harvest. Where the site has been well managed, the methane gas can be produced for up to 20 years after the waste has been landfilled.

Using LFG for electricity generation or alternative fuel for vehicle fleets?

After the enormous challenges in developing the eThekwini landfill to electricity projects, the municipal project developer from within the Electricity Department, Mr John Parkin, has suggested that municipalities should strongly consider direct use of the gas in vehicles, rather than conversion to electricity.

Although direct use of the gas would involve ‘cleaning’ it, not having to build and manage a power station (losing 50% of the energy in the form of heat), would offer cost and time savings. A municipality could either use the gas directly in the municipal vehicle fleet, or sell the gas to industry should there be a market/buyer nearby.

However, some challenges exist that require consideration and it is recommended that a thorough analysis of cost to produce electricity vs gas be done before a municipality decides which path to pursue. A major challenge is that while use of the gas to fuel the waste collection trucks sounds a perfect solution, the experience worldwide is that municipalities struggle to maintain the vehicle conversion kits. This option would require that municipalities sort out the full supply chain story for gas-powered vehicles. If selling into industry, the municipality would need to have a very good understanding of the gas market and prices.

Currently there is limited gas around and prices are good, but as more such projects come on board the economic case may well swing back in favour of electricity production.
The following “rule of thumb” can be used for estimating biogas production and related electricity generation potential:

- 100 000 tons of domestic waste entering a landfill per year = roughly equivalent to a potential electricity capacity of 1MW
- 600 – 700 m$^3$/hour of gas can generate 1 MW of electricity
- 1 ton of highly organic waste will produce 6 – 10 m$^3$ of landfill gas per year for 10 – 15 years from placement
- 1 Mton of average city residential waste can produce roughly 500 m$^3$/hour (roughly 4.3 m$^3$ of gas per year)


Although a useful indicator, a rule of thumb provides only a very crude estimation. Actual gas values and potential electricity generation do not solely depend on the amount of waste received but on a number of other factors, which may include climatic conditions, historical quantity of waste received, waste composition and landfill site management. To determine the viability of such project at a landfill site, detailed assessment studies must be conducted.

Feasibility studies done on South African landfill sites indicate a great electricity potential variability and detailed feasibility studies are critical. In addition real gas yields should be monitored, once they have stabilized, before efficient sizing of generation plants are made.

Table 1: Annual waste tonnage and electricity potential of 3 landfill sites indicating variability in electricity potential across sites

<table>
<thead>
<tr>
<th>Landfill site</th>
<th>Tons of waste per year</th>
<th>Electricity potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linbro Park landfill, Johannesburg</td>
<td>360 000</td>
<td>3.3 MW</td>
</tr>
<tr>
<td>Robinson Deep, Johannesburg</td>
<td>400 000</td>
<td>5.5 MW</td>
</tr>
<tr>
<td>Rietfontein, Ekurhuleni</td>
<td>355 000</td>
<td>Potential doubtful</td>
</tr>
</tbody>
</table>

Source: GIZ case study series

Bringing all stakeholders on board

Municipal stakeholders: It is important that all municipal stakeholders – political leadership, municipal officials and affected communities are brought on board from the beginning of such a project. In terms of municipal officials this must ensure that staff related to each component of the project be included in the project planning and development from the start. This would critically include:

- Waste
- Energy and Electricity
- Air quality control
- Finance and procurement

National Department of Energy: DOE and NERSA for generation licensing, IPP office if the project is to bid within the REIPPPP, and, where carbon credits may be part of the project, then engagement with the Designated National Authority (DNA).
National Department of Environment: for permitting and authorization, Air Quality licensing processes.

Private sector: this will depend on the business model being pursued by the municipality.

International: if the project is to include a carbon credit component, then a range of accredited carbon credit stakeholders would need to be engaged. This will depend on what particular carbon market is being pursued.

Developing the project: business models, financing and contracting

Under current conditions, it makes sense for the municipality to pursue this project ‘in-house’ drawing on capital expenditure budget, infrastructure grant funding or sourcing development finance/loan. The municipality must ensure that finance is sourced for both the infrastructure, or capital costs and the operations and maintenance costs. These come from different budgets, but must both be considered in the financial plan and secured and approved within the municipal budget.

Where upfront capital finance is not available a partnership with the private sector may be considered, through a Build, Own, Operate and Transfer (BOOT) arrangement. In such a project the contract would be for the full lifespan of the plant – usually 15 – 20 years. The appointed contractor is responsible for financing the project, or part of it, and is paid during the course of the project through the revenues generated from the sale of the electricity. The municipality would receive royalties or agreed upon profits. Two legal opinions obtained by the City of Johannesburg, who contracted on this basis, confirmed that landfill gas is not a municipal asset (from which a private company may not derive profit, in terms of the Municipal Finance Management Act – MFMA) and that the project was not a PPP (Private Public Partnership). However it has been contentious and any municipality pursuing such a model should contact National Treasury early on in the project development.

Where the municipality is the project developer the project is a standard procurement project with outsourcing of operations and maintenance: the municipality owns the asset and the operation of the gas capture and power plant is outsourced to service providers. Once finance has been secured, the municipality would need to consider the most suitable contracting arrangements for the design, supply, installation and commissioning of the landfill gas to electricity/energy plant. Operation and maintenance contracts can be built into the development and installation contract, through an O&M item listed under the Bill of Items. How the different elements of the project are contracted will need to be decided internally.

The project will likely involve a series of contract elements/contracts, potentially managed through different departments, for:

Phase 1: the (a) design and construction and (b) operation and maintenance of the gas wells and flaring site.

Phase 2: the (a) design and construction and (b) operation and maintenance of the energy generation site.

Combining service provision should be considered: there may be efficiency gains through one contract for both elements (though sequencing the phases is important given that the gas should be monitored for some time.

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**Figure 7: Breakdown of capital costs of a typical LFG capture plant**

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment</td>
<td>44%</td>
</tr>
<tr>
<td>Civil</td>
<td>29%</td>
</tr>
<tr>
<td>Engineering</td>
<td>3%</td>
</tr>
<tr>
<td>Construction</td>
<td>19%</td>
</tr>
<tr>
<td>Contingency</td>
<td>5%</td>
</tr>
</tbody>
</table>

Source: World Bank, 2005
to establish optimal energy generation capacity). Risks may be better controlled where the gas production and energy generation are under the control of a single service provider.

Operation and maintenance contracts would be 3 – 5 years and thus procurement would require public participation processes in accordance with Section 76 and in line with Section 33 of the Municipal Finance Management Act (MFMA). This should not present too many obstacles given that the project is financially viable and would not place a burden on the tax payer or financial risk on the municipality. The additional benefits of job creation, local and global emissions reduction and energy security may generate additional public goodwill.

Once decided, municipal staff must draft tender documents and go through the necessary internal assessment and approval processes to determine who will design, construct and operate the site.

**Risk sharing and performance**

In a municipal-owned project the municipality would bear the risk even though part of this could be shifted to the service provider within the O&M contract — a portion of payment would be against units of energy produced. However, where gas collection and electricity/energy generation component are managed by different service providers and different departments this can be challenging as electricity cannot be generated if gas is not produced and collected.

**Permitting and licensing**

The usual building approval processes need to be followed. Since 2011 however, adjustments to the environmental regulations mean that landfill gas extraction projects of less than 10MW no longer require a full Environmental Impact Assessment (EIA) process to be undertaken.

Depending on whether the gas will be used to generate electricity or produce gas or synfuel, the respective licensing would be required. If electricity generation exceeds the municipality’s ‘own consumption’ of electricity a generation license application would need to be undertaken; where it is only used for ‘own consumption’ the municipality would be exempt from generation licensing in terms of Schedule 2 of the Electricity Regulation Act, 4 of 2006. However, it is generally accepted good practice to inform the National Energy Regulator through a generation license application process. Further, it is a requirement of the Gas Act that all off-grid gas to energy projects be registered (the assumption being that on-grid will be registered through NERSA).

A useful overview of the legislative and permitting requirements can be found on: [http://awtguide.environment.gov.za/content/technologies-overview-legislative-requirements](http://awtguide.environment.gov.za/content/technologies-overview-legislative-requirements)

**Barriers and opportunities**

A landfill gas to energy project offers the municipality the opportunity to generate baseload electricity or alternative fuel at a cost that will be stable over the 15 – 20 year lifespan of the project. The unit price is now almost cost-comparable with Eskom mega flex rates, making these projects financially viable. In addition the municipality will generate benefits through climate mitigation, improved air and water quality and improved waste management. Job creation and economic benefits of local energy production are also promising.
Sustainability: It must always be remembered that zero waste is the sustainable development goal. Municipalities should ensure that this is the goal they are working to achieve and not allow WtE projects to divert resources from this, or indeed become and end in themselves.

Quality of landfill site and lack of enforcing legislation: landfill sites must be optimally managed for successful extraction of gas. As waste management is driven by municipalities with waste taxes being below cost recovery, municipalities generally generate insufficient income for environmentally sound waste management. Currently there is not legislation enforcing gas extraction.

Onerous project planning and development process: experience in South African municipalities indicate that the project development time for a LFG to energy project can take anything from 3 – 8 years. It involves complex contracting and innovative financing arrangements. Any carbon credit arrangements involve costly and lengthy registration processes, with international stakeholder engagement. MFMA requirements will necessitate a full public participation exercise for the operation and maintenance contracts. In order to meet these challenges a municipality will need buy in and drive from highest level and coordinated throughout the municipality, plus a dedicated champion/ project manager.

Institutional challenge and risk sharing: The nature of WtE projects is that they involve both waste and energy. Traditionally these two areas are managed in two separate municipal departments, involving different sets of skills, budgets and management lines. Where gas capture is undertaken as a separate project to energy generation, it may result in two sets of contracts and service providers answerable to different departments. This raises a complex issue of risk and performance based contracting: feedstock to produce energy is dependent on gas capture. Establishing who carries the risk when the feedstock cannot be supplied is vital.

Permitting and authorizing: New rulings have reduced the EIA requirements for landfill gas to energy projects, which will assist in a quicker project development process. Projects must register in terms of the Gas Act. However, ‘own use’ of any power generated is recommended over resale into the national grid for greater project implementation simplicity.

Technical and financial: The status of landfill gas to electricity project is rapidly changing. Until recently the financial performance of projects has generally been insufficient to attract enough investment funding from financial institutes (i.e. the project is unattractive compared to the interest rates provided by local banks). With rising electricity prices and the potential for inclusion within the REIPPPP these projects will be receiving far greater attention.

Spare parts can be difficult to source in South Africa and often need shipping from overseas. Such hiccoughs can often result in lower than anticipated production levels. However, technical experience and expertise around LFG to electricity production has grown substantially in South Africa, enhancing project implementation (time and cost reductions).

Because methane is such a large emitter carbon opportunities cannot be overlooked. However, these may be risky (market price fluctuations) and the costs of engaging in that funding stream must be assessed. The process of registering with UNFCCC is long and costly, the cost of verification is high – gas emissions data needs to be collected every few seconds using rigorous monitoring methods and expensive software packages; data requires in depth analysis to explain irregularities for verification purposes plus auditing verification costs.
Case study 1: Pioneering landfill gas to electricity in Africa: eThekwini Municipality LFG to electricity*

**EThekwini Municipality** launched Africa’s first LFG to electricity project in Africa with the commissioning of their two major sites, Mariannhill and Bisasar Road, in 2006 and 2008 respectively. Bisasar Road landfill site is the busiest landfill in Africa accepting 3500 to 5500 tonnes of municipal waste daily. Bisasar has stopped receiving waste in 2016, but estimations are that it will continue producing gas for another 15 years.

The project is successfully producing 45 000 MWh/year and has resulted in the creation of 15 permanent technical jobs. A driving goal of the project was the reduction of CO₂ – and gaining of associated emissions reduction revenue streams. The carbon finance which the project had banked on, however, has proved disappointing. The collapse of the carbon market has rendered the sizeable efforts to secure Certified Emissions Reductions (CERs) meaningless.

Although carbon money has proved elusive, significant positive effects on local air and groundwater quality and safety have been achieved. 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. The project has been an invaluable ‘learning by doing’ site for LFG to electricity in Africa.

**Overview of project**

EThekwini LFGs 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:

- **The process of flaring** – burning methane to produce CO₂ (methane is approximately 21 times more potent a greenhouse gas than CO₂)
- **Offset of coal generated electricity through the use of methane powered generators for electricity** (reduction in electricity use from coal fired power stations)

At the time of development the project would not have been considered viable without the CDM funding. In fact, the generation of electricity was considered secondary when compared to the anticipated CDM credit income from the flaring process. This changed with the collapse of the carbon price from around 15 euros to a few cents per ton of CO₂

**Technical description**

At both sites the gas is collected using an array of wells and a pumping system. The harvested gas is burnt in spark ignition gas engines driving generators to produce electricity which is then fed into the municipal grid. Mariannhill takes 450 tons of waste per day, peaking at 700 tons. It has 17 vertical and 6 horizontal wells. A 1 MW generator engine is installed here. Bisasar Road used to take some 3 500 tons of waste per day, peaking at 5 000 tons. The site is composed of 77 vertical and horizontal wells each, and has 38 leachate pumps. It has the potential to generate 8MW, though installed engine capacity is currently 6.5 MW – made up from six gensets of 1 MW and one 500kW engine. The organic waste component within the landfill is around 35%.

The capacity factor has been 68%. Capital costs per MW installed in the project was around R16.8 million (in 2005–8 terms). Operational costs per MWh are around R290 (2015 terms).

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* This case study draws extensively from SALGA-GIZ Case Study Series: eThekwini Landfill Gas to Electricity Case Study: http://www.cityenergy.org.za/uploads/resource_340.pdf. Unless referenced otherwise, information is sourced from this document.
The project development: drivers, business model and role of the municipality

This has been a city-driven project, with added impetus from the involvement of the World Bank’s Prototype Carbon Fund (PCF) post the Johannesburg World Summit on Sustainable Development. The landfill sites are all municipal owned. As a pioneering endeavour the project took a lengthy 5 – 7 years from initial contact to commissioning of the sites. Many of these obstacles have since been reduced – notably the adjustment of the EIA requirement process (a full EIA is now no longer required for LFG to electricity smaller than 10MW) and the potential to not require the additional carbon finance stream for LFG development. Complex social issues relating to communities living alongside the landfill and challenging carbon finance ethics also required substantial time and effort.

Internal championing, communication and buy in at the highest level was instrumental to getting the project implemented. A strong financial, environmental and social case was made for the project. The persistent efforts of dedicated champions from within both the eThekwini Cleansing and Solid Waste Department and Electricity Department were the foundation of the project’s success. High level buy-in was also sought from the outset. The mayor (Cllr Mlaba) was involved directly in the negotiations with the World Bank around the sale of carbon credits generated by the project.

The project was designed as a procurement project, with the investment made by the Municipality, with additional finance obtained through the DTI/DOE and PCF. eThekwini Municipality thus owns the asset and the operation of the power plants is outsourced to service providers. The capital and operational costs are supported by two revenue streams: the sale of the electricity (or offset of the production cost against that of purchasing electricity from Eskom) and sale of the carbon credits.

The electricity sale was structured through a Power Purchase Agreement between the eThekwini Cleansing and Solid Waste Department (as project developers) and the Electricity Distribution Utility. Since this was an
internal contract there were no obstacles encountered. The sale had to be at a rate lower than Eskom Megaflex rate, which at the time was below cost recovery rates. Thus the project required additional revenue for financial viability.

The additional revenue for project viability was to be through the sale of carbon credits. However the development of a registered and verified CDM project added substantial complexity and involved a large array of external stakeholders. Given the collapse of carbon markets and the increase in Eskom Megaflex tariffs, this route may no longer be necessary and would save enormously on time and associated costs. The experience in eThekwini was that the cost of verification is significantly more than the financial benefit of the credits. The process of CDM registration was also long and costly and monitoring for verification is a very onerous process. Municipalities would do well to understand this fully before making project finance decisions based on carbon revenue streams.

While eThekwini Municipality has a dedicated staff member assigned to managing the plants, the complexity of the process of running the facilities required the drawing in of external expertise through an O&M contract. This contract was initially in place for 3 years, but has now been extended to a 5 year contract, with due public participation processes being undertaken.

Case study 2: Ekurhuleni Municipality LFG to electricity*

Ekurhuleni Metropolitan Municipality (EMM) has installed a 1 MW LFG to electricity plant at its Simmer and Jack landfill site in Germiston. This project, commissioned in September 2014, has the potential to reduce electricity purchases from Eskom by 7 GWh/year. It is part of the Electricity and Energy department’s endeavours to meet its 10% renewable energy target. Further installations are envisaged.

Technical overview

As in the case of eThekwini, the project has its roots in the initial groundwork and championship of the Waste Department who embarked on gas collection and flaring at 4 landfill sites, from 2005 – 2007. This first phase included the installation of vertical and horizontal gas wells, gas collector pipework, high temperature gas flares and a continuous gas monitoring system.

With the failure of the Carbon Development Mechanism to deliver financing for ongoing project development, the EMM council approved budget for the establishment of a LFG to electricity plant. In January 2013 a tender was published for the design, supply installation and commissioning of a LFG to electricity plant. The plant was commissioned in September 2014, due to various contracting delays. The 1 MW gas engine is installed in a container, which uses the landfill gas to generate electricity at 400V AC (alternating current). The power is then stepped up to 6.6kV AC and fed into the municipal distribution grid.

Capital cost per MW installed is estimated at R12.8 million (2015 terms) and operational costs per MWh at around R235. Payback on the electricity generation plant alone is estimated at around 4.5 years, with the lifespan of the plant around 12 years.

The site achieved a production of 594 MWh in its first month of production – around an 80% capacity factor. However production has been hampered by contractual challenges and the site has not been fully utilised to date. Gas is still flared on site as the gas production is greater than the generator can utilise. EMM has plans to increase site capacity to 2MW and to add additional electricity generation capacity on other sites.

Electricity is exported to the municipal grid, for ‘own use’ within the municipality. Although ‘own use’ may be defined as being exempt from generation licensing in terms of Schedule 2 of the Electricity Regulation Act, 4 of 2006, the Gas Act will require that this project is registered. EMM has made a formal application to the national regulator (NERSA).

**Business Model**

As with eThekwini, the municipality is the owner and developer of this project. The finance has come through their capex and opex budgets, and the service of gas extraction and flaring and of electricity generation are outsourced to service providers – at this stage still through short-term contracts.

Gas collection and flaring remains the business of the EMM Waste Department. While no performance standards are specified in the contracts with service providers, tight conditions around maintenance of operations (such as a 24 hour period turn around on fixing breakages or stoppages) ensure smooth operation. Similarly the energy generation component is based on a flat O&M rate, rather than performance (unit output) based. The different management of these contracts – by two different departments – has posed challenges, however, as the operations are so closely interlinked.

No actual electricity sale takes place. The electricity produced is simply seen as equivalent in value to the offset purchase of Eskom electricity. The municipality has plans to account for this internally and thereby enable some return to the Electricity and Energy department for further renewable energy generation investments.

**Carbon as a potential municipal revenue stream**

Despite the current low value of carbon, the municipality is still pursuing the carbon market as a potential revenue stream. This is driven through the Waste Department. A first verification of credits generated in underway. Initial approval by the Emissions Board was given in November 2014, and the municipality is hoping for issuance of Verified Emissions Reduction certificates (VERs). These can be sold into the voluntary market while
the lengthy CDM carbon credit certification process is underway. The municipality intends to put these VERs out to tender to test the market for interest in the project and to gauge the value of the emissions reductions. The municipality is also hoping that the carbon offsets programme, set to be implemented in South Africa alongside the introduction of the Carbon Tax, will open up a potential ER market with a much higher value than the current carbon market. Since project inception a total of 573 494 tCO₂eq (as at 29 February 2015) has been reduced to the atmosphere.

Case study 3: Waste diversion and electricity generation at Bronkhorstpruit Biogas project, Tshwane*

Cattle manure has traditionally been used as a source of biomass for heating and cooking. It can also be used to produce electricity. The Bronkhorstpruit Biogas Project (BBP) is the first large scale animal waste-to-energy project in South Africa, addressing clean and secure energy needs while resolving waste issues. BMW South Africa (the electricity off-taker) has signed a power purchasing agreement (PPA) with the project developer, Bio2Watt.

A prerequisite for the PPA was the Wheeling Agreement of the City of Tshwane and Eskom, for the transfer of the power between the project developer (Bio2Watt) and the power purchaser (BMW). The project aligns strongly with the City’s broad Sustainability Programme and as such the City has agreed to wheel the power and is also finalizing a plan to divert some of its organic waste to be processed directly in the biogas plant.

The process involves the Anaerobic digestion of agricultural waste in a Covered in Ground Anaerobic Reactor (CIGAR). The project is being constructed by the South-African construction and engineering company Bosch Projects. The Danish company ComBigaS (Complete Biogas Solutions) supplied the biogas technology.

Due to the size of the proposed development (a footprint of greater than 1-hectare of agricultural land), a full environmental impact assessment (EIA) had to be undertaken according to the Environmental Impact Assessment (EIA) regulation (2006).

> Figure 10: Beefcor feedlot

Source: Bosch Munitech

* This case study draws extensively from Supporting private renewable development in a municipality: waste diversion and wheeling of power for biogas to electricity project City of Tshwane Metropolitan Municipality: Bronkhorstpruit Biogas: http://www.cityenergy.org.za/uploads/resource_337.pdf. Unless referenced otherwise, information is sourced from this document.