Ekurhuleni Metropolitan Municipality, the City of Johannesburg and eThekwini Metropolitan Municipality have all three developed landfill gas to electricity projects. These aim to capture the methane from their landfill sites to generate electricity. The gas capture has also greatly improved local air quality and the environmental conditions of the communities living alongside or nearby the site.

The 3 projects studied 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.

This factsheet aims at summarising the data available from these 3 projects and drawing some generic lessons learnt which could be valuable for other municipalities willing to explore similar opportunities.

**Project Overview**

The three projects initially started with gas collection and flaring as a means to reduce greenhouse gas emissions and improve air quality around the landfills. The generation of electricity from the collected gas came as a second stage. Landfill gas extraction and flaring falls under the responsibility of the waste department of the municipality, while the electricity or energy department would be involved in the gas to electricity phase. Such projects require advanced contracts and sometimes innovative financing concepts, to ensure that all the risks are optimally understood and managed. Developing a landfill gas to electricity project would thus require close cooperation between several municipal departments, including financial and supply chain management.

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).

As waste management processes improve, less and less waste will be brought to landfills. In the future, landfill gas to electricity projects will not be needed anymore as one can hope that there will be close to no waste brought to landfills. However, the waste which has already been landfilled will keep producing gas for the next 12 to 20 years. Implementing gas to electricity in landfill should thus be seen as a solution needed to limit greenhouse gases emissions in landfills for the next 20 / 25 years and should be developed in parallel with integrated and alternative waste management strategies.
**Technology**

Landfill gas to electricity

**From initial studies to commissioning**

Between 3 and 8 years, depending on the complexity of the project.

**Capacity**

From 1 MW, to ensure commercial viability

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**Owners**

Often the municipality remains the owner. However in a BOOT model a service provider may initially own the asset before transferring them to the municipality.

**Financers**

The municipality, with capital budget expenditure, through loans or grants, or the service provider in case of a BOOT model

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**Project delivery model**

Municipal project, with O&M contract outsourced to a service provider or a Build, Own, Operate and Transfer (BOOT) model

**Electricity production**

Generally electricity is fed into the municipal grid. In the case of Johannesburg, electricity is sold to Eskom through the REIPPPP.

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**Some Indicators**

**Capacity factor**

\[ \text{capacity factor} = \frac{\text{actual output}}{\text{potential output at full capacity}} \]

Electricity can be produced as base-load, i.e. with a capacity factor of up to 95%.

**Capital cost per MW installed**

(MZAR/MW installed)

Between R 12 and 18 million (for both gas and electricity component)

**Operational cost per MW installed**

(ZAR/MW installed/month)

Between R 140 000 and R 230 000

**Operational costs per MWh**

(ZAR/MWh)

Between R 230 and R 330

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The calculations are high level based on average data and limited available information. Comparison between projects is risky and should not be done without full understanding of the projects and their particularities.

All values are projected and not actual since the projects are still under construction.
Technical Description

Landfill gas (mostly methane and carbon dioxide) is produced during the anaerobic decomposition of the organic waste in landfill sites.

**Phase 1: landfill gas extraction and flaring**

In the first stage, landfill gas is captured and destroyed by using a flare. Landfill gas is extracted continuously from the landfill body through a pipe network made up of perforated tubes that are drilled into the landfill. The installation includes vertical and horizontal gas wells, gas collector pipework, high temperature gas flares and continuous gas monitoring system.

Flaring landfill gas results in numerous benefits. It reduces the amount of methane emitted in the atmosphere. Methane is a greenhouse gas 21 times more potent than carbon dioxide. Capturing the methane also greatly improves air quality around the landfill. Monitoring the production of gas for a certain period – a year to take seasonality into account – allows for greater certainty of the quantity of gas produced. The results from the gas monitoring will allow the project developer and the landfill owner to better size the electricity generation unit.

It is possible to claim carbon credits for flaring landfill gas, even though processes are unclear at this stage (international markets, national carbon tax, and voluntary market). This phase of the project will generally be undertaken not necessarily for financial viability but mainly for the other associated benefits such as compliance with air quality threshold, environmental benefits and climate mitigation.

**Phase 2: electricity generation**

In the second stage, and based on the results of the gas monitoring system, 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. As in the first phase, the purpose of flaring is to dispose of the flammable constituents, particularly methane, safely and to control odours, health risks and adverse environmental and climate impacts.

Due to the increase in electricity pricing, the generation of electricity from landfill gas (phase 2 separately) is becoming financially viable and can be financed as a stand-alone project (project finance).

**Determining the gas and electricity potential**

The methane gas can be produced for up to 20 years after the waste has been landfilled. 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.

Ener-G systems gives the following three rules of thumb for estimating biogas production:

1. 100 000 ton of domestic waste in a landfill per annum is roughly equivalent to 1 MW
2. 600 m³/hour of gas can generate 1 MW of electricity
3. 1 ton of highly organic waste will produce at least 6 m³ of gas.

This is not an exact science - the actual gas yield is influenced by a variety of factors that include organic content and moisture in landfill. These rules give an indication of viability for municipalities considering similar projects.

However, these are just estimations, which should be used carefully. For example, in our 3 case studies, the Linbro Park landfill in Johannesburg receives around 360 000 tons per year and its potential is estimated at 3.3 MW. Robinson Deep receives 400 000 tons of waste per year for a potential of 5.5 MW, while Rietfontein in Ekurhuleni received 355 000 tons of waste in 2010/11 and studies show that the potential for electricity generation in the landfill is doubtful. These approximate values for gas and ultimately for 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.
The following project costs are presented to provide an indication of the project finance requirements. All costs are calculated per 1 MW installed. However, costs are stated in ZAR at the time of the investment (not constant ZAR), which makes it difficult and risky to compare the values obtained.

The costs greatly depend on the business model and contract setup between the municipality and the service(s) provider(s).

Developing phase 1 and 2 at the same time, with the same contractors, might be cost saving. This might be because risks are better controlled: the electricity generators also controls the gas production. However, the amounts of gas produced by the landfill are less certain.

When developing and evaluating the project, including during procurement, both upfront capital costs and operational and maintenance (O&M) costs should be taken into account. This was the case in most of the existing projects, since O&M was included in the initial contracts. Ideally, the feasibility study and procurement documents will be based on life cycle costs, i.e. the costs of the project from construction to decommissioning.

It should be noted that eThekwini costs include the costs linked to the Clean Development Mechanism (CDM) protocol and verifications, which initially aimed at raising additional financing for the project through international climate finance. This however had limited positive impact because of the decline of the price of carbon and high costs to meet the requirements of the CDM.

### Project Costs

<table>
<thead>
<tr>
<th></th>
<th>Capital Costs</th>
<th>Operational Costs</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Phase 1 (gas)</td>
<td>Phase 2 (electricity)</td>
</tr>
<tr>
<td><strong>eThekwini</strong></td>
<td>8 MZAR</td>
<td>11.3 MZAR</td>
</tr>
<tr>
<td><strong>Johannesburg</strong></td>
<td>13.8 MZAR</td>
<td>226 000 ZAR/month</td>
</tr>
<tr>
<td><strong>Ekurhuleni</strong></td>
<td>12 MZAR</td>
<td>12.8 MZAR</td>
</tr>
</tbody>
</table>

Extraction of landfill gas to be used for electricity generation

Original source: Ener-G
Project Business Model

The business models and funding solutions were specific to each project, with many similarities in the projects in Durban and Ekurhuleni. These 2 municipalities self-financed their projects: eThekwini used grants to conduct the feasibility study and raised loans from international finance institutions to develop the project, while Ekurhuleni entirely financed their (smaller) project in-house. On the other hand, the City of Johannesburg decided to minimise the use of municipal budget and opted for a Build, Own, Operate and Transfer (BOOT) model.

Design, supply, installation and commissioning
This contract is "classic": a company is appointed, through a tender process, to perform a service, in this case the design, supply, installation and commissioning of landfill gas to electricity 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. It is a procurement project with outsourcing of operations and maintenance: the municipality owns the asset and the operation of the power plants is outsourced to service providers.

Including O&M in the procurement ensures that the plant will be well maintained for a longer period of time (often 3 to 5 years) and will make it easier to correct potential defaults in the first years of operations. The payments linked to the O&M portion of the contract can be linked to performance or outputs.

Funding
In this case, the municipality is in charge of funding the project. This can be done through loans, grants received from external parties or internal capital expenditure budget.

Financial viability
It is necessary to ensure that the project is viable and that the municipality will be able to operate and maintain the asset over its lifespan. However, the main motivation for such project may not be return on investment or quick pay-back period. The municipality may decide to undertake such project mainly to improve air quality, reduce greenhouse gases emission or to increase security of electricity supply.

Risks
Most risks are born by the municipality, even though, through an O&M contract, part of the technical and financial risks can be shared with the service provider (performance based remuneration of the service provider).

If the project is developed in 2 phases or with different service providers, the interface and risk sharing mechanisms between the gas collection and electricity generation components must be well understood and managed, as electricity cannot be generated if gas is not produced and collected.

Electricity
The easiest option is for the plant to be grid-tied to the municipal distribution grid and electricity to be exported to the municipal grid at an effective 'offset' rate equivalent to average Eskom Megaflex tariffs. The value of the electricity produced, in other words, is represented through the saving achieved by reduced electricity imports from Eskom. An internal power purchase agreement can be set up between the different municipal departments (at average Eskom Megaflex rate). This ensure financial accounting for the project. The savings, if any, can be ring-fenced and used to finance new renewable energy projects.

This model is also feasible if the landfill site is connected to the Eskom grid, through a wheeling contract. Eskom has put in place rules for third party transportation of electricity, which allow for the electricity to be transported from a project (the landfill) to a consumer (the municipality).

Generation license
In the case where electricity is exported to the municipal grid, for own use within the municipality, the project may qualify for generation license exemption in terms of Schedule 2 of the Electricity Regulation Act, 4 of 2006. It is however recommended to contact the regulator NERSA during project preparation and keep them informed about the project development.

Build, own, operate and transfer
This is a stand-alone project with often long contract periods, up to 15 or 20 years. Such contract can be project-financed: the initial investment cost (in full or in part) is paid back by the revenue, or savings, derived from the project. The municipality can derive profit or royalties from such contract.

1 The case study called "Municipal Waste Water Treatment Works - Biogas to Energy (Co-Generation) in the City of Johannesburg, Northern Works Biogas to Energy" describes an example of such performance payment contract.
Project Timeline

**Pre-requisite**
Political commitment, waste and electricity departments on board, landfill site fully licensed, dedicated project manager.

**Studies**
Initial feasibility studies relating to gas extraction and flaring potential. Potential RFI. Council / mayoral decision to pursue the project and associated budget approved or funds sourced.

**Procurement**
Development, publication of the Request for Proposal. Can combine phase 1 (gas) and phase 2 (electricity) or procure separately. Design, supply, installation, commissioning, initial operation and maintenance.

**Construction**
The gas extraction and collection systems would take place first with the gas being monitored and flared. This phase is the phase most prone to contingencies.

**Start of O&M contract**
The gas extraction and collection systems would take place first with the gas being monitored and flared. This phase is the phase most prone to contingencies.

**Further O&M contract**
Further service providers will be appointed through tender process. MFMA section 33 to be adhered to if the contract is longer than 3 years. eThekwini metropolitan municipality and City of Johannesburg have gathered experience in this process and peer learning can be facilitated.

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**Funding**
The appointed contractor is responsible for the financing of the project, or part of it, and is paid during the course of the project. For a landfill gas to electricity, the contractor will be paid by selling the electricity generated. As such, the more electricity is produced, the more payment the contractor received. There is a built-in performance incentive.

**Financial viability**
The service provider will only enter into such contract if the expected benefits and Return on Investment (RoI) are high enough.

**Risks**
In such contracts, most risks may be transferred to the service provider. This however depends on each individual project and should be closely studied and analysed when drafting the contract. The interface and risk sharing mechanisms between the municipality and the service provider must be well managed, particularly with regard to the security of supply (waste or gas), depending on the project’s scope.

**Electricity**
The sale of electricity is the source of revenue for the whole project. The price of the production of electricity from landfill gas can still be marginally higher than the average purchase price of electricity from Eskom at Megaflex tariff. Municipalities are compelled by the Municipal Finance management Act (Act 56 of 2003 section 112) to procure services at the best value for money. Where electricity may be procured at lower rates from Eskom, municipalities have interpreted this as essentially ruling out purchase of higher cost renewable-sourced electricity.

In the case of Johannesburg, turning to the REIPPPP was an innovation arising out of necessity, but has proved an important step in the project. However, REIPPPP is a bidding process, and selection into the programme cannot be counted upon during project development by a municipality. Innovative funding mechanisms could be designed to facilitate the development of similar projects (see last section on opportunities).

**The gas**
Two legal opinions obtained by the City of Johannesburg confirmed that landfill gas is not a municipal asset and that their project did not constitute a PPP. In some cases, BOOT projects may fall into the PPP regulation. It is always advisable to contact NT in case of such innovative projects soon in the project development.

**Generation license**
In such scenario, the project developer will need to obtain an electricity generation license from Nersa, as the project is grid connected with the electricity being sold. The municipality may assist in the process. The project in Johannesburg obtained its license from the REIPPPP Programme and it is unclear at this stage whether other individual municipal projects would easily get generation licenses.

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2 For more details see full case study
Challenges, enablers and lessons learnt

Improved Service delivery
This is very often the main objective of a landfill gas to electricity project. The main reason to initiate a landfill gas to electricity project can be to comply with air quality licensing thresholds and improve the quality of life of local residents. Commercial viability can be seen as an added benefit facilitating the financing of the project and the electricity produced a further motivation towards security of supply.

Political and institutional commitment
The projects demonstrated the importance of strong political and institutional commitment to greenhouse gases emission reduction and the deployment of renewable energy. Project development is further facilitated by a well-developed, council-approved, Energy Strategy implemented by dedicated staff or by full integration of the project in the municipal Integrated Development Plan. Good internal communication and buy-in at the highest level was a key factor in getting the projects implemented. Having a dedicated project manager within the waste department together with strong assistance and commitment from the electricity department are crucial for the success of the project.

Permit and licensing processes
Thanks to adjustments to the environmental regulations, landfill gas projects that are less than 10MW no longer require a full EIA. This greatly facilitates the project development processes. Waste licenses and a fully compliant landfill site are necessary conditions for the project.

An electricity generation license is required for projects where the project is not developed by the municipality for its own use. There is currently no policy framework explicitly dealing with renewable energy projects outside of the REIPPPP and this might result in difficulties in obtaining the generation license.

Procurement, contracting
Contractual capacity has been the main challenge. The contracts can be complex (guarantees, performance, etc.) and strong internal capacity needed. However, the indication is that through undertaking such pioneering projects, staff capacity is rapidly developed.

Section 33 of the MFMA
For contracts longer than three years, additional obligations, including a public engagement process, are required before the municipality can sign the contract. Initially reluctant to enter into such process, some municipalities successful managed to enter into contracts longer than 3 years following all procedures. Support from senior management on supply chain management processes was crucial in meeting all the supply chain management requirements.

Carbon finance
The collapse of the anticipated emissions reduction/carbon credit revenue stream has presented challenges in the projects developed. Validating the project as a Clean Development Mechanism (CDM) with the UNFCCC is a lengthy process. The certification of carbon credits within the CDM is very costly and without an investor and committed buyer of the credits may remain on hold. The process to develop Voluntary Emission Reduction (VERs) to be sold on the voluntary carbon market may prove fruitful in time if the carbon prices gain some value. Some projects also expect that the carbon tax which may soon be introduced by the South African government could benefit the development of similar projects.

Financing
When the municipality can use its capital budget expenditure or raise loans to finance the project, it greatly facilitates project development and structuring. The use of existing municipal grants to finance landfill gas to electricity could be explored.

In case of a BOOT or for a PPP, the service provider can finance the investment costs. The existing projects have shown that it is innovative, feasible and avoids burdening the municipal budget. It also leads to a risk-sharing arrangement beneficial to the municipality. Such business model are however more complex and take more time to put in place. The main challenge is to find willing buyer for the electricity, particularly if prices are above the average megaflex paid by the municipality. Innovative options should still be explored to facilitate the development of such projects.

Operational and technical challenges
Effective and optimal management of operations at the landfill site is crucial for the successful extraction of gas and consequent production of electricity. The landfills must be operated at the highest technical levels to ensure sufficient flow of gas.

Some spare parts can be difficult to source in South Africa. It is important to keep some spare parts at hand, for those regularly requires, to avoid delays in maintenance.

Risk sharing:
Risk management can be complex in projects where the service provider is reliant on feedstock from the municipality (waste or gas) to generate electricity. Risk sharing should be managed on a commercial basis, however this requires capacity and resources which may not exist in all municipalities.

Capacity building and job opportunities
These projects have resulted in capacity development within municipalities (procurement, contracting and technical skills), as well as skill development. At the same time the capacity developed and lessons learnt have been invaluable for the whole industry.

Generation unit at Mariannhill landfill site
Source: eThekwini municipality
**Brief overview of the 2 existing contracting models**

<table>
<thead>
<tr>
<th>Procurement project with outsourcing of O&amp;M</th>
<th>Build, Own, Operate and Transfer (BOOT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Municipality is the owner and appoints a service provider for the design, supply, installation and commissioning of landfill gas to electricity plant, as well as operation and maintenance.</td>
<td>The municipality appoints a service provider to build own and operate over a 10 to 20 years’ period. At the end of the contract, the assets are transferred to the municipality.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Funding</th>
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<tbody>
<tr>
<td>By the municipality, through loans, grants received from external parties or internal capital expenditure budget, included from national grants.</td>
<td>By the appointed contractor and potentially partially by the municipality. The contractor will be paid by selling the electricity generated. The municipality can derive profit or royalties from such contract.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Financial viability</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>The project must be viable and not burden the municipal budget. However, the main motivation for such project may not be return on investment or quick pay-back period but better service delivery.</td>
<td>The service provider will only enter into such contract if the expected benefits and Return on Investment (RoI) are high enough.</td>
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<thead>
<tr>
<th>Risks</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Most risks are born by the municipality, even though technical risk mitigation is possible through an O&amp;M contract.</td>
<td>Most risks may be transferred to the service provider. The main risk area is the interface between the municipality and the service provider, particularly with regard to the security of supply (waste or gas).</td>
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</table>

<table>
<thead>
<tr>
<th>Use of electricity</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Own use on the municipal grid.</td>
<td>Sold by the service provider who generates it to a third party, generally the municipality. With the cost to produce electricity from landfill gas still higher than Eskom Megaflex tariffs makes it difficult to finalise Power Purchase Agreement.</td>
</tr>
</tbody>
</table>

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<thead>
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<th>Generation license</th>
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<tbody>
<tr>
<td>May qualify for generation license exemption.</td>
<td>Electricity generation license from Nersa is a requirement.</td>
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</table>

<table>
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<th>Status of gas</th>
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<td>Two legal opinions obtained by the City of Johannesburg confirmed that landfill gas is not a municipal asset and that their project did not constitute a PPP . In some cases, BOOT projects may fall into the PPP regulation. It is always advisable to contact NT in case of such innovative projects soon in the project development.</td>
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Authors: Aurelie Ferry (SALGA), Sofja Giljova (GIZ), Megan Euston-Brown (SEA)

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