THE PROTOTYPE CARBON FUND

Durban, South Africa
Landfill Gas to Electricity

Baseline Study

Revised Draft
July, 2003

1 Purpose of the Baseline Study

The provisions of the Kyoto Protocol require that "Reductions in emissions (…) be additional to any that would occur in the absence of the certified project activity." The purpose of this study is to determine the baseline scenario for each GHG component of the Durban Landfill-Gas-to-Energy-Project and to explain the reasons for the selected baseline in a transparent manner.

The baseline scenario is defined as the most probable future development in the absence of the proposed CDM activity. Being counterfactual in nature, some aspects of the baseline scenario cannot be observed and thus remain uncertain. In order not to exaggerate the emission reductions achieved by the project, the study takes a conservative approach whenever assumptions about future developments need to be made.

The Durban Landfill-gas-to-energy-project intends to operate as a CDM project under Article 12 of the Kyoto Protocol and as such will have to comply with all requirements and guidelines for CDM projects and governing the creation of Certified Emission Reductions (CER).

2 Description of the Project

2.1 Aim of the project

The project consists in an enhanced collection of landfill gas at three landfill sites of the municipality of Durban and the use of the recovered gas to produce electricity. The produced electricity will be fed into the municipal grid and replace electricity that the municipal electric company is buying from other suppliers. Currently, the Mariannhill and the Bisasar Road landfills collect and flare a portion of the methane generated for local, site specific reasons. The third landfill site, La Mercy, which is located far away from residential areas, only has passive venting in place to ensure that the concentration of landfill gas does not reach hazardous levels. The proposed project will substantially upgrade the current low 7.4% efficiency of the collection system (that is only a partial collection system), rising to about 83% collection efficiency at the peak in 2012, and dropping in the long-term down to about 45% collection efficiency at the end of the commercial project life.

2.2 The GHG components

Greenhouse gases targeted by the project are methane (CH_4) and CO_2. The project results in an increased capture of landfill gas which is composed of about 40-60% methane, the majority of which would otherwise be released into the atmosphere, progressively over time. Second, electricity generated from landfill gas will displace electricity from the grid which in South Africa largely originates from the burning of coal and thereby reducing CO_2 emissions.

2.3 Project location

While the La Mercy site is located at 35 km north of Durban, the Mariannhill and the Bisasar Road landfill sites are both adjacent to the metropolitan area. The Mariannhill site is separated by a hill from residential areas. The Bisasar Road landfill site is situated only 7km from the Durban CBD (Central Business District). The Mariannhill landfill site is located in the western area of the Durban unicity around 20 km to the west of Durban in the Metro area formerly called the Inner West City Council (IWCC).

Durban is geographically located in the southeast region of South Africa on the Indian Ocean coast. The Durban metropolitan area is South Africa's second-largest industrial hub and one of the country's fastest growing urban centers with a population of about 2.3 million.

2.4 Operation of the project

The project will be implemented by Durban Solid Waste (DSW) which is the municipal solid waste department of eThekwini Municipality. The electricity produced from the landfill gas will be sold to the municipal electricity department, eThekwini Electricity. Power purchase discussions have been initiated between DSW and eThekwini Electricity with no technical hurdles identified. The main issue will be the price of the electricity being equal to or below that purchased by eThekwini Electricity from other suppliers. The eThekwini Electricity purchases its electricity primarily from Eskom, the national electricity utility company.

2.5 Basic characteristics

The proposed project comprises the installation of approximately 180 production wells for landfill gas extraction at the three landfill sites. They will be allocated according to the following scheme:

Table 1: Allocation of gas extraction wells

Landfill site	Existing wells	Wells added through project	Final amount of wells
Bisasar Road	9 safety* 0 production	110** production	9 safety 110 production
Mariannhill	6 production	30 production	36 production
La Mercy	0	40 production	40 production
Total	**9 safety** **6 production**	**180 production**	**9 safety** **186 production**

* Safety curtain and production wells differ in terms of location and operation. In general, production wells are more productive than safety curtain wells since they are located where a maximum of methane can be expected. Safety curtain wells, on the other hand, are based at the side of the landfill to prevent odor nuisances and subsoil migration of LFG to neighboring areas. These are operated with no regard to optimizing methane content for energy recovery, pulling in excess air for odor control and/or safety purposes. When estimating the potential for gas recovery, a distinction needs to be made between production and safety curtain wells.
** This includes 13 wells currently being commissioned. Evidence, that they have been commissioned in view of acquiring carbon finance can be provided.

While some of the wells will be put in place at project start, other wells will be added later on as the landfills' working surface expands. The project plan for installing new wells assumes starting well installation in the calendar year 2003 with the installation of 20 additional wells at Bisasar Road bringing the total to 42 by year end, 1 additional well at Mariannhill[1] bringing the total to 7, and all of the planned 40 wells at La Mercy. Adequate flare capacity would also be installed while waiting on engine-generator delivery and installation. Also, with the exhaustion of older wells new wells have to be added to ensure a sufficient amount of gas for electricity production. The wells will be spread throughout the whole landfill site and be located especially at the deepest parts of the landfills where the greatest amount of methane can be expected. Besides the gas extraction purpose, the wells will also be equipped for leachate removal. Because the installation of wells will be guided by the intent to optimize gas formation and recovery but will be limited by civil engineering realities, the number of wells and timing is to be considered as the current plan and that some limited modification of location and numbers is possible over a 21 year period.

The project further involves the installation of a total capacity of around 10 MW[2] gas-fired electricity generators (spark-ignition piston engine generators) over time, which will be located in units of 1 MW at all three sites. At an 85% annual capacity factor a maximum of 67.8 GWh per year will be delivered to the grid.[3] Based on a methane recovery projection plan additional capacity could be added during the project lifetime.

1 This assumes that none of the existing 6 wells must be replaced.
2 In order to guarantee a firm working capacity some spare units will be put in place so that the overall installed capacity may reach 12 MW.
3 Suppliers of the generators have indicated that the actual capacity factor can be as high as 96-98%.

2.6 Project lifetime

The project lifetime is the period of time during which the project can potentially generate electricity for commercial purposes based on the available LFG. In the case of the Durban Landfill-Gas-to-Energy-Project the emission reductions stem from the methane capture with conversion to CO_2 and the displacement of coal-based energy from the grid. The production of methane in landfills can theoretically continue in excess of 30 years but, after reaching its peak, is a decreasing function in time. Although the project could potentially generate emission reductions for a very long time period it will end when the recoverable amount of methane left in the landfill becomes insignificant. While the La Mercy landfill is soon to be closed, the Bisasar Road and Mariannhill landfills are sized and operated to be used for up to 15 more years. The 3 landfills currently receive as much as 5,000 tons per day of municipal solid waste while averaging well over 3,500 tons per day. That amount will continue to increase in the near-term. The biggest bulk of methane extraction is expected to occur over the first seven years after project start. However, the extracted methane may be sufficient for the purpose of electricity production for as much as 15-20 years. The gas fired engines have a conservatively projected useful life of 10 years; the engines would have to be replaced at around this time to permit a continuation of the commercial operations of the electricity generation activity.

2.7 Crediting period

The Marrakech Accords state that project participants shall select a crediting period for a proposed project activity from the following:

a) A maximum of seven years which may be renewed at most two times, provided that, for each renewal, a designated operational entity determines and informs the Executive Board that the original project baseline is still valid or has been updated taking account of new data where applicable; or
b) A maximum of ten years with no option of renewal.

Given its economic and technical lifetime projection **the project is opting for a crediting period of 21 years.**

2.8 Project boundaries

The project boundaries are limited to the geographic boundaries of the three landfills sites. The following project activities and emission sources are considered within the project boundaries:

- Landfill gas production from the landfills through production and safety curtain wells
- Landfill gas collection using gas pumps and pipelines
- Landfill gas flaring
- Combustion of landfill gas in engines and electricity generation for on site consumption and for sale

Other sources of greenhouse gas emissions within the project boundaries are not affected by the project activity.

2.9 System boundaries

For assessment of the emission reductions from displaced grid-electricity, the system boundaries to be considered include the national grid, i.e. the power suppliers that deliver electricity to the city of Durban. The bulk of this supply is from South African regional coal-fired power plants located long distances from Durban. The interconnection is through high voltage transmission lines. EThekwini Electricity buys 99.99% of its power (approximately 10 000 GWh per year at a maximum demand of 1, 600 MVA) from Eskom. South Africa’s national grid is partly interconnected with neighboring countries. Being a net exporter of power, the additional capacity generated through the project however mainly affects power generation in South Africa. Thus, the system boundary to be considered is the national grid only.

3 Possible and feasible future scenarios

The first step in determining the baseline scenario consists in assessing the options available to the project operator. Only after full assessment of all possible scenarios it is possible to determine which of the scenarios is the most likely to occur in the absence of the project (baseline scenario). When assessing the possible options for landfill gas to electricity projects one has to take into account the future development of waste sector practices as well as options at hand for the production or purchase of electricity.

Apart from climate change considerations, landfill gases are collected and flared for reasons of local safety and odor control. Landfill gas contains over a hundred trace compounds that can be malodorous and persistent in that they tend to become absorbed onto textiles. The typical odor associated with landfill gas is not the result of its major components CH_4 and CO_2 but trace volatile reduced sulfur, volatile fatty acids and volatile amines. Some components of landfill gas such as hydrogen sulfide and concentrations of CO_2 above 3% by volume in air are hazardous to health. Methane is explosive if it reaches a concentration of 5%-15% by volume in air. Especially if landfill sites are located close to residential areas these negative environmental impacts give reason to control landfill gases. The local considerations for the collection of landfill gas have to be considered when drawing up possible scenarios.
The models used to predict the methane production from the Durban landfills are essentially First Order Decay models, Waste in Place Models, or a combination model based on both approaches. The models assume that the site is sealed, exceeds a certain depth, and is compacted to a specified density. The standard inputs to such models include at a minimum:

- kg or tons of waste in place
- average acceptance of waste in kg or tons for future years
- time since depositing started
- time since depositing stopped

- A decay constant (adjusted for climatic conditions i.e., temperature and rainfall)

The models all use a gas recovery factor ranging from 70 – 75% of the calculated gas produced. The Enviros/DSW approach used an additional factor of 80% of that to make the results extremely conservative and to deal with the uncertainty of the "future" waste composition.

3.1 Possible options

For the Durban landfill-gas-to-electricity project two possible baseline scenarios including the project alternative are identified.

Scenario 1: Business-as-usual

In the business-as-usual scenario the landfill operator continues to maintain the existing equipment and takes all necessary action to ensure local safety. This includes the installation of new safety curtain wells as they become necessary over time.

Today landfill gas extraction wells exist in two of the three landfills.

- The **La Mercy** site is an old landfill soon to be closed and far away from residential areas. So far, no efforts have been made to capture the landfill gas, and such efforts are also not envisaged or required
- The largest of the three, the **Bisasar Road** landfill currently has 9 safety curtain wells in place. The 13 production wells that are currently undergoing commissioning are not included in the business-as-usual scenario as DSW is installing them in view of acquiring carbon finance.
- The **Mariannhill** landfill site is separated from residential areas by a hill. Due to the usual wind direction blowing odors away from these areas, the landfill operator is not obliged to install safety curtain wells. The Mariannhill site does have 6 production wells in place[4]. The Mariannhill site was officially designated a Nature Conservancy in late 2002. This is the only landfill in South Africa granted such a status. In promoting public accessibility to the site the installed production wells serve to enhance its local value.

The landfill gas collected today is sent to flares where it is burnt with a design efficiency of 99%. Given the fact that the flames are blown out by the wind on average twice a month the real efficiency is however lower.

As far as the production of electricity is concerned, the municipal electric company, EThekwini Electricity, currently purchases most of its electricity from Eskom, the national utility company. The electricity comes from the high voltage system and after transformation to low voltage is injected into the municipal grid.

[4] These 6 wells have been recently evaluated by an independent and consultant as their performance has been substandard. They may have to be replaced and the inclusion in the baseline could be of question.

In the business-as-usual scenario

- the currently existing wells continue to operate until viable recovery of CH_4 ceases
- new wells are added only as deemed necessary for local safety
- landfill gas is being burned in flares with a 99% design efficiency
- EThekwini Electricity continues to purchase its electricity needs on the national market
- The municipal solid waste is deposited at the site in a manner defined by civil engineering considerations.

Scenario 2: Proposed project

In the project case, an estimate total of 180[5] additional production wells will be installed on all three landfill sites. The recovered methane will be used to generate electricity for the municipal grid (municipal auto-generation), thus replacing power purchases from Eskom. Remaining gas that cannot be used productively will be sent to flares.

In the project scenario:

- The methane recovery system is progressively upgraded from the current 7.4% of CH_4 produced to 83% in 2012, and thereafter progressively dropping in parallel to diminishing gas production to 44.3% in 2025 at the probable end of the commercial project life
- 10 MW capacity of landfill gas turbines are installed
- generated electricity is fed into the municipal grid, replacing power purchases from Eskom
- excess landfill gas is burned in flares with a 99% design efficiency level to maintain balance between engine demand and gas production system requirements and as a back-up for major engine outages
- the municipal solid waste is deposited at the site in a manner specifically designed to optimize gas formation and recovery.

Intermediate scenario:

An obvious third baseline scenario option for the project developer is to upgrade the methane collection system as in the project case but instead of utilizing the collected gas simply flare it. This option involves significant costs but generates no income in the absence of carbon finance. Because the economics of this intermediate options is inferior to the business-as-usual option, the intermediate scenario is clearly not the most likely baseline scenario to happen in the absence of the CDM activity. The intermediate scenario is therefore not further considered as a plausible baseline scenario and is not specified any further.

5 This is a tentative number and includes the 13 wells at Bisasar Road being commissioned at this time.

Other possible options for waste management:

Because of the high financial and environmental cost of developing new landfills further away from the city center and the high environmental and financial costs of shipping eThekwini Municipality's waste to the new landfills the city will continue with business as usual in the near-term until a new integrated waste management plan is formulated for future development. Because of the growing waste generation per capita in the Municipality, and the availability of the Bisasar Road and Mariannhill landfills to meet the demand in the near-term, there is no plan to close either the Bisasar Road site or the Mariannhill site during the PCF project life. The La Mercy site will likely close during the PCF project life, but the gas collection will continue throughout the project life.

Some limited composting is already done at the landfills to produce an input to the completed cell cover material. It does not appear to be financially viable to perform additional composting since the market for the product appears to be limited in the urban area. The landfills are and will continue to be operated with a cellular approach capping cells when reaching the desired fill level, and will under the new landfill gas recovery project be installing gas collection systems as the cells are capped.

Given the heavy residential population around the landfill and the very high financial cost of incineration system with or without energy recovery, the incineration option is not considered an environmentally or financially sound option by the Municipality at this time.

3.2 Regulatory Framework

The South African Department of Water Affairs & Forestry (DWAF) requires all landfill operators to monitor CO_2 and CH_4 concentrations. These must not exceed 1.0% in the case of CH_4 and 0.5% in the case of CO_2 by volume in air. The DWAF specifies the requirements for landfill operators as follows:

"The Permit Holder shall implement adequate measures to the satisfaction of the Regional Director, to ventilate or to prevent lateral migration of CH_4 gas generated in the site so that build up of dangerous concentrations is prevented. The concentration of flammable gas outside the waste disposal area and inside the Site shall not exceed 1% by volume in air and the concentration of CO_2 should not exceed 0.5% by volume in air, amended for Standard Temperature and Pressure." (from Landfill Permit Requirements)

The minimum requirements for waste disposal by landfill in South Africa include gas monitoring at all hazardous and large landfills, reporting to the department if the concentration of soil gas exceeds 1%, and permanent venting systems if the methane concentration exceeds 5% in air.

"While gas monitoring is a minimum requirement at all hazardous and large landfills, monitoring systems must be installed whenever potential gas problems exist. These must be monitored at three monthly intervals during the operation and at the discretion of the

Department after site closure. If the soil gas concentrations exceed 1% by volume at Standard Temperature and Pressure, the Department must be informed (…).
Methane concentration in the atmosphere inside buildings on or near the site should not exceed 1%(by volume) in air. If the methane levels are found to be between 0.1% and 1% in air then regular monitoring must be instituted. Methane levels on landfill boundaries should not exceed 5% in air. If the methane levels are found to be greater than 5% in air, then a permanent venting system should be implemented." (from Minimum Requirements for Waste Disposal by Landfill, Second Edition 1998.)

In the past, the environmental standards for landfills have been tightened on average every four years with the last revision dating back to 1998. Currently, there is no indication that the DWAF will require gas capture and flaring from permit holders in the near future being aware of the high costs that such a requirement would incur on landfill operators. The Bisasar Road, the Mariannhill and the Durban Mobeni landfills are currently the only landfill sites in South Africa which have installed an active gas flaring system. Rather, ongoing discussions indicate that the upcoming revision of the permit requirements will loosen the acceptable standard for CO_2 concentration.[6] The project operator will however need to monitor for changes in the regulations that might eventually require landfill gas capture.

3.3 Feasible options

Given the regulatory framework, both, the business-as-usual and the project scenario are feasible options. In both cases, the mandated concentration thresholds will not be exceeded. In the past, DSW has monitored the concentrations of CO2 and CH4 and has taken the necessary measures to ensure compliance with the regulations.
Current regulations do not mandate any gas capture and flaring but the concentration targets could be met through passive venting alone. However, if gas flaring becomes a legally mandated activity within the lifetime of the project, this becomes the baseline, and no emission reductions from flaring can be credited from that point on. The project operator is therefore required to monitor changes in the regulation.

4 Determination of the baseline scenario

To assess the most likely future development in the absence of the CDM activity a baseline methodology is applied to all feasible options. The baseline methodology is a rigorous approach to single out the most likely future development. According to the Executive Board of the CDM it is an application of one of the approaches defined in paragraph 48 of the Marrakech Accords.

4.1 The baseline methodology

The methodology proposed here to identify the baseline scenario is a cost-based **investment analysis for municipal auto-generation**. Its underlying behavioral

[6] It has become clear that drilling into certain areas of the landfill inevitably results in local CO_2 concentrations exceeding the threshold of 0.5%.

assumption is that of a rational investor who in the absence of the CDM would choose the most economically attractive option. The methodology builds on paragraph 48(b) "Emissions from a technology that represents an economically attractive course of action, taking into account barriers to investment". The investor in this project is the Durban municipality which acts through its operating entity Durban Solid Waste. In order to assess the most economic attractive option one has to compare the economics of each option from a municipal perspective. The proposed methodology thus reflects the decision making process of the investor. The methodology is justified as it is deemed the most appropriate for the kind of investment decision at hand.

The Durban landfill-gas-to-electricity-project is constructed as a grid-connected project. The project would be economically attractive, if Durban can generate electricity at a cost that is lower than the price it would have to pay for electricity purchased on the market through its operating entity EThekwini Electricity. If, however, the generation costs exceed the expected market price a rational investor would not be expected to invest in the project. In the latter case, the business-as-usual scenario would most likely prevail as baseline scenario. Because the project reduces emissions against this baseline scenario, the proposed project activity can be considered additional (environmental additionality).

4.2 Long run marginal costs and the expected market price for electricity

The municipal electric company, EThekwini Electricity, purchases its electricity primarily from Eskom, the national electricity utility company. Eskom electricity is among the lowest cost sources of electricity in the world, and the vast majority of Eskom generated electricity is derived from fully depreciated, mine-mouth coal-fired power stations. Ninety percent (90%) of the MWh generated by Eskom are derived from coal-steam power plants.

Today, the 24 hour weighted average tariff Eskom charges eThikwini Electricity is about 13.7 Rand cent (US$0.0156) per kWh with off peak tariffs being as low as US$0.00694. In order to estimate the long-term market price for electricity one needs to look at the development of the long run generation costs. If generation costs go up so will the price charged to customers. It is assumed, that Eskom will meet the demand for electricity at least cost. The least cost technology that can satisfy the projected demand over the project crediting period thus gives an indication for the development of the market price.

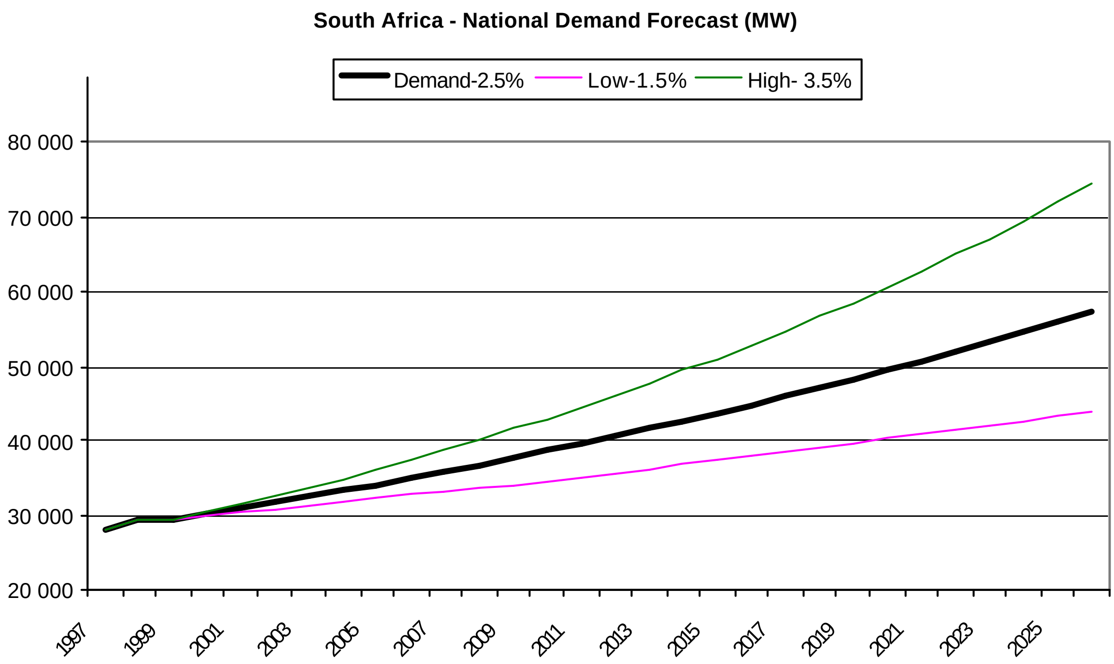
Supply and demand forecast

Today, South Africa's power generation capacity exceeds demand due to a decline in economic activity starting in the late 1980s and South Africa's large investment in power capacity in the 1970s and early 1980s. Assuming reasonable growth of 2.5%, the demand for electricity can be met by existing capacity over the next eight to nine years. South Africa has about 30,000 MW operating capacity and another 10,000 MW fully amortized excess capacity consisting of moth-balled coal-fired steam power plants which could easily be reactivated. As South Africa is currently investing in new gas pipeline capacity, it is possible that, at the time when demand has caught up with capacity (anticipated to

occur in eight or nine years), the country would build new gas-fired power capacity to meet the growing demand. Alternatively, the coal-fired power generation capacity could be expanded or some mixture of gas and coal derived power could be added.

According to Eskom's annual reports and statistical reports the 4 year average electricity demand growth from 1996 –2000 was only 1.5%, but the 1 year growth between 1999-2000 was 2.8%. Eskom's forecast of electricity demand is based on three scenarios of economic growth at 3.5%, 2.5% and 1.5%. With actual annual GDP growth of 2.7% (treasury department), the middle scenario seems the most realistic estimate.

Figure 1: Electricity demand forecast, South Africa 1997-2025



Source: NER

<u>Long run marginal costs with excess supply</u>

The long run marginal costs of the South African grid are determined by the generating costs of the existing capacity up to the point where investment in new capacity is required. That is, until existing capacity is exhausted and new capacity must he installed, the long-run marginal costs in South Africa are equivalent to the short-run marginal costs. The current generation costs per kWh in a fully depreciated Eskom power plant are estimated to be US$0.004. Depending on coal price, heating content and plant efficiency this could range from US$0.003 to US$0.005 per kWh.. Reactivation of the moth-balled power plants will lead to slightly higher generation costs. For the new World Bank Renewable Energy Program being developed in South Africa, the current Eskom generation costs are conservatively assumed to be US$0.0105 per kWh rising to no more

than US$0.0225 – in 5 to 7 years at the soonest – including the reactivation of moth-balled capacity.[7]

Long run marginal costs to meet growing future demand

Natural Gas from Mozambique is a possible least cost expansion option for Eskom to develop within South Africa after the demand has outgrown existing capacity. No political obstacles are to be expected since South African firms are already controlling many gas fields in Mozambique. This assumes that no new coal-fired capacity would be developed in South Africa. However, South Africa maintains the option to increase coal-fired power capacity and may pursue this option, if such coal-based capacity results in lower power generation costs than the use of pipeline gas. The coal-based option therefore serves as a low-cost fall back option, e.g. if gas prices increase significantly. Assuming gas-fired power expansion, with which landfill gas-derived electricity would have to compete, appears therefore as a conservative assumption.

The most likely gas price range for the gas transmitted by pipeline from the relatively nearby gas fields would be in the vicinity of US$2.00 – 2.50 per million Btu. That would put it close to the point where a Combined Cycle plant would be competitive with a Simple Cycle plant. For purposes here, both cases will be considered as will gas prices of $2.00 and $2.50 per million Btu, based on the calculation given in table 3. The financing term is a 10 years period.

Table 2: Generation costs of a simple and a combined cycle gas turbine

	Simple Cycle	Combined Cycle
Capital Cost – US$/MW	0.55	0.85
Efficiency - %	38	49
Heat Rate – Btu/kWh	8,980	6,965
Fuel Cost/kWh ($2 gas) - $/kWh	0.0179	0.0139
Fuel Cost/kWh ($2.5 gas) - $/kWh	0.0224	0.0174
O&M + admin.. Cost - $/kWh	0.0025	0.0030
Debt Service - $/kWh	0.0104	0.0161
Estimated LRMC	**US$0.0308 – 0.0353**	**US$0.0330 – 0.0365**

Source: Own calculations

The projected increase in power demand over time and the options to meet this demand results in an increase over time of generation costs in the South African power system (Table 3). The Table shows in Line (1) the current demand, which is met by existing mostly coal-based capacity in a situation of excess generation capacity, and the associated costs (mainly operating and maintenance costs). Line (2) shows the costs at a time when demand growth has caught up with existing capacity (projected in eight to

[7] See World Bank (2002) South Africa: Renewable Energy Market Transformation, Project Concept Document (PCD) Africa Regional Office, AFTEG

nine years). And Line (3) shows the long-run marginal costs that include the addition of new capacity to the system in order to meet further growing demand.

Table 3: LRMC in relation to MW demand

System condition	Demand	LRMC in US$ per kWh
(1) Current demand	Up to 30.000 MW	0.004-0.0105
(2) Demand catches up with existing capacity	Up to 40.000 MW	0.0225
(3) New capacity added	> 40.000 MW	0.0308-0.0365

Source: Own calculations based on World Bank (2002) South Africa: Renewable Energy Market Transformation, Project Concept Document (PCD) Africa Regional Office, AFTEG and Table 2.

There seems to be no shortage with respect to South Africa's natural gas purchase from Mozambique and Namibia, and coal as a fall-back option is abundant and low cost in South Africa. It is thus save to assume that over the project lifetime, long run marginal costs of the South African grid will not exceed US$0.0365. For the 10 year period until 2012 the generation costs will not likely exceed US$0.0225.

4.3 Identification of the baseline and project additionality

The project is considered to meet the CDM additionality requirements, if it is environmentally additional, i.e., if it reduced emissions against the baseline. This requires as the first condition that the project itself must not be part of the baseline scenario. Pursuant to the methodology applied here, and based on the above observation that only two scenarios are plausible baseline alternatives, the baseline scenario can be determined by demonstrating that the proposed project activity would not be undertaken in the absence of the CDM. In line with the cost-based investment analysis applied here as baseline method, the project would not be undertaken, if the long run market price for electricity is lower than the project's generation costs. The long run market price has been approximated in the previous section by South Africa's expected long run marginal costs. Thus, the test can be reformulated in whether the generation costs exceed the long run marginal costs of the South African grid during the crediting period.

The total cost for the project is estimated at US$12.20 million based on adjusted budget quotes.[8] This total includes all development costs including the Environmental Impact Assessment (EIA) preparation, the generation system installed costs, the interconnection costs, the gas well costs (not including the baseline wells), the financing costs including interest during construction, and an appropriate contingency of less than 10%.

The project is being structured to enable contracting for a firm annual delivery of 67.8 GWh. It is possible that the project will deliver more kWh per year if the buyer will accept it, but the (maximum annual) guaranteed amount will be 67.8 GWh per year.

[8] As reported in the DSW project spreadsheets prepared by Engineer Lindsay Strachan. The budget quotes suggested a price of over US13 million but historically final prices have been lower than the budget quotes received from these suppliers, hence a small downward adjustment has been made.

The first order indicator of the cost of production per kWh in a case wherein the fuel is considered free (other than capital cost recovery for the wells) is the debt service requirement for 100% debt finance.

Assumptions:

1. The Power Purchase Agreement will be for 10 years with options for 2 additional 5 year extensions.
2. The debt period is assumed to be 8 years to meet risk management criteria of typical financing sources.
3. The interest rate is assumed as 10% in US$ terms.

The annual debt service requirement (including repayment of principal) on a debt of US$12.20 million with an 8 year loan at 10% interest would be US$181,440 per million of debt or US$2,213,568 per year. That translates into a debt service component in the cost of production of US$0.0326 per kWh. A 10 year, 10% loan would reduce this down to US$0.0283 per kWh for sensitivity purposes. Because the lifetime of the engines (which form the main component of investment costs) is around 10 years, it can be assumed that a new loan will come into effect to purchase replacement engines at about the time when the first loan is fully repaid. Alternatively, equity financing of continued operation (including replacement engines) would arrive at a similar result, when taking depreciation and a reasonable return on investment into account.

The O&M cost per long term use of the piston engine generators is estimated to be US$0.008 per kWh produced including all labor and materials charges for routine maintenance and for major overhauls. Adding the O&M component cost to the debt service component cost results in an estimated cost of production of US$0.0406 per kWh. Adding in an administrative and insurance burden of US$0.0016 per kWh results in a total estimated cost of production of **US$0.0422 per kWh**.

While inputs such as equity can change the answer somewhat, this value is considered as an accurate, yet conservative indicator of the cost of production for the proposed facility. The cost calculation is considered conservative, in particular because it does not include considerations of risks associated with the operation of a landfill gas-to-electricity project such as technology and resource risks.

With the project's generation costs clearly exceeding the long run marginal costs of the South African grid, it is highly unlikely that the project would be implemented. Hence, the most likely course of action and development in the absence of the CDM, and thus the most likely baseline scenario, is the continuation of the business-as-usual scenario. Moreover, since the project is designed and clearly expected to generate emission reductions against this baseline, it also meets the ~~environmental~~ additionality criterion of the CDM.

4.4 The baseline scenario and its development over time

Given that the project would not be able to compete against power purchased from Eskom, the baseline scenario is determined to be the zero investment business-as-usual scenario as described in Section 3.1.

The above determined baseline scenario may develop and change over time, in particular if (a) the factors that influence the cost comparison change over time making power from the proposed project cheaper than Eskom's power, and (b) regulatory changes require the collection and flaring of landfill gas. It appears unlikely and therefore not reasonable to anticipate that developments other than those two would occur and result in changes in the baseline scenario and they are therefore not further considered.

(a) The cost comparison has been conducted on a long-term basis, which include the costs for power capacity additions in the ten to twenty year time frame. Given these projections and considering South Africa's traditional low cost electricity, it is unlikely to anticipate that the baseline methodology results in a different outcome at a future point in time within the 21 year crediting period. It is therefore not anticipated that the proposed project activity would be selected as baseline option during this period and no monitoring requirement in this regard is imposed in the monitoring plan.

(b) The regulatory framework in South Africa has been discussed above. Although the current operation of the three landfills fully complies with South Africa's landfill regulation, the latter is likely to be tightened over time, in which case more of the landfill gas may have to be collected and flared in the baseline scenario. The monitoring plan will therefore include a requirement to report on relevant regulatory changes and adjust the baseline scenario accordingly.

The baseline scenario can therefore be described as the business-as-usual scenario as outlined in Section 3.1 above with possible modifications over time that comply with future new regulatory requirements for landfills in South Africa.

4.5 Indirect emission effects (leakage)

Indirect emission effects are changes in emission levels that are caused by the project but occur outside of the baseline and project boundaries. Indirect emissions can be positive (decrease in emissions) or negative (increase in emissions). If indirect effects are negative and significant, calculated emission reductions within the project boundaries must be corrected for leakage.

In the case of the Durban landfill-gas-to-energy-project no significant negative leakage is identified, neither for the waste nor for the electricity related part of the project. The baseline wells and the system feeding the auto-generators (pipelines) are not likely to be the source of any leakage as the majority of the system is under negative pressure. If there are leaks in the pipeline, oxygen gets into the system which reduces the efficiency of the engines. Therefore, the project operator has a strict interest in reducing the amount of leakage. The oxygen content of the landfill gas is monitored on a routine basis. If any oxygen shows up in the sample, the project operator will search for the leak and fix it. In

any event, no significant amounts of methane should leak from the system due to the negative pressure. In the shorter positive pressure part of the system between the methane evacuation pump and the engines the normal site monitoring for ambient methane would quickly identify and leaks and any such leaks would be rapidly found and repaired. If air enters into the system this will not affect the accuracy of the measurements using the output of the engines. Furthermore, the MP includes a regular monitoring of the composition of landfill gas. It is acknowledged that the work associated with project preparation and implementation (drilling of wells, civil works, productions and maintenance of gas engine) will result in some CO2 emissions, however these emissions are considered minimal and therefore insignificant. Moreover, these emissions are probably more than off-set by the generally conservative calculation of emission reductions and the demonstration effect the project is likely to have. Consequently, no requirements to correct calculated emission reductions for leakage are included in the monitoring plan.

5. Additional environmental and social benefits

Article 12 of the Kyoto Protocol requires that a CDM project activity contributes to the sustainable development of the host country. Assessing the project's side effects on the local environment and on society is thus a key element for each CDM project. To ensure a maximum of local benefits the project's performance in relation to certain environmental and social issues will also be included in the Monitoring Plan.

With regard to the local environment the project has positive effects on local air and groundwater quality. By displacing electricity from the grid the project reduces emissions related to coal-fired power production which include sulfur oxides, nitrogen oxides and particulates. It also reduces the adverse impacts related to transportation of coal and coal-mining (dust and acid mine drainage). Near the landfill sites the project improves local air quality by further reducing the amount of landfill gas released into the atmosphere and thus reducing the risk of dangerous methane gas concentrations and of exposure of neighboring residents to odor. This is particularly relevant for the Bisasar Road and the Mariannhill landfill sites which are located close to residential areas. All gas capturing wells to be installed will be equipped for leachate removal which contributes to the protection of groundwater.

With regard to local employment the project will result in a small increase in the area of skilled jobs for operation and maintenance of the equipment.

The following table summarizes the Project's local and environmental, social and other benefits.

Table 4: Domestic and Local Project Benefits

"Issue" Area	Explanation
Local environmental benefits	– The Project will contribute to the South African integrated power system, replacing thermal generation with clean energy. – As a result of the Project, local air pollution will be reduced. – The project will allow for further expansion of existing schemes to re-introduce indigenous biodiversity and to reforest the periphery of the landfill site(s) and completed landfill phase areas.
Socio-economic benefits	– The Project will lead to net employment generation during the construction period and also during project operation. – The project will improve the quality of life of low-income classes (there is an informal settlement adjacent to one site) both through the elimination of potential safety and odor issues, and through the improvement of vegetative area on and around the site.
Capacity building	– Extensive pre-negotiations consultations have been carried out with Durban Solid Waste, the project sponsors, who will also attend a workshop to be conducted by the PCF at the Department of Environment and Tourism. – The project is the first CDM project for which the South African government has issued a letter of approval, hence the project preparation and implementation process is a template for in-country training and capacity building.
Technology transfer	– Introduction and demonstration of environmentally friendly waste management, emissions management, and power generation techniques is an explicit objective of the project. – The demonstration that ERs from renewable energy can earn additional income and the introduction of CDM know-how is expected to raise environmental awareness and may create interest in low carbon energy technologies, leading to a number of replicable projects throughout the region.
Host Country criteria	The Government of South Africa is still in the process of defining requirements for CDM projects. A Memorandum of Understanding with the RSA has been obtained, and the Letter of Approval from the RSA has been received.
Sustainable Development Criteria	The Government of South Africa has developed a list of criteria to be used by the Secretariat when making a decision whether to approve a project or not. This list has also been applied in the approval process of the project
Environmental Impact Assessment (EIA)	The project EIAs will be carried out in accordance with South African law.

The Environmental Impact Assessment (EIA) for adding the gas extraction and generation projects to the 3 sites will be contracted for by the eThekwini Municipality after the receipt of the Letter of Approval from the National Designated Authority. The LOA was received by the municipality in early January 2003, hence the EIA contractor procurement should be commencing. The municipality has been advised of the requirement to follow World Bank Environmental and Social Guidelines in the preparation of the EIA in addition to any South African requirements