HARNESSING LANDFILL METHANE TO ADDRESS GLOBAL WARMING AND RENEWABLE ENERGY: AN OVERVIEW OF THE DURBAN CDM LANDFILL GAS TO ELECTRICITY PROJECT

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SUMMARY: A project is currently under development by the eThekwini Municipality which is aimed at addressing global warming and climate change which is a most serious environmental issue facing the world today. Africa is already suffering significant effects of this. The City (the eThekwini Municipality) is proposing to enter into a first project for Africa which will highlight success of the recent World Summit on Sustainable Development (WSSD, Johannesburg, 2002). The project is for the utilisation of landfill gas from three sites to yield annual 10MW. This paper initially describes the three project sites, the gas modelling and yield predictions, and utilisation technologies and options. It then goes on to describe in further detail the CDM (Climate Change Mechanism) and the financial viability of the eThekwini Municipality project.

1. INTRODUCTION

Global warming with climate change and rising sea levels should be a serious issue to all Governments around the world. The climate is changing and many dry regions are likely to get drier and wet regions wetter (Hoff, 2003). Hoff (2003) continues that the world's hydrological cycle is said to be intensifying and extreme weather events are increasing. It is now accepted that climate change due to mans actions is occurring, and measures need to be taken to control the rate of climate change and the impact from climate change. There is a lobby in the UK for nuclear power because it does not impact on climate change, despite the long term danger from radioactive waste.

According to the Kyoto Protocol (Dec 1997), there are six gases that have been listed as greenhouse gases (GHG) these being: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_20), hydrofluorocarbons (HFC's), perfluorocarbons (PFC's) and sulphur hexafluoride (SF_6). Landfill gas typically contains 60% CH_4 and 40% CO_2 as it is generated. CH_4 has at least 21 times more effect as a greenhouse gas than CO_2. Therefore, CH_4 has got to be a key gas to address in reducing global warming. Reducing CH_4 emissions has over 21 times the effect of reducing CO_2 emissions albeit that there are considerably more CO_2 emissions from industry and transport than CH_4 emissions.

EU countries, and the majority of first world countries, have legislation (Regulations) to control the emissions and combust landfill gas. When landfill gas is combusted the CH_4 is converted to CO_2. However, some countries do not have legislation which requires the combustion of landfill gas, and landfill gas is allowed to vent to atmosphere, allowing a greater impact on global warming. These countries qualify for the purchase of emission reductions (ERs). At present there is a demand for ERs which exceeds the supply, and the income received from ERs for landfill gas combustion can fund the extraction and utilisation of the gas, with a additional income to the authority.

eThekwini Municipality (Durban Solid Waste (DSW)) has three active landfill sites at Bisasar Road, Mariannhill and La Mercy. eThekwini Municipality recognised the need to control landfill gas control at these sites, notably Bisasar Road and Mariannhill which are respectively in and near urban areas, and already have some active landfill gas extraction and flaring. However, eThekwini Municipality also recognised the opportunity for income from selling ERs to fund the management of the landfill sites, together with conservation and social improvement.

Consequently, during the World Summit on Sustainable Development that was hosted by South Africa (WSSD, Johannesburg, 2002), officials from the Prototype Carbon Fund (PCF), a fund organisation managed by the World Bank, approached the DSW regarding the proposed development of a landfill gas utilisation project. Because of DSW's advanced research in collaboration with the University of Natal into the management of landfill gas emissions (Trois et al, 2001), the eThekwini Municipality were the first RSA municipal authority to be approached by the World Bank. The PCF fund receives contributions from several international corporations as well as national governments worldwide namely Canada, Finland, The Netherlands, Norway and Sweden (PCF, 2002). Following 2002 DSW have developed, negotiated and agreed an Emissions Reduction Trading Agreement (ERTA) with the World Bank and PCF, and this was signed off in June 2004 in Washington. DSW are now progressing with the implementation of their ERs schemes, with new landfill gas management works at the landfills (Note: the ERs for Bisasar Road are dependent upon final agreement of the EIA (Environmental Impact Assessment)).

2 THE PROJECT SITES

Current landfill gas collection and flaring projects constructed at the Bisasar Road and Mariannhill landfills only manage some 7% of the total gas yield. This proposed landfill gas utilisation project will realise the collection and destruction of in excess of 70% of the landfill gas from the sites.

2.1 The Bisasar Road landfill site

The 21 million cubic metre capacity Bisasar Road landfill was first established in early 1980 and is expected to serve the waste disposal needs of the City of Durban for up to another 15 years. Bisasar Road is arguably the busiest landfill on the African continent accepting a daily average of some 3,500 tons of MSW, which has peaked at some 5,200 tons.

There are currently 13 operational wells at the site and DWS predict that operations in 2004 will allow the installation of 20 new wells by December. Waste deposition will also see 4 of 13 currently operational wells to be covered. This will give a total of 29 operational wells by December 2004. Further wells will be provided as waste is disposed and the site is progressively restored from South to North. Some of the phase operations will also see the construction of temporary wells that will be covered by tipping in later years. Wells will be provided at around 50m spacings and given an active site area of 350,000m^2, the site is large enough to accommodate 130 wells. The final wells will be installed by 2016.

2.2 The Mariannhill landfill site

The Mariannhill Landfill was opened in July 1997 and is considered by DSW to be a "New Generation Landfill" (Strachan et al, 2002). This 4.4 million cubic metre capacity landfill has been located to "text-book standards", being well screened from the public eye by the natural topography and established growth of numerous large trees in the peripheral buffer zone. The site receives a daily average of some 700 tons of Municipal Solid Waste (MSW). A landfill gas extraction scheme, comprising six gas wells, linked to a 500Nm^3/hr flare unit, has been installed on the site. The site is currently producing around 170m3/hr landfill gas. The Mariannhill landfill has been approved as a National Conservancy Site (Strachan et al, 2002).

2.3 The La Mercy landfill site

The La Mercy landfill site has been operated as a *landfill* by DSW since 1996, with it previously being operated as an *open dump* by the designated local authority of the area. The site is unlined, it is situated on a sandy clay material and currently consists of two 'cells'. The projected landfill closure date for La Mercy is 2006. The total available surface area of this site is 72 000 m^2, as opposed to the 44 hectare and 18 hectare landfills of Bisasar Road and Mariannhill respectively. The site receives approximately 300 tonnes/day. Historical data suggests that prior to 1996 there was approximately 600 000m^3 of waste in place. As at April 2004 there will be approximately 1.15 million cubic metres of refuse in place in the landfill.

3.GAS MODEL AND GAS PREDICTIONS

3.1 Gas Generation Models

Two landfill gas generation models have been used to assess gas generation at the sites; the Environment Agency GasSim model and the Enviros model. The Environment Agency in the UK has been developing a gas circulation model for some years and this was trialled and then released in 2002. Enviros developed a gas generation model in the early 1990's with Oxford University. This has been proven since that date for a range of projects around the world. The Enviros model was developed out of six years of research undertaken in collaboration with Dr Alan Young of Oxford University which culminated in DoE project CWM040/92 entitled "Modelling Landfill Processes".
The full report is available on http://users.ox.ac.uk/ayoung/LF/cwm039b.pdf.

We have assessed gas generation for Bisasar Road and Mariannhill against the two models, and the La Mercy site against the GasSim model. The GasSim model is only used for the La Mercy site because it was decided to use the results from this model as it is more conservative that the Enviros model.

The rate of gas production at any time is a function of a number of variable factors including

- Composition and density of the waste
- Age of the waste
- Moisture content of the waste
- Temperature within the landfill
- Availability of nutrients
- PH/alkalinity of leachate

Although each of these factors is comparatively well understood, the interrelationships between them are not and it is not possible to describe the relationships with any certainty. For effective landfill gas management it is necessary to assess the future potential for gas production to predict the pattern and rate of gas extraction.

3.2 Gas Predictions

The accuracy of the model predictions are dependent upon the accuracy of the input information, i.e. waste arisings, types, moisture content, compaction, infiltration, etc. The Enviros model predicts a peak of some 30% more than the GasSim model, although it has a more rapid decay curve after the peak. The GasSim model has been used to calculate ERs as it is more conservative.

3.2.1 Bisasar Road

The GasSim model predicts a peak generation of 7,600m^3/hr in 2014. There are existing wells in old waste to the north of the site. Gas is currently being extracted from these at 350m^3/hr, and this has been taken as the baseline. The baseline yield has been predicted to reduce in accordance with the GasSim model.

A yield of 50m^3/hr for a newly constructed well at Bisasar Road has been taken. The landfill and wells are relatively deep. However, the gas yield from the wells will decrease exponentially over time and is expected to fall to a yield of about 30m^3/hr after 20 years. Wells will be maintained and progressively replaced as needed during their life. The maximum achievable extraction efficiency of the gas system is assumed to be 80% of the gas produced. Gas production and utilisation for Bisasar Road is summarised in Table 1, section 5 below..

3.2.2 Mariannhill

Waste is to be deposited at Mariannhill beyond 2024, and it is predicted that 1775m3/hr will be produced by 2024.

It is predicted that newly constructed wells will yield 50m3/hr. The landfill and wells are relatively deep. However, the yield for these wells will decrease exponentially and follow a similar trend to the wells at Bisasar Road. The yield from the wells has been calculated in the same manner as Bisasar Road.

3.3.3 La Mercy

Wells at La Mercy will be installed to extract the gas in the southern area of the site in 2004 and the northern area in 2006. The waste at La Mercy site is shallower than Bisasar Road and Mariannhill and a theoretical maximum of 30m^3/hr gas yield for each well has been taken. Gas production at La Mercy is calculated to peak at 770m^3/hr when the site is closed in 2006. Given that there will be 25 wells installed by 2006 the theoretical maximum yield for each well given 80% efficiency of gas collection can be calculated to be 23m^3/hr. After capping is complete gas extraction is taken to follow the gas production model curve at 80% efficiency.

4. UTILISATION OPTIONS ASSESSMENT

4.1 Options

There are basically three options for landfill gas utilisation i.e. direct end use; electricity generation; or indirect end use.

Direct end use as a fuel is the most cost efficient process for landfill gas, and was the first to utilise landfill gas. Landfill gas has been used as a direct end use replacement fuel in cement and brick kilns, bitumen production, leachate treatment, district heating (Stegman, 1996). Direct end use requires an end user within 2 to 3 km of the landfill site, preferably with a continuous demand similar to the gas energy, and preferably with a process that can use dirty, low calorific value gas.

The majority of landfill gas utilisation projects and around the world are electricity generation by containerised reciprocating engines. There have been landfill gas electricity schemes in the UK since 1984. Lean burn, turbocharger reciprocating engines e.g. Jenbacher, Caterpillar, Deutz; have now become established as the main suppliers. Dual fuel engines, supported by other gas, were used in the late 1980's, early 1990's, but these are not as cost effective as lean burn, single fuel engines.

A rule of thumb for sizing landfill gas engines is that 1MW will be produced by 670 m^3/hr landfill gas at 45% CH_4 (Couth 2000), although engines are becoming more efficient. Electricity can also be generated using gas turbines. Whilst gas turbines are more efficient than reciprocating engines, they require a greater supply of gas (greater 2500 m^3/hr), greater clean up of the gas, a much high input pressure, and are consequently less flexible than reciprocating engines for landfill gas utilisation. Puente Hills, one of the largest landfills in the USA, burns landfill gas to produce steam and drive a steam turbine.

There have been a number of projects around the world to upgrade landfill gas to a similar energy value to natural gas e.g. Holland (Coups et al,1996), USA (Monteirs, 1995), Brazil (Roe et al, 1998). To do this, landfill gas needs to be dried, and have CO_2, sulphur and halogenated components removed. However, these have not been significantly developed to date.

4.2 Assessment

Bisasar Road landfill is near a commercial area and an investigation was made as to whether there were any industries which could utilise the gas. None were found. Hence electricity generation is being progressed.

Mariannhill and La Mercy landfill are more rural and the only option for them is electricity generation.

It is predicted that sufficient gas will be extracted for at least 6MW at Bisasar Road and 1.5MW at Mariannhill. This will be provided by modular units, built up over time. It is considered financially viable to install an engine at La Mercy and provide electrical connect to the site. A 0.5MW engine is proposed, but this will be reviewed when the gas extraction system has been commissioned. The units will not be installed until the gas yield has been confirmed by extraction.

5. CERTIFIED EMISSION REDUCTION (CER)

CER, in terms of carbon dioxide equivalent, for each of the three sites is shown below. The total CERs for the three sites is given in the Summary at the beginning of this paper.

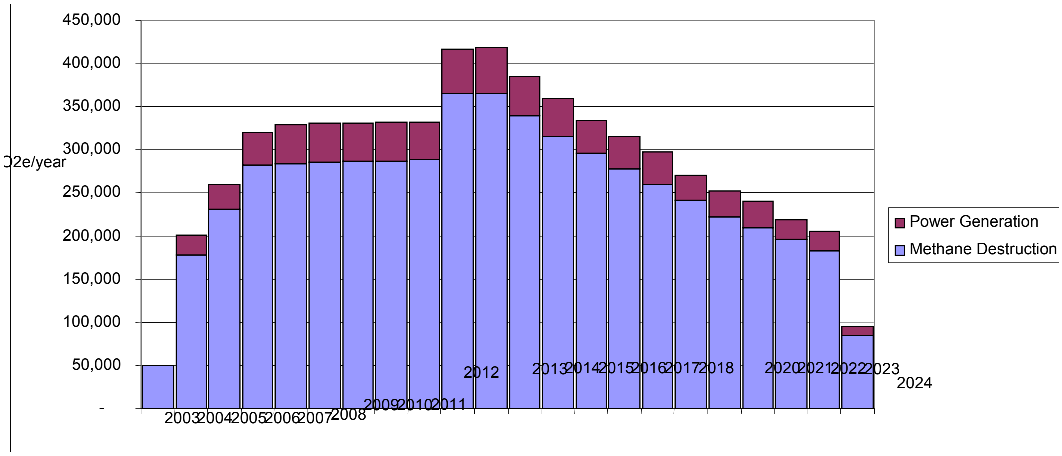

Figure 1 CER Generation Profile at Bisasar Landfill

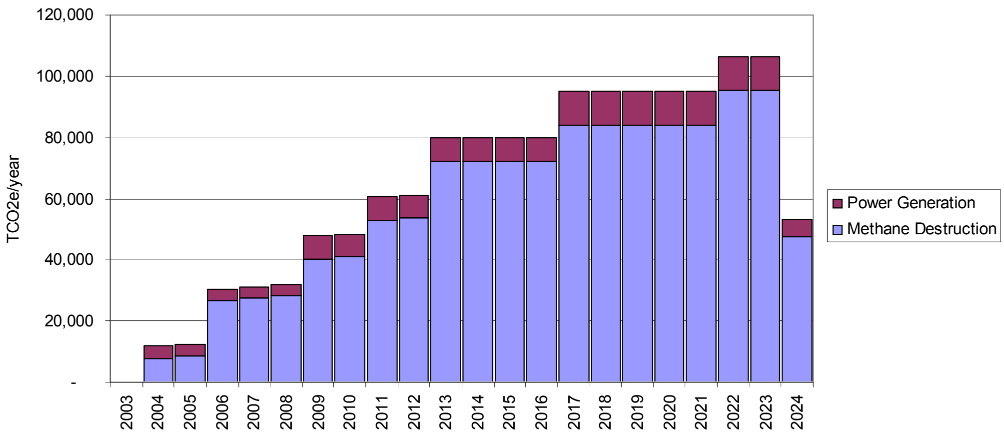

Figure 2 CER Generation Profile at MarainHill Landfill

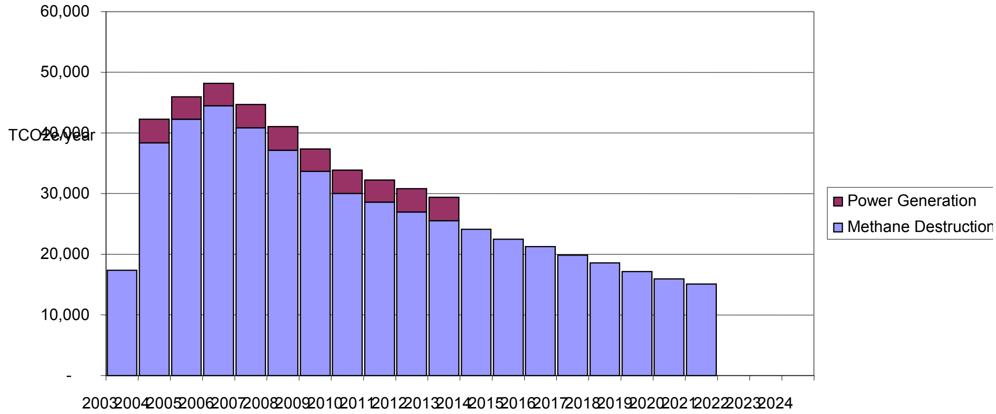

Figure 3 CER Generation Profile at La Mercy Landfill

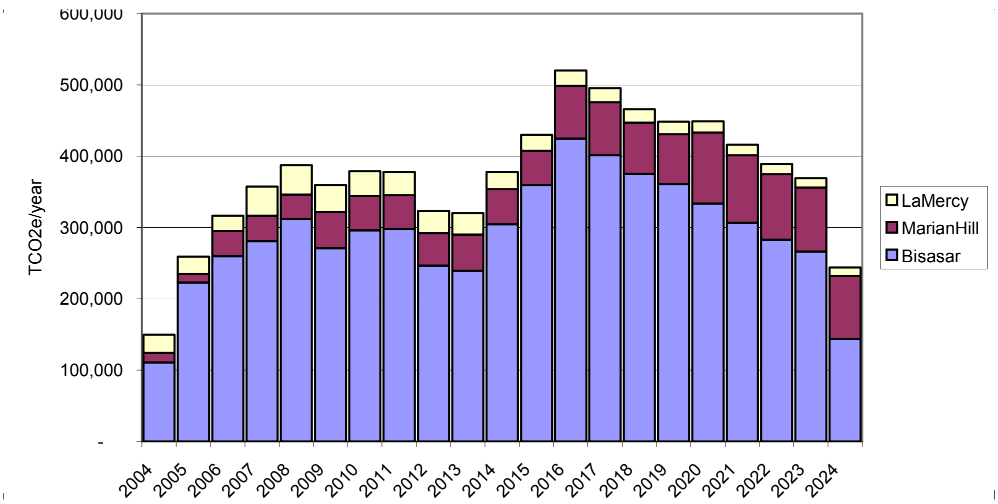

Figure 4: CER Generation Profile, total for 3 landfills.

Table 1: Total proposed emission reductions (ER) for the Durban CDM project

Site	**Methane Destruction**	**Electricity Generation**	**TOTALS**
Bisasar Road	5,295,296	800,704	6,096,000
Mariannhill	1,112,568	112,344	1,224,912
La Mercy	488,972	24,511	513,483
TOTALS	**6,896,836**	**937,559**	**7,834,395**

Note: ER Figures shown represent tons of CO_2 equivalent that are predicted for 21 years from 2003.

6. FINANCIAL VIABILITY

6.1 CERs and the PCF

The CDM is one of three Flexibility Mechanisms under the Kyoto Protocol, along with Emissions Trading and Joint Implementation (JI). The CDM allows developed and industrialised countries (Annex 1 countries) to invest in projects in developing countries that would realise GHG emission reductions (SACAN, 2002). Industrialised countries may then use such Certified Emission Reductions (CER), generated under the CDM, to contribute to compliance with their own emission reduction commitments.

In South Africa (RSA), most of the electrical power is generated by the parasitical company Eskom through coal-fired power plants. Durban currently purchases electrical power for an overall unit purchase price of R0.12 per KWh (SA Rand – approximately $0.015 US). Following several investigations into the utilisation of landfill gas by DSW, no project has been deemed to be financially viable. With particular regard to electrical generation from landfill gas, a unit selling price of no less than R0.25 per KWh could be offered to the electricity department. Indeed this would require a financial "top-up" of no less than 100% for any proposed LANDFILL GAS-to-electricity-generation project.

6.2 PCF, World Banking

ER credits will however make the utilisation of landfill viable, and successful development of this project should provide an internal rate of return in excess of 25% for the City. The project agreement will be for the sale of 3.8 million tons emission reductions, or also referred to as "carbon dioxide equivalents (CO_2eq)" at the rate of $3.95 per ton over the maximum period of 21 years. Of this amount, it is agreed that $0.20 per ton must be credited to a social benefit. In this regard the PCF has agreed that the total amount that the project will generate for the social benefit project may be payable "up front". The City is to identify suitable community projects for this social benefit payment, which are to meet with the City's sustainable development criteria. Additionally, the project will facilitate the allocation of capital funds to enable the extraction of the landfill gasses which have caused distinct odour concerns to surrounding communities (Stretch et al, 2001).

Financial projections for the delivery of 3.8 million tons of ER, indicate a total project cost of R150 million which is the summation of capital expenditure of R64 million and operating costs of R86 million. The anticipated revenue from the project is R205 million which is the summation of an ER sales to the PCF totalling R114 million and R91 million from the sale of electricity to the grid. This would realise a net profit to the City of R55 million over the expected agreement period of 12 years. However, the project may produce ongoing significant profits by way of the sale of Certified Emissions Reductions (CER) to other buyers on the world market. The preliminary project design works have already been completed and procurement of the gas management and utilisation contracts is asked to progress.

7. CONCLUSIONS

Subsequent to South Africa's ratification of the Kyoto Protocol, and since South Africa's recent signing of a Host Country agreement, the availability of "Carbon Finance" has realised the financial viability of landfill-gas-to-electricity-generation projects in Africa. Methane gas, a major constituent of landfill gas, is a distinctly serious greenhouse gas and such projects, if realised, will assist towards global emission reductions (ER) of GHG. The City of Durban is set to pioneer the CDM-pathway with what may be Africa's first CDM project, with a first Landfill Gas to Electricity generation project for the continent. Indeed the project is a prototype, which is suitably the name of the World Bank's fund organisation that is to provide "Carbon Finance" for this project, namely The Prototype Carbon Fund (PCF). The project engineering and associated project financials are well established, and the City has signed Emission Reductions Purchase

Agreement (ERPA) with the PCF. The project, incorporating three landfills will harness LANDFILL GAS to be fed to spark-ignition electrical generating units for a planned power production of over 8MW. It is anticipated that up to 7.7 million tons of certified emission reductions (CER) could be realised by the project, albeit that the PCF agreement is for the purchase of 3.8 million tons of ER. Indeed, it is hoped by all parties that the project will become a CDM project, following approval by the CDM executive board of the UNFCCC, and kick-start similar projects on the African continent.

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