CLEAN DEVELOPMENT MECHANISM
PROJECT DESIGN DOCUMENT FORM (CDM-PDD)
Version 02 - in effect as of: 1 July 2004)

CONTENTS

Annexes

SECTION A. General description of project activity

A.1 Title of the project activity:

Manaus Landfill Gas Project

Document version number 1

2 December 2005

A.2. Description of the project activity:

The project will be developed by Conestoga-Rovers & Associates Capital Limited (CRA) at the Manaus Landfill (Site), originally called Aterro Municipal de Manaus. The Manaus Landfill has received non-hazardous solid municipal, industrial, commercial, institutional, and some agricultural wastes for approximately 20 years. The landfill normally emits carbon dioxide (CO_2) and methane (CH_4) into the atmosphere, with these compounds being generated by the anaerobic decomposition of the above-noted wastes placed at the site.

The project will involve construction of a landfill gas (LFG) collection and flaring system, and subsequently a power generation facility. In phase 1 of the project, the landfill gas collection and flaring system will be constructed. In phase 2, to commence a year later, the electrical generation facility will be constructed.

The LFG collection system will consist of a grid of horizontal trenches and vertical gas extraction wells, centrifugal blower(s), and all other supporting mechanical and electrical subsystems and appurtenances necessary to collect the LFG. The power generation facility will be comprised of state-of-the-art LFG engine-generator sets of high performance standards. The engine-generator sets will be the primary equipment to combust the collected LFG once the utilization facility is constructed. A fraction of the collected LFG will be diverted to the flare, which will be used as both a contingency backup unit and to combust any gas in excess of the fuel demand for the engines.

To combust the non-utilized LFG collected from the site, an enclosed LFG flare with full process controls and instrumentation will also be constructed and operated. This will be a state-of-the-art flare capable of providing sufficient temperature and retention time of the extracted landfill gas for complete destruction of hydrocarbons. Specifically, the retention time of the landfill gas within the enclosed flare will be 0.5 seconds at a temperature of 875^{o}C.

Purpose of the Project Activity:

The purpose of the proposed project activity is to collect landfill gas at the Manaus Landfill and combust the extracted LFG over a ten year-period utilizing LFG engines and a high-efficiency enclosed flare, thereby reducing greenhouse gas emissions (GHGs) and generating approximately 9,032,648 tonnes of Certified Emission Reductions (CERs).

Contribution of the Project Activity to Sustainable Development:

The project will make a strong contribution to sustainable development in Brasil. Over and above reducing emissions of GHGs and electricity generation, there are other benefits related to sustainable development as follows:

a) Contribution to human health and the environment:

With the combustion of landfill gas, the population living around the landfill will have an environment that is cleaner and healthier, with improved air quality and reduced risk due to landfill gas subsurface migration. Further, potential for fires resulting from uncontrolled landfill gas will be minimized, as will potential for groundwater contamination. Additionally, the electrical generation component of the project, to be implemented as a phase two, will displace energy derived from other sources such as fossil fuels, which contributes to environmental impacts locally.

b) Contribution to the improvement of working conditions and employment creation:

Starting with the construction phase, local manpower will be used during the implementation of the project. Local employment will be directly created during the construction phase of the project, which entails installation of vertical wells and assembly and operation of equipment such as blowers, flares, and engine-generators sets. All these jobs will be created fully obeying the current Brazilian employment legislation. During the operational phase, which will take place 24 hours/day, 7 days/week, there will be new jobs created locally for duties related to operations and maintenance, landscaping, plumbing, monitoring and security personnel. These people will be fully trained by CRA on their duties and tasks.

c) Contribution to income generation:

As one of the early projects in Brasil, the utilization of landfill gas at the Manaus Landfill will generate royalty revenue for the municipality of Manaus throughout the ten-year crediting period of the project.

d) Contribution to technological capacity building:

CRA will make available on its Web site (http://www.CRAworld.com) all information pertaining to the project activity and it is also ready to answer any questions regarding the project to whoever may be interested (municipalities, universities, and the general public) through the e-mail address: Manaus@CRAworld.com.

e) Contribution to regional integration and cooperation with other sectors:

Manaus will serve as a reference for other municipalities that are willing to implement similar projects at their landfill sites under the CDM incentive. Other sectors of the economy will be stimulated by the innovative nature of the project and the prospect of investing royalty monies to bring about social and environmental benefits. The electricity supply to the Manaus grid derived from the project activity will also contribute to local programs of expansion of electricity generation capacity, improving sustainable economic growth.

A.3. Project participants:

A list of the involved parties is indicated below.

Name of Party Involved (host indicates a host party)	Private and/or public entity(ies) project participants	The party involved wishes to be considered as project participant (Yes/No)*
Brasil (Host Country)	Prefeitura Municipal de Manaus, City of Manaus, State of Amazonas (Public Entity)	No
Canada	Conestoga-Rovers & Associates Capital Limited (Project Sponsor; Private Entity)	No
United Kingdom	BCG International (Private Entity)	No

* indicates project participant status of the party listed in first column of table

A.4. Technical description of the project activity:

A.4.1. Location of the project activity:

The project activities will take place at the Manaus Landfill in the City of Manaus, Brasil.

A.4.1.1. Host Party(ies):

The host country is Brasil.

A.4.1.2. Region/State/Province etc.:

The site is located within the State of Amazonas.

A.4.1.3. City/Town/Community etc:

The site is located within and owned by the City of Manaus.

A.4.1.4. Detail of physical location, including information allowing the unique identification of this project activity (maximum one page):

The Manaus Landfill (2^{o}57'29.92" South and 60^{o}00'54.74" West) is located 3.5 kilometres (km) north of the City of Manaus, State of Amazonas and east of Highway AM-10. The entire Site covers an area of 60 hectares (ha) and the current waste fill area of the site is approximately 41 ha in size.

A.4.2. Category(ies) of project activity:

The project activity will be a landfill gas emission reduction with power generation project under sectoral scope 1 (energy industry, renewable and non-renewable sources) and 13 (waste handling and disposal).

A.4.3. Technology to be employed by the project activity:

The technology used to gather the LFG is a grid of trenches and wells within the landfill, connected to a centralized blower system used to induce vacuum. Upon gathering the LFG, the methane component of the LFG is combusted in state-of-the-art, high-efficiency engine-generators or enclosed flares. The Global Warming Potential (GWP) of the LFG will thus be reduced by the destruction of the methane portion of the LFG.

Vertical gas extraction wells will be established in the waste material and will be connected to the blower system through a network of underground piping installed on and around the perimeter of the landfill. The extraction wells will be connected to the subheader or directly to the header through smaller diameter laterals. As the blower is operated, a vacuum is applied through the piping network, which in turn applies a vacuum to each well and extracts LFG out of the waste. The flow of gas can be controlled at each of the individual vertical extraction wells through the use of a valve located at the top of the well piping. Each well will be individually controlled to ensure that the collection system can be effectively set up and balanced. The system will be manually monitored and controlled and each wellhead will be equipped with a secure monitoring chamber and monitoring ports for gas composition, pressure, and temperature readings.

Horizontal collection trenches will be installed by excavating into the refuse. Horizontal collection trenching will be installed in an excavated trench lined with clear stone. Collection pipe within the trench will be perforated so that a vacuum can be applied and LFG drawn from the landfill. Horizontal collection trenches operate in a similar manner to vertical wells, with the main difference that the zone of influence for trenches is typically oval in shape in the vertical plane due to the higher horizontal permeability of the refuse compared to the vertical permeability. For horizontal collection trenches, the complete length of the trench will be monitored and adjusted at a single location at the connection point along a sub-header piping section. Individual trenches will be manually monitored and controlled to help with set-up and balancing of the LFG collection field. Controls for each trench will be located in a valve chamber installed in line with the trench which will include a secure monitoring chamber and monitoring ports for gas composition, pressure, and temperature readings.

Non-perforated LFG collection piping will be utilized to convey the LFG from the extraction wells and horizontal collection trenches to the gas control plant. The LFG collection piping consists of a perimeter header, sub-headers, and laterals. Header piping conveys the LFG collected from sub-header and horizontal collection trenching to the gas control plant. Sub-header piping conveys LFG from lateral piping to header piping, and lateral piping conveys LFG collected primarily at vertical extraction wells to sub-header piping.

At the gas control plant, the blower system will be equipped at all times to allow for regular down time for maintenance and to provide backup in the event of a component failure. The blower system will exert vacuum through the piping system to the system of vertical wells and horizontal trenches.

Extracted LFG will be sent to gas engine-generator sets or diverted to an enclosed flare for destruction of the methane component of the extracted landfill gas. All utilization or enclosed flare equipment will be high-efficiency state-of-the-art models available in the international market. Generated electricity will be supplied to the local electrical grid.

The proposed utilization facility will be comprised of gas engines specifically designed for landfill gas using and incorporating the newest technologies, achieving engine efficiencies above 40%. Associated equipment includes injection blower, gas chiller, condenser and after-cooler, coolant pumps, moisture separator and on-line gas analyzer. The on-site generated power will be delivered to the grid through hook-up connections.

The stack height of the flare will be specified to provide sufficient residence time for destruction of compounds in the gas at high temperature and in a controlled environment to destroy extracted methane. Flame temperature will be controlled by means of a system of automatically and manually controlled air inlet dampers and thermocouples located in the stack. Retention time of the landfill gas within the enclosed flare will be 0.5 seconds at a temperature of 875°C. Flaring is a proven technology for the combustion of landfill gas and has been demonstrated to be reliable and environmentally safe.

The industry standard destruction efficiencies for gas engines and enclosed flares are upwards of 99.99% for hydrocarbons.

A.4.4. Brief explanation of how the anthropogenic emissions of anthropogenic greenhouse gas (GHGs) by sources are to be reduced by the proposed CDM project activity, including why the emission reductions would not occur in the absence of the proposed project activity, taking into account national and/or sectoral policies and circumstances:

Anthropogenic emissions of GHG's occur at the Manaus Landfill when methane produced at the landfill is not destroyed.

The collection and destruction of the methane in the project activity will reduce GHG emissions from the "business as usual case" currently employed by the Manaus Landfill. The current practice at this landfill is to allow the uncontrolled release of LFG into the atmosphere. The LFG generated at the site consists approximately of 50% methane and 50% carbon dioxide, both known GHGs with Global Warming Potentials (GWP) values of 21 and 1, respectively. However, the carbon dioxide portion of landfill gas is considered to be biogenic in origin and part of the natural carbon cycle, and thus not considered an anthropogenic source of greenhouse gas.

Currently, there are no national or sector policies or regulations governing the release of LFG into the atmosphere. The proposed CDM project activity will establish a landfill gas collection and utilization system at the Manaus Landfill, thus generating emission reductions that satisfy all of the tests for creation of CERs over the extended life of the project. The proposed project activity will be associated with GHGs emission reductions derived from:

- Collection and destruction of the methane content of LFG; and
- Displacement of electricity that would be generated from other sources.

In the first phase of the project, a landfill gas collection and flaring system will be implemented to achieve destruction of the methane component. In the second phase of the project, to commence approximately one year subsequently, an electrical generation facility will be constructed that will similarly destroy the methane component and, further, displace electricity generated from fossil fuels.

It is important to note that the abovementioned GHGs emission reductions are additional to the current site conditions and current practices, and would have not occurred in the absence of the project; thus, the project complies with the concept of additionality defined under Kyoto's Clean Development Mechanism.

Over the 10-year period of credit certification, the anticipated total reductions in tonnes of CO_2 is estimated as 9,032,648 tonnes of CO_2 equivalent.

A.4.4.1. Estimated amount of emission reductions over the chosen crediting period:

By utilization of the LFG generated at the site, the proposed project is expected to generate 9,032,648 tonnes of emission reductions expressed as tonnes of CO_2e over the crediting period.

The annual expected amount of emission reductions generated over the entire project lifespan is indicated below:

Year	Annual estimation of emission reductions in tonnes of CO2 e
2006	199,576
2007	677,102
2008	801,824
2009	836,030
2010	871,054
2011	906,940
2012	943,749
2013	981,524
2014	1,020,350
2015	1,060,267
2016	734,232
Total estimated reductions (tonnes of CO_2e)	9,032,648
Total number of crediting years	10
Annual average over the crediting period of estimated reductions (tonnes of CO_2e)	903,264

A.4.5. Public funding of the project activity:

No public funding of any kind has been provided for this project.

SECTION B. Application of a baseline methodology

B.1. Title and reference of the approved baseline methodology applied to the project activity:

The baseline methodologies applied to this project are:

- The approved ACM0001 – Consolidated Baseline Methodology for Landfill Gas Project Activities; and
- The ACM0002 – Consolidated Baseline Methodology for Grid-Connected Electricity Generation from Renewable Sources.

B.1.1. Justification of the choice of the methodology and why it is applicable to the project activity:

ACM0001 was developed as a consolidated document that incorporates all previously-approved methodologies applicable to landfill gas project activities where the baseline scenario is the partial or total atmospheric release of landfill gas. This methodology is applicable to "landfill gas capture project activities where the baseline scenario is the partial or total atmospheric release of the gas and the project activities include situations such as: the captured gas is used to produce energy (e.g. electricity/thermal energy) and emission reductions are claimed for displacing or avoiding energy generation from other sources".

For the proposed project activity, the baseline scenario is the total atmospheric release of the gas, and the project activity is the utilization of the captured gas, where emission reductions will be claimed for displacing energy generation from other sources. As a result, ACM0001 is applicable to the project activity.

The consolidated methodology ACM0002 was developed based on elements of methodologies applicable to grid-connected electricity generation from renewable sources. ACM0002 is applicable to "electricity generation from landfill gas capture to the extent that it is combined with the approved Consolidated Baseline Methodology for Landfill Gas Project Activities (ACM0001)".

Since the proposed project activity will generate grid connected electricity from LFG capture, ACM0002 is therefore applicable to the extent that it is combined with ACM0001.

The CERs exchange mechanism provided under the CDM is considered a real and concrete incentive in the decision to proceed with the project activity and the project activity will not be initiated without registration as a CDM project.

B.2. Description of how the methodology is applied in the context of the project activity:

As mentioned above, based on the current LFG management practices at the site and the current environmental regulations in Brasil, the GHG emission reductions generated by the implementation of the project activity are considered fully additional.

There are no existing or pending regulatory requirements requiring the landfill site to implement any form of LFG emission reductions program. There is also no current system in place for landfill gas recovery and combustion or utilization at the site. Therefore, the project baseline is the uncontrolled release of the landfill gas into the atmosphere.

The greenhouse gas emission reductions achieved by the project activity during a given period are the difference between the amount of methane actually destroyed/combusted and the amount of methane that would have been destroyed/combusted in the absence of the project activity, times the GWP of methane. For this project, the baseline is the total release of landfill gas into the atmosphere.

B.3. Description of how the anthropogenic emissions of GHG by sources are reduced below those that would have occurred in the absence of the registered CDM project activity:

The ACM0001 methodology requires the use of the "Tool for the demonstration and assessment of additionality" to demonstrate and assess additionality, which is a step-wise approach that includes:

- Identification of alternatives to the project activity;
- Investment analysis to determine that the proposed project activity is not the most economically or financially attractive (in the absence of the CDM incentive);
- Barriers analysis;
- Common practice analysis; and

- Impact of registration of the proposed project activity as a CDM project activity.

The "Tool for the demonstration and assessment of additionality" (UNFCCC, 22 October 2004) is applied as follows.

Step 0. Preliminary screening based on the starting date of the project activity

The actual methane destruction crediting period is expected to start on 1 September 2006; by then, all necessary local and UNFCCC approvals in are expected to be in place ie. the crediting period will commence subsequent to registration of the project activity. As a result, Step 0 is not applicable.

Step 1. Identification of alternatives to the project activity consistent with current laws and regulations

Alternatives to the project activity consistent with current laws and regulations are defined through the following sub-steps:

Sub-step 1a. Define alternatives to the project activity:

The below table presents an analysis of different alternatives to the project activity along with a discussion of probable outcome.

Alternatives to Project Activity	Probability of Scenario
Landfill gas recovery not implemented (continuation of the current situation)	Most probable: there are no regulations requiring the capture and destruction of landfill gas at the site. Additionally, the technical expertise and financial investment to engage in the project is not available in Brasil.
Project undertaken as a non-CDM project activity	Not probable: The project activity requires funds for both construction of the required facilities and to maintain operations. There are no known or available funding sources available to support this project and there are no known or proposed regulatory requirements that would require the emissions to be controlled. The project activity will not be initiated without registration as a CDM project.
Electricity generation from the methane component of the extracted landfill gas	Not probable: the technical expertise and financial resources in Brasil are not available to initiate electrical generation. Additionally, utilization systems are more capitally-intensive than landfill gas capture and flaring systems, requiring significantly more investment. Electrical generation from landfill gas utilization is not likely without registration as a CDM project.

The above analysis shows that the only reasonable alternative to the project activity is the continued uncontrolled release of landfill gas to the atmosphere as part of the "business-as-usual" scenario. As a result, the project activity is the only viable alternative to address the reduction of greenhouse gas emissions at the site

Sub-step 1b. Enforcement of applicable laws and regulations:

Each of the above alternatives complies with the applicable laws and regulations in Brasil. In terms of the project activity, the active collection and utilization or flaring of LFG is not mandatory at the Manaus landfill, and as such, the site is currently in compliance with all local environmental regulations with respect to air emissions.

Step 2. Investment analysis

According to the "Tool for the demonstration and assessment of additionality" (UNFCCC, 22 October 2004), an investment analysis or barrier analysis is required. For the investment analysis, if the CDM project activity generates financial or economic benefits other than CDM related income, then an investment comparison analysis (option II) or benchmark analysis (option III) should be applied.

Sub-step 2a. Determine appropriate analysis method:

Benchmark analysis (option III) of "Tool for the demonstration and assessment of additionality" was thus applied and the likelihood of development of this project in the absence of the CDM incentive is properly assessed as described below.

Sub-step 2b – Option III. Apply benchmark analysis:

The IRR (Internal Rate of Return) is the chosen financial indicator as this is a widely acceptable practice for this type of projects. The benchmark value to be compared with the project IRR was determined as a value to represent standard returns in the market, considering the specific risks applicable to the project activity.

As a minimum, competitive rate for long-term financing for the proposed project activity would be of approximately 11% per year (Export Development Canada, http://www.edc.ca/). Therefore, 11% per year is considered the benchmark value for the purpose of this investment analysis.

Sub-step 2c – Calculation and comparison of financial indicators:

The project activity involves the implementation of a landfill gas collection system and utilization facility to generate grid-connected electricity, combusting the methane component of landfill gas. This will require capital expenditures for the gas collection wells and piping; the mechanical instrumentation required to induce vacuum; the analytical instrumentation necessary to monitor landfill gas composition; the gas engines to generate electricity and combust the methane component of the landfill gas and all associated gas treatment and electrical interconnect equipment. Additionally, on-going expenses will be incurred to operate the facility and to maintain the system components.

The introduction of the CDM incentive will enhance the project economics with the generation of two revenue streams:

- The destruction of methane via the project activity would result in an income derived through revenues generated from the CER exchange mechanism under the CDM; and
- The revenues generated from the CER exchange mechanism resulting from the displacement of electricity derived from fossil fuel sources.

For the scenario where the proposed project activity would be developed in the absence of the CERs revenue, the only revenue would be the sale of the independently produced electricity. An analysis of the landfill gas resource at the Site indicates an average capacity of power plant of approximately 18 MW throughout the crediting period. Considering the capital, maintenance and operation costs for a power plant of 18 MW and the associated revenue from the sale of electricity, the associated IRR is -3.7%. The economic model was based on the following assumptions:

- Considering the remote location of the City of Manaus and specific characteristics of the proposed project activity, the implementation of LFG collection system and a gas-engine power plant of 18 MW, the capital cost was estimated in US$ 43 million to be invested in 2007. The annual operation and maintenance cost was estimated in US$ 1.5 million per year to be spent between 2007 and 2016;
- Electricity is sold to the grid at R$ 0.08 per kWh (http://www.manausenergia.com.br/);
- Exchange rate of US$ 1.00 = R$ 2.30 (Central Bank of Brasil, http://www.bcb.gov.br); and
- The project will be operated as must-run power plant at full capacity (8,760 hours per year).

Comparing the IRR of the project activity (-3.7%) with the benchmark applicable to the project (11%), it can be observed that the project is not financially attractive and therefore would not be implemented in the absence of the CDM incentive.

Sub-step 2d – Sensitivity Analysis:

A sensitivity analysis was conducted by altering the parameters considered most likely to fluctuate over time:

- Project revenue increases as ANEEL (Brazilian Federal Electricity Regulatory Agency, http://www.aneel.gov.br) authorizes an increase in the price of electricity and Manaus Energia (the City of Manaus Power Utility, http://www.manausenergia.com.br/) agrees to increase the price of electricity supplied by independent producers; and
- Reduction in project capital, operation and maintenance costs.

The Table below shows the impact of revenue increase or reduction in project costs by 5% and 10% over the project IRR.

Scenario	*IRR*
Original	-3.7%
Increase in project revenue by 5%	-2.6%
Increase in project revenue by 10%	-1.5%
Decrease in Project Costs by 5%	-2.6%
Decrease in Project Costs by 10%	-1.6%

As can be seen, the IRR remains low, confirming that the project is not financially attractive in the absence of the CDM incentive.

Step 3. Barrier analysis

The goal of step 3 is to determine whether the proposed project activity faces barriers that:

(a) Prevent the implementation of this type of proposed project activity in the absence of the CDM incentive; and
(b) Do not prevent the implementation of at least one of the identified alternatives.

Sub-step 3a. Identify barriers that would prevent the implementation of type of the proposed project activity:

The implementation of a landfill gas collection and utilization system at the Manaus landfill site faces a number of investment and technologic barriers in the absence of the CDM incentive. These barriers are briefly discussed below.

- *Investment Barriers*

Currently, the availability of debt funding or access to international capital markets for this type of project is restricted in Brasil, as is the availability of government subsidies.

- *Technological Barriers*

Today, Brasil lacks the necessary technical knowledge to implement LFG Management projects. Although the main infrastructure for the implementation of this type of project is readily available, the technical and engineering expertise, and the main components of the LFG management systems, are not available in Brasil and therefore need to be provided by sources outside the country.

Sub-step 3b. Show that the identified barriers would not prevent the implementation of at least one of the alternatives (except the proposed project activity):

Alternative #1: Landfill gas recovery and utilization not implemented (continuation of the current situation)

The identified barriers would not affect the current "business-as-usual" scenario of emitting the landfill gas into the atmosphere. The "business-as-usual" scenario does not require any investments or technological improvements and is fully compatible with regulatory requirements.

Alternative #2: Project undertaken as a non-CDM project activity

Implementation of a landfill gas capture and utilization system without registration as a CDM project will not proceed as a result of the significant investments required to initiate the project. Investment barriers prevent the implementation of this alternative.

Alternative #3: Electricity generation from the methane component of the extracted landfill gas

The technical expertise resources in Brasil are not available to initiate electrical generation and as a result, this alternative presents a technological barrier. Further, as capital expenditures for landfill gas utilization systems are significantly higher than for landfill gas capture and utilization systems, there is an additional investment barrier associated with this alternative.

As a result of the above analysis, the only plausible scenario is the continuation of the current scenario ie. landfill gas recovery not implemented. The project activity overcomes the stated barriers by incorporating revenues from the generation of CERs to undertake a project that would otherwise be unattractive and which has no regulatory or contractual driver for implementation.

Step 4. Common practice analysis

Sub-step 4a. Analyze other activities similar to the proposed project activity:

With the exception of small demonstration pilot scale undertakings, landfill gas management systems are non-existent in Brasil. There are, however, several LFG management projects, some of which include a utilization component, being filed under CDM with the local DNA, and this demonstrates the necessity of CER revenue for the implementation of this type of project.

Sub-step 4b. Discuss any similar options that are occurring:

Implementation of landfill gas capture and utilization system in Brasil currently under development is reliant on revenues generated from the CER exchange mechanism under the CDM. Thus, these projects face similar barriers to implementation as the project activity.

Step 5. Impact of CDM registration

Once the proposed project activity is registered under CDM, the project will be entitled to proceed with the trade and and/or exchange of the generated Certified Emission Reductions (CERs) in the open market. The sale of CERs to interested parties will generate a revenue source that will leverage the project Internal Rate of Return (IRR) to a point considered to be attractive by its investors in a way that the project will become economically feasible. Therefore, the CDM registration will facilitate and allow the implementation of the proposed project activity and ensure its financial viability. As a consequence of this, real reductions in anthropogenic greenhouse gas emissions will be realized.

B.4. Description of how the definition of the project boundary related to the baseline methodology selected is applied to the project activity:

According to ACM0001, the project boundary is delineated by the area of the Manaus Landfill. However, as the project activity will generate electricity, the project boundary related to the baseline methodology ACM0002 should also include the area delineated by the Manaus power grid.

B.5. Details of baseline information, including the date of completion of the baseline study and the name of person (s)/entity (ies) determining the baseline:

Date of Completion: The baseline study was completed on 28 November 2005. Detailed baseline information is included as Annex 3 of this document.

Name of Entities Determining the Baseline: The baseline was determined by Conestoga Rovers & Associates Capital Limited (project participant). Contact information is presented below:

Frank A. Rovers, P. Eng.
Frederick (Rick) A. Mosher, P. Eng.
Edward A. McBean, Ph.D., P. Eng.
Conestoga-Rovers & Associates Capital Limited
651 Colby Drive
Waterloo, ON
Canada N2V 1C2
Telephone: +1-519-884-0510
Fax: +1-519-884-5256
http://www.CRAworld.com

SECTION C. Duration of the project activity / Crediting period

C.1 Duration of the project activity:

C.1.1. Starting date of the project activity:

The project is expected to be commissioned in 1 September 2006.

C.1.2. Expected operational lifetime of the project activity:

10 years and 0 months.

C.2 Choice of the crediting period and related information:

C.2.1. Renewable crediting period

C.2.1.1. Starting date of the first crediting period:

Not applicable.

C.2.1.2. Length of the first crediting period:

Not applicable.

C.2.2. Fixed crediting period:

C.2.2.1. Starting date:

1 September 2006

C.2.2.2. Length:

10 years and 0 months.

SECTION D. Application of a monitoring methodology and plan

D.1. Name and reference of approved monitoring methodology applied to the project activity:

The approved monitoring methodologies applied to this project activity are the ACM0001 – Consolidated Monitoring Methodology for Landfill Gas Project Activities and ACM0002 – Consolidated Monitoring Methodology for Zero-Emission Grid-Connected Electricity Generation from Renewable Sources.

D.2. Justification of the choice of the methodology and why it is applicable to the project activity:

ACM0001 was developed as a consolidated document that incorporates all previously-approved monitoring methodologies applicable to landfill gas project activities where the baseline scenario is the partial or total atmospheric release of landfill gas. This methodology is applicable to "landfill gas capture project activities where the baseline scenario is the partial or total atmospheric release of the gas and the project activities include situations such as: the captured gas is used to produce energy (e.g. electricity/thermal energy) and emission reductions are claimed for displacing or avoiding energy generation from other sources".

For the proposed project activity, the baseline scenario is the total atmospheric release of the gas, and the project activity is the utilization of the captured gas, where emission reductions will be claimed for displacing energy generation from other sources. As a result, ACM0001 monitoring methodology is applicable to the project activity.

The ACM0001 monitoring methodology is based on the direct measurement of the quantity of LFG captured, collected and destroyed by the gas engines and flare. The actual tonnage of methane emissions reduced by the project is calculated based on flow rate of the landfill gas, methane concentration, and destruction/conversion efficiency of the combustion equipment. The monitoring plan proposed by CRA provides for the continuous measurement of both LFG quantity and quality using a continuous flow meter and on-line LFG analyzer. The methane emissions reduced by gas engines and flares are determined based on the operating hours measured by a run-time meter and the measured/calculated methane destruction efficiencies.

The consolidated methodology ACM0002 was developed based on elements of monitoring methodologies applicable to grid-connected electricity generation from renewable sources. ACM0002 is applicable to "grid connected electricity generation from landfill gas capture to the extent that it is combined with the approved Consolidated Baseline Methodology for Landfill Gas Project Activities (ACM0001)".

Since the proposed project activity will generate grid connected electricity generation from LFG capture, ACM0002 is therefore applicable to the extent that it is combined with ACM0001.

The emission reductions derived from the displacement of fossil fuels used for electricity generation from other sources will also be monitored in accordance with ACM0002. The following parameters will be included in the monitoring plan: electricity generated by the proposed project activity, data needed to recalculate operating margin (OM) and build margin (BM) emission factors.

D.2. 1. Option 1: Monitoring of the emissions in the project scenario and the baseline scenario

The section was left blank on purpose. Option 2 was selected.

D.2.1.1. Data to be collected in order to monitor emissions from the project activity, and how this data will be archived:

ID number *(Please use numbers to ease cross-referencing to D.3)*	Data variable	Source of data	Data unit	Measured (m), calculated (c) or estimated (e)	Recording frequency	Proportion of data to be monitored	How will the data be archived? (electronic/ paper)	Comment

D.2.1.2. Description of formulae used to estimate project emissions (for each gas, source, formulae/algorithm, emissions units of CO_2 equ.)

The section was left blank on purpose. Option 2 was selected.

D.2.1.3. Relevant data necessary for determining the baseline of anthropogenic emissions by sources of GHGs within the project boundary and how such data will be collected and archived :

ID number *(Please use numbers to ease cross-referencing to table D.3)*	Data variable	Source of data	Data unit	Measured (m), calculated (c), estimated (e),	Recording frequency	Proportion of data to be monitored	How will the data be archived? (electronic/ paper)	Comment

The section was left blank on purpose. Option 2 was selected.

D.2.1.4. Description of formulae used to estimate baseline emissions (for each gas, source, formulae/algorithm, emissions units of CO_2 equ.)

The section was left blank on purpose. Option 2 was selected.

D. 2.2. Option 2: Direct monitoring of emission reductions from the project activity (values should be consistent with those in section E).

D.2.2.1. Data to be collected in order to monitor emissions from the project activity, and how this data will be archived:

ID number *(Please use numbers to ease cross-referencing to table D.3)*	Data variable	Source of data	Data unit	Measured (m), calculated (c), estimated (e),	Recording frequency	Proportion of data to be monitored	How will the data be archived? (electronic/ paper)	Comment
1 (ACM0001). $LFG_{total,y}$	Total amount of landfill gas Captured	On-Line LFG flow meter	m^3	m	Continuous	100%	Daily: electronic Monthly: paper	Measured by a flow meter.
2 (ACM0001). $LFG_{flare,y}$	Amount of landfill gas flared	On-Line LFG flow meter	m^3	m	Continuous	100%	Daily: electronic Monthly: paper	Measured by a flow meter.
3 (ACM0001). $LFG_{electricity,y}$	Amount of LFG combusted in power plant	On-Line LFG flow meter	m^3	m	Continuous	100%	Daily: electronic Monthly: paper	Measured by a flow meter.
5 (ACM0001). FE	Flare/combustion efficiency	Thermistors, Samples	%	m/c	(1) quarterly; (2) continuously	100%	Daily: electronic Monthly: Paper	(1) Quarterly measurement of methane content of flare exhaust gas; (2) Continuous measurement of operation time of flare (with temperature).
6 (ACM0001).	Methane fraction in the	On-Line LFG analyzer	m^3 CH_4/ m^3 LFG	m	Continuous	100%	Daily: electronic Monthly:	Measured by continuous gas quality analyser.

$w_{CH4,y}$	landfill gas						Paper	
7 (ACM0001). T	Temperature of the landfill gas	Temperature probe	^oC	m	Continuous	100%	Daily: electronic Monthly: paper	
8 (ACM0001). p	Pressure of the landfill gas	Pressure gauge	Pa	m	Continuous	100%	Daily: electronic Monthly: paper	
9 (ACM0001).	Total amount of electricity and/or other energy carriers used in the project for gas pumping	Electricity meter	MWh	m	Continuous	100%	Daily: electronic Monthly: paper	Required to determine CO_2 emissions from use of electricity. .
10 (ACM0001).	CO_2 emission intensity of the electricity and/or other energy carriers in ID 9(ACM0001).	Calculated	tCO_2/MWh	c	Annually	100%	Daily: electronic Monthly: paper	Required to determine CO_2 emissions from use of electricity.
11 (ACM0001).	Regulatory requirements relating to landfill gas projects	Documented evidence	Text	n/a	Annually	100%	Electronic	
1 (ACM0002). EG_y	Electricity quantity	Electricity meter	MWh	m	Continuous	100%	Daily: electronic Monthly: paper	This parameter refers to electricity supplied by the project activity to the grid.
2 (ACM0002). EF_y	Emission factor	CO_2 emission factor of the grid	tCO_2 / MWh	c	Annually	100%	Electronic	Calculated as a weighted sum of the OM (if applicable) and BM emission factors.
3 (ACM0002). $EF_{OM, y}$	Emission factor	Dispatch centres or local statistics	tCO_2 / MWh	c	Annually	100%	Electronic	Calculated only if imports occur.

4 (ACM0002). $EF_{BM, y}$	Emission factor	Dispatch centres or local statistics	tCO_2 / MWh	c	Annually	100%	Electronic	Calculated for recently built power plants as approved baseline methodology ACM0002.
5 (ACM0002). $F_{i,y}$	Fuel Quantity	Power producers information, dispatch centers or local statistics	Mass or volume unit	m	Annually	100%	Electronic	Amount of each fuel fossil consumed by each power plant.
6 (ACM0002). $COEF_i$	Emission factor coefficient	Plant or country specific information or IPCC values	tCO_2 per mass or volume unit	m	Annually	100%	Electronic	
7 (ACM0002). $GEN_{j/k/n,y}$	Electricity quantity	Power producers information, dispatch centers or local statistics	MWh/a	m	Annually	100%	Electronic	
8 (ACM0002).	Plant Name	Dispatch centres or local statistics	Text	e	Annually	100% of set of plants	Electronic	Identification of plants (j,k, or n) to calculate Operating margin (OM) emission factors
9 (ACM0002).	Plant Name	Dispatch centres or local statistics	Text	e	Annually	100% of set of plants	Electronic	Identification of plants (m) to calculate Build margin (BM) emission factors
10 (ACM0002). λ_y	Parameter	Dispatch centres or local statistics	Unit number	c	Annually	100%	Electronic	Applicable only if Imports occur. Factor accounting for number of hours per year during which low-cost/must-run sources are on the margin.
11 (ACM0002).	Merit order	Documented evidence	Text	m	Annually	100%	Paper for original documents, else electronic	Required to stack the plants in the dispatch analysis

11a (ACM0002). $GEN_{j/k/l,y}$ *IMPORTS*	Electricity quantity	Dispatch centres or local statistics	kWh	c	Annually	100%	Electronic	Applicable only if imports occur.
11b (ACM0002). $COEF_{i,j,y}$ *IMPORTS*	Emission factor coefficient	Country-specific information (preferably) or IPCC values	tCO_2 per mass or volume unit	c	Annually	100%	Electronic	Applicable only if imports occur.

It is noted that all data will be archived during the crediting period and for two years after.

D.2.2.2. Description of formulae used to calculate project emissions (for each gas, source, formulae/algorithm, emissions units of CO_2 equ.):

Landfill gas not captured by the landfill gas collection and utilization system cannot be monitored, as this emission is diffused over the landfill. The amount of landfill gas collected and utilized or combusted can be monitored at a centralised location using flow meters. Project emissions are thus comprised of the quantity of methane collected and not utilized due to equipment inefficiency, and this amount is subtracted from the measured amount of collected methane. The overall gas engine and flare efficiencies of hydrocarbons combustion are assumed to be upwards of 99.99%.

The total amount of methane destroyed by the utilization and flaring facility in a given period is calculated in accordance with ACM0001 as:

$MD_{project,y} = [LFG_{flared,y}\ (2.)\ x\ \ w_{CH4}\ \ (6.)\ x\ D_{CH4}\ x\ FE\ (5.)] + [LFG_{electricity,y}\ (3.)\ x\ \ w_{CH4}\ \ (6.)\ x\ D_{CH4}]$

Where:

$MD_{project,y}$ = methane destroyed during a specified monitoring period (tonnes of CH_4)
$LFG_{flared,y}$ = average flow of LFG flared during specified monitoring period t in m^3
w_{CH4}= percentage by volume of CH_4 in LFG (m^3 CH_4/m^3 LFG)
D_{CH4} =methane density at standard pressure (1 atm) and temperature (0°C) conditions, 0.0007168 tonnes/m^3 , as per consolidated methodology ACM0001
FE = destruction efficiency of the flare (%)
$LFG_{electricity,y}$ = average flow of LFG fed into electricity generator during specified monitoring period t in m^3

D.2.3. Treatment of leakage in the monitoring plan

D.2.3.1. If applicable, please describe the data and information that will be collected in order to monitor leakage effects of the project activity

ID number *(Please use numbers to ease cross-referencing to table D.3)*	Data variable	Source of data	Data unit	Measured (m), calculated (c) or estimated (e)	Recording frequency	Proportion of data to be monitored	How will the data be archived? (electronic/ paper)	Comment

No leakage effects need to be accounted under methodology ACM0001 or ACM0002.

D.2.3.2. Description of formulae used to estimate leakage (for each gas, source, formulae/algorithm, emissions units of CO_2 equ.)

No leakage effects need to be accounted under methodology ACM0001 or ACM0002.

D.2.4. Description of formulae used to estimate emission reductions for the project activity (for each gas, source, formulae/algorithm, emissions units of CO_2 equ.)

The following formulae will be used to estimate emission reductions for the project activity.

$ER_y = (MD_{project,y} - MD_{reg,y}) * GWP_{CH4} + EG_y * CEF_{electricity,y} + ET * CEF_{thermal,y}$

Where:

- ER_y are the emission reductions, measured in tCO_2e;
- $MD_{project,y}$ is the amount of methane actually destroyed/combusted during time period t, measured in tCH_4;
- $MD_{reg,y}$ is the amount of methane that would have been destroyed/combusted during time period t in the absence of the project activity, measured in tCH_4;
- GWP_{CH4} is the approved Global Warming Potential value for methane, 21 tCO_2e/tCH_4;
- EG_y is net quantity of electricity displaced during a given period t, measured in MWh;

- $CEF_{electricity,y}$ is the CO_2 emissions intensity of the electricity displaced, measured in tCO2e/MWh.
- ET is the quantity of thermal energy displaced, measured in TeraJoules (TJ);
- $CEF_{thermal,y}$ is the CO_2 emissions intensity of the thermal energy displaced, measured in tCO2e/TJ.

It is noted that while the term for thermal energy have been included to be consistent with the overall formulation stated in ACM0001, thermal energy generation is not a component of the proposed project activity. As a result, the above equation reduces to the following form for the project activity:

$$ER_y = (MD_{project,y} - MD_{reg,y}) * GWP_{CH4} + EG_y * CEF_{electricity,y}$$

Considering that there is no regulatory or contractual requirement determining MD_{reg}, an adjustment factor (AF) is used in the Manaus Landfill project:

$$MD_{reg,y} = MD_{project,y} * AF$$

The methane destroyed by the project activity during a given time period can be determined by the following: monitoring the quantity of methane actually flared and LFG used to generate electricity and to produce thermal energy, and is given by:

$$MD_{project,y} = MD_{flared,y} + MD_{electricity,y} + MD_{thermal,y}$$

For the proposed project activity, $MD_{thermal} = 0$, as there is no thermal energy generation component of the project. As a result, the total actual quantity of methane captured and destroyed will be metered *ex post* once the project activity is operational, and:

$$MD_{project,y} = MD_{flared,y} + MD_{electricity,y}$$

And,

$$MD_{project,y} = LFG_{flared,y} * w_{CH4,y} * D_{CH4} * FE + LFG_{electricity,y} * w_{CH4} * D_{CH4}$$

Where:

- $MD_{flared,y}$ is the quantity of methane destroyed by flaring in a given time period t, measured in tCH_4;
- $LFG_{flared,y}$ is the quantity of landfill gas flared during a given time period t, measured in cubic meters (m^3);
- w_{CH4} is the average methane fraction of the landfill gas as measured during the given time period t and expressed as a fraction of CH_4 volume per LFG volume (m^3 CH_4 / m^3 of LFG);
- FE is the flare efficiency (the fraction of the methane destroyed);

- D_{CH4} is the methane density, expressed in tonnes of methane per cubic meter of methane (tCH_4/m^3CH_4), and measured at STP (0 degree Celsius and 1.013 bar), which is 0.0007168 tCH_4/m^3CH_4 (as per consolidated methodology ACM0001); and
- $LFG_{electricity,y}$ = average flow of LFG fed into electricity generator during specified monitoring period t, measured in cubic meters (m^3).

D.3. Quality control (QC) and quality assurance (QA) procedures are being undertaken for data monitored

Data *(Indicate table and ID number e.g. 3.-1.; 3.2.)*	Uncertainty level of data (High/Medium/Low)	Explain QA/QC procedures planned for these data, or why such procedures are not necessary.
1.(ACM0001) - Table D.2.2.1	Low	Calibration of equipment as per manufacturer specifications to ensure validity of data measured.
2.(ACM0001) -Table D2.2.1	Low	Calibration of equipment as per manufacturer specifications to ensure validity of data measured.
3.(ACM0001) - Table D2.2.1	Low	Calibration of equipment as per manufacturer specifications to ensure validity of data measured.
5.(ACM0001) - Table D 2.2.1	Medium	Regular maintenance to ensure optimal operation of controlled combustion environment.
6.(ACM0001) - Table D2.2.1	Low	Calibration of equipment as per manufacturer specifications to ensure validity of data measured.
7.(ACM0001) - Table D2.2.1	Low	Calibration of equipment as per manufacturer specifications to ensure validity of data measured.
8.(ACM0001) - Table D2.2.1	Low	Calibration of equipment as per manufacturer specifications to ensure validity of data measured.
9.(ACM0001) - Table D2.2.1	Low	Calibration of equipment as per manufacturer specifications to ensure validity of data measured.
10.(ACM0001) - Table D2.2.1	Low	Calculated value following from ID9.
11.(ACM0001) - Table D2.2.1	Low	Reliable sources will be used. The information acquired will be peer reviewed
1.(ACM0002) - Table D.2.2.1	Low	Calibration of equipment as per manufacturer specifications to ensure validity of data measured.
2.(ACM0002) - Table D.2.2.1	Low	Reliable sources will be used. The information acquired will be peer reviewed
3.(ACM0002) - Table D.2.2.1	Low	Reliable sources will be used. The information acquired will be peer reviewed
4.(ACM0002) - Table D.2.2.1	Low	Reliable sources will be used. The information acquired will be peer reviewed
5.(ACM0002) - Table D.2.2.1	Low	Reliable sources will be used. The information acquired will be peer reviewed
6.(ACM0002) - Table D.2.2.1	Low	Reliable sources will be used. The information acquired will be peer reviewed
7.(ACM0002) - Table D.2.2.1	Low	Reliable sources will be used. The information acquired will be peer reviewed
8.(ACM0002) - Table D.2.2.1	Low	Reliable sources will be used. The information acquired will be peer reviewed
9.(ACM0002) - Table D.2.2.1	Low	Reliable sources will be used. The information acquired will be peer reviewed
10.(ACM0002) - Table D.2.2.1	Low	Reliable sources will be used. The information acquired will be peer reviewed
11.(ACM0002) - Table D.2.2.1	Low	Reliable sources will be used. The information acquired will be peer reviewed
11a.(ACM0002) - Table D.2.2.1	Low	Reliable sources will be used. The information acquired will be peer reviewed
11b.(ACM0002) - Table D.2.2.1	Low	Reliable sources will be used. The information acquired will be peer reviewed

D.4 Please describe the operational and management structure that the project operator will implement in order to monitor emission reductions and any leakage effects, generated by the project activity

All continuously measured parameters (LFG flow, CH_4 concentration, flare temperature, flare operating hours, engine operating hours, engine electrical output), will be recorded electronically via a datalogger, which will have the capability to aggregate and print the collected data at the frequencies as specified above.

Before commencement of the O&M phase, Conestoga-Rovers & Associates Capital Limited (CRA) will conduct a training and quality control program to ensure that good management practices are ensured and implemented by all project operating personnel in terms of record-keeping, equipment calibration, overall maintenance, and procedures for corrective action. An operations manual will be developed for the operating personnel. The procedures for filing data and calculations to be performed by the LFG utilization operator will be included in a daily log to be placed in the main control room.

D.5 Name of person/entity determining the monitoring methodology:

The monitoring methodology for the project is determined by Conestoga-Rovers & Associates Capital Limited., who is the project proponent. The details of the monitoring plan are provided in Annex 4 and contact information is presented below:

Frank A. Rovers, P. Eng.
Frederick (Rick) A. Mosher, P. Eng.
Edward A. McBean, Ph.D., P. Eng.
Conestoga-Rovers & Associates Capital Ltd.
651 Colby Drive
Waterloo, ON
Canada N2V 1C2
Telephone: +1-519-884-0510
Fax: +1-519-884-5256
http://www.CRAworld.com

SECTION E. Estimation of GHG emissions by sources

E.1. Estimate of GHG emissions by sources:

It is estimated that a total of over 11,000,000 tonnes of Municipal Solid Waste (MSW) was disposed at the Manaus Landfill from 1986 to the end of 2005. The Site is expected to continue accepting MSW until 2015. The total methane generation at the site has been estimated based on the waste tonnage of the landfill using a United States Environmental Protection Agency (USEPA) first-order kinetic model for landfill gas:

$G_i=(M_i)x\ (k)\ x\ (L_o/1000)\ exp^{-(k\ x\ t)}$

Where,

G_i=emission rate from the ith section of waste (m^3 CH_4/year)
k=CH_4 generation rate (1/year)
L_o=CH_4 generation potential (m^3 CH_4/tonne of refuse)
M_i=mass of refuse in the ith section (tonnes)
t_i=age of the ith section of waste (years)

The following USEPA default input parameters (U.S. Environmental Protection Agency, 1998, User's Manual – Landfill Gas Emissions Model) were used to estimate methane emissions at the Manaus Landfill:

$k = 0.05\ year^{-1}$, $L_o = 170\ m^3_{methane}$/tonne.

The assumptions used to calculate methane emissions are presented as follows:

Lag phase of methane production = 1 year;
Methane content in LFG = 50%;
LFG collection efficiency = 60%; and
Density of methane = 0.0007168 tonnes/m^3 (as per consolidated methodology ACM0001)

Table 1 (below) presents the waste tonnage accepted at the Manaus landfill and the methane emission estimates based on the USEPA model. It is noted that the values presented in Table 1 represent modelled quantities of methane generation for the stated time period. The actual amount of GHGs reduced will be calculated based on the actual quantities of LFG collected and utilized.

Table 1: Methane Emissions Estimate for the Manaus Landfill

Waste		*Emissions*
Quantity		tonnes CH_4/year
Year	*(tonnes)*	
1986	392,548	0
1987	407,190	2,392
1988	422,378	4,756
1989	438,132	7,098
1990	454,475	9,421

1991	471,427	11,730
1992	489,011	14,031
1993	507,251	16,326
1994	526,171	18,620
1995	545,798	20,918
1996	566,156	23,223
1997	587,273	25,540
1998	609,179	27,873
1999	631,901	30,225
2000	655,471	32,601
2001	679,920	35,004
2002	705,281	37,440
2003	731,588	39,911
2004	758,876	42,422
2005	787,182	44,977
2006	**807,024**	**47,579**
2007	**837,126**	**50,176**
2008	**868,350**	**52,829**
2009	**900,740**	**55,543**
2010	**934,338**	**58,323**
2011	**969,188**	**61,171**
2012	**1,005,339**	**64,093**
2013	**1,042,838**	**67,092**
2014	**1,081,736**	**70,174**
2015	**1,122,085**	**73,342**
2016	**0**	**76,602**
2017	0	72,866
2018	0	69,312
2019	0	65,932
2020	0	62,716
2021	0	59,658

Based on the above calculations, the total methane emissions in the absence of the project activity are calculated as 619,671 tonnes of methane during the crediting period. The landfill gas collection and utilization system will capture only a portion of the generated landfill gas. Thus, a conservative estimate of 60% LFG collection was applied to the estimate of LFG produced. Under assumption that generated LFG is composed of 50% methane, Table 2 illustrates the quantities of methane collected by the project activity during the crediting period.

Table 2: Quantity of Methane Captured by the Project Activity

Year	*Percentage of Methane Captured*	*Amount of Methane Captured by Project Activity (*tonnes CH_4/year*)*	*Amount of Methane Not Captured by Project Activity (*tonnes CH_4/year*)*
2006	60%	9,516	6,344
2007	60%	30,106	20,070
2008	60%	31,697	21,132
2009	60%	33,326	22,217
2010	60%	34,994	23,329
2011	60%	36,703	24,468
2012	60%	38,456	25,637
2013	60%	40,255	26,837

2014	60%	42,104	28,070
2015	60%	44,005	29,337
2016	60%	30,641	20,427

The total methane captured by the project activity is estimated as 371,803 tonnes of methane during the crediting period.

Emissions from the project activity are expected to be negligible. The use of a high-efficiency gas engines and enclosed drum flare has capability to destroy in excess of 99.99% of hydrocarbons in the controlled combustion environment. As required, uncombusted methane will be measured and accounted for according to the requirements set forth in methodology ACM0001, but quantities of uncombusted methane are expected to be negligible. For the purpose of estimating project activity emissions, a destruction efficiency of 99.99% was applied to the quantities of methane captured (Table 2). Project activity emissions are summarized in Table 3.

Table 3: Emissions Resulting from Uncombusted Methane in the Project Activity

Year	*Destruction Efficiency of Gas Engines and Enclosed Flare*	*Amount of Uncombusted Methane* (tonnes CH_4/year)	*Project Activity Emissions (tonnes CO_2e/year)*
2006	99.99%	0.95	20
2007	99.99%	3.01	63
2008	99.99%	3.17	67
2009	99.99%	3.33	70
2010	99.99%	3.50	74
2011	99.99%	3.67	77
2012	99.99%	3.85	81
2013	99.99%	4.03	85
2014	99.99%	4.21	88
2015	99.99%	4.40	92
2016	99.99%	3.06	64

The only source of project activity emission is uncombusted methane. As a result, the total emissions attributed to the project activity are estimated as 781 tonnes CO_2e over the duration of the crediting period, and E.1 = 781 tonnes CO_2e.

E.2. Estimated leakage:

No leakage effects need to be accounted under methodology ACM0001 and ACM0002 (E.2=0).

However, methodologies ACM0001 and ACM0002 clearly state that the CO_2 emission intensity of the electricity consumed by the project activity must be taken into account. In the project activity, electrical consumption is associated with the equipment required to draw and process landfill gas, and the total electrical requirement is estimated as 120 kW. This corresponds to electrical consumption of 1,051MWh/year. Electrical requirements of the power plant can be satisfied by the generated electricity.

The Manaus power generation grid is considered very particular, since it is not connected to the overall Brazilian power grid. According to the 2004 Financial Report of Manaus Energia (the local power utility, http://www.manausenergia.com.br/) and ANEEL (Brazilian Federal Electricity Regulatory Agency, http://www.aneel.gov.br), the power grid in Manaus is comprised of hydroelectric (21.7%) diesel fuel thermoelectric (64.7%) and oil fuel thermoelectric (13.6%).

According to the International Panel on Climate Change (IPCC; http://www.ipcc.ch/), the specific emission factor for hydroelectric power is 0 kg CO_2/MWh. For purposes of estimating a grid emission factor for Manaus, IPCC emission factors (20.2 tC/TJ for diesel and 21.2 tC/TJ for oil fuel) are utilized and an overall estimate of the grid emission factor for Manaus is thus calculated as 0.6845 tonnes of CO_2/MWh. Table 4 illustrates the total emissions resulting from electrical consumption in the project activity during the crediting period.

Table 4: Emissions Resulting from Electrical Consumption in the Project Activity

Year	*Electrical Consumption in Project Activity (MWh/year)*	*Emissions Resulting from Electrical Consumption (tonnes of CO_2/year)*
2006	350	240
2007	1,051	719
2008	1,051	719
2009	1,051	719
2010	1,051	719
2011	1,051	719
2012	1,051	719
2013	1,051	719
2014	1,051	719
2015	1,051	719
2016	701	480

It is noted that in 2008, the first year of electrical generation utilizing landfill gas as a fuel, the power plant will be able to supply both the requirements of the power plant and of the blowers required to collect the landfill gas. As a result, the data contained in Table 4 will be an overestimation of the actual emissions resulting from electrical consumption and should be seen as conservative estimate for the period prior to implementation of the power plant.

The total emissions resulting from electrical consumption in the project activity is estimated as 7,191 tonnes CO_2 over the crediting period, and E.2 = 7,191 tonnes CO_2.

E.3. The sum of E.1 and E.2 representing the project activity emissions:

Table 5 presents the total project activity emissions, attributable to uncombusted methane release and emissions associated with electrical consumption during the crediting period.

Table 5: Total Project Activity Emissions

Year	*Project Activity Emissions from Uncombusted Methane (tonnes CO_2e/year)*	*Project Activity Emissions from Electrical Consumption (tonnes of CO_2/year)*	*Total Emissions Resulting from the Project Activity (tonnes of CO_2/year)*
2006	20	240	260
2007	63	719	782
2008	67	719	786
2009	70	719	789
2010	74	719	793

2011	77	719	796
2012	81	719	800
2013	85	719	804
2014	88	719	807
2015	92	719	811
2016	64	480	544

The sum of project activity emissions during the crediting period is estimated as 7,972 tonnes CO_2e, and E.3 = 7,972 tonnes CO_2e.

E.4. Estimated anthropogenic emissions by sources of greenhouse gases of the baseline:

Emission Reductions Associated with Methane Destruction:

Based on the model projections of total emissions illustrated in Section E.1, the total methane emission in the baseline scenario (no collection or destruction of methane at the site) is 619,671 tonnes of methane, which represents 13,013,091 tonnes of CO_{2e}. Multiplied by an estimated collection efficiency of 60%, this results in an emissions reduction of 7,807,863 tonnes of CO_{2e}.

Emission Reductions Associated with Electricity Displacement from Other Sources:

The increasing demand of the electricity in Manaus is currently addressed by the construction of new thermoelectric plants. Manaus Energia has consistently issued calls for proposals to independent power producers for the supply of electricity generated by thermoelectric plants (Manaus Energia, http://www.manausenergia.com.br/). The emission reductions derived from the displacement of fossil fuels used for electricity generation from other sources are then estimated based on this scenario and strictly guided by ACM0002, as follows.

Step 1. Calculate the Operating Margin emission factor(s)($EF_{OM,y}$)

The operating margin (OM) emission factor for the proposed project is zero, because the Manaus grid does not import or export electricity from other electricity systems. Therefore, $EF_{OM,y} = 0$.

Step 2. Calculate the Build Margin emission factor ($EF_{BM,y}$)

According to ACM0002, the larger annual generation sample should be chosen between (1) the five power plants that have been built most recently and (2) the power plants capacity additions in the electricity system that comprise 20% of the system generation and that have been built most recently. For the case of Manaus system generation, the larger annual generation sample is the five power plants that have been built most recently, as detailed in the Table below:

Name	*Fuel Type*	*Start up Year*	*Capacity (MW)*
Usina Flores	Diesel	2004	77.5
Usina Cidade Nova	Diesel	2003	16.0
Usina São José	Diesel	2003	40.0
Usina D El Paso Amazonas	Diesel	2000	80.0
Usina W (Wartsila) El Paso Rio Negro	Oil	1999	157.5

Source: ANEEL and Manaus Energia.

For purposes of estimating an emission factor for these plants, IPCC emission factors (20.2 tC/TJ for diesel and 21.2 tC/TJ for oil fuel) are utilized (http://www.ipcc.ch/). The build margin emission factor for the five plants in the above table was calculated as $EF_{BM,y}$ = 0.9652 tCO2/MWh, according to ACM0002.

Step 3. Calculate the Baseline Emission Factor (EF_y)

The baseline emission factor is defined by ACM0002 as the weighted average of the Operating Margin emission factor and the Build Margin emission factor, as follows:

$EF_y = w_{OM} * EF_{OM,y} + w_{BM} * EF_{BM,y}$

The weights w_{OM} and w_{BM}, by default, are 0.5 and alternative weights can be used, as long as $w_{OM} + w_{BM} = 1.0$ (ACM002). For the proposed project activity, the Operating Margin emission factor is zero, and therefore no weight average should be applied.

The Baseline Emission Factor (EF_y) is then calculated as $EF_y = EF_{BM,y}$ = 0.9652 tCO2/MWh.

Emission reductions for the substitution of grid electricity generation with fossil fuel fired power plants by renewable electricity can now be calculated as defined by ACM0002:

$ER_y = EG_y * EF_y – PE_y – L_y$

Where:

- ER_y are the emission reductions associated with the project activity (tonnes of CO_{2e});
- PE_y are the project activity emissions (tonnes of CO_{2e}); and
- L_y are the emissions due to leakage (tonnes of CO_{2e}).

Since emissions due to leakage are not considered for landfill gas projects (ACM0001 and ACM0002), the emission reductions for the electricity displacement is then simplified as:

$ER_y = EG_y * EF_y – PE_y$

Considering 8,760 hours/year from 2008 to 2016, and 90% as a capacity factor for the installed average capacity of 18 MW, the baseline emissions can be estimated and summarized as per the following table.

Year	*Electricity generated by gas engines and delivered to the grid (MWh)*	*Electricity Displacement Baseline Emissions (tonnes of CO_2/year)*
2006	0	0
2007	47,304	45,658
2008	141,912	136,973
2009	141,912	136,973
2010	141,912	136,973
2011	141,912	136,973
2012	141,912	136,973
2013	141,912	136,973
2014	141,912	136,973
2015	141,912	136,973

2016	94,608	91,315

The baseline emissions for electricity displacement from other fuel sources are estimated as 1,232,757 tonnes of CO_{2e} between 2006 and 2016.

Therefore, E.4 is the sum of the emission reductions associated with methane destruction and the emission reductions associated with electricity displacement from other sources, which is calculated as E.4 = 9,040,620 tonnes of CO_{2e}.

E.5. Difference between E.4 and E.3 representing the emission reductions of the project activity:

The total emission reduction of the project activity is the difference between E.4 and E.3 and results in an estimated emission reduction of 9,032,648 tonnes of CO_{2e} between 2006 and 2016.

E.6. Table providing values obtained when applying formulae above:

Table 6 summarizes the net emission reduction associated with the project activity.

Table 6: Summary of Emission Reductions by Project Activity

Year	Gross Estimation of project activity Emission Reductions for Methane Destruction (tonnes of CO_2e)	Estimation of Baseline Emission Reductions (tonnes of CO_2e)	Estimation of Leakage and Project Activity Emissions for Methane Destruction (tonnes of CO_2e)	Net Estimation of project activity Emission Reductions due to Methane Destruction (tonnes of CO_2e)	Estimation of project activity Emission Reductions due to Electricity Displacement (tonnes of CO_2e)	Total Estimation of Net Emission Reductions for Methane Destruction and Electricity Displacement (tonnes of CO_2e)
2006	199,836	0	260	199,576	0	199,576
2007	632,226	0	782	631,444	45,658	677,102
2008	665,637	0	786	664,851	136,973	801,824
2009	699,846	0	789	699,057	136,973	836,030
2010	734,874	0	793	734,081	136,973	871,054
2011	770,763	0	796	769,967	136,973	906,940
2012	807,576	0	800	806,776	136,973	943,749
2013	845,355	0	804	844,551	136,973	981,524
2014	884,184	0	807	883,377	136,973	1,020,350
2015	924,105	0	811	923,294	136,973	1,060,267
2016	643,461	0	544	642,917	91,315	734,232
Total (tonnes of CO_2e)	7,807,863	0	7,972	7,799,891	1,232,757	9,032,648

SECTION F. Environmental impacts

F.1. Documentation on the analysis of the environmental impacts, including transboundary impacts:

There are expected to be no significant environmental impacts due to the project activity. All condensate generated by the project activity will be collected and sanitary water will be properly collected and treated to comply with local environmental regulations. Emissions from the gas engines and flare include the carbon dioxide component of landfill gas, but this carbon dioxide is considered to be a natural product of the carbon cycle. In the combustion of landfill gas, carbon dioxide is additionally produced, but this is also considered to be part of the natural carbon cycle and not of anthropogenic origin. There is minimal visual impact from the utilization and flare facilities, and noise and vibration from the blower, gas engines and flare will be limited to the localized site.

There is a positive environmental impact on the environment due to the project activity. Landfill gas emissions are decreased, reducing greenhouse gas emissions and impacts to localized air pollution. Odour will be diminished at local receptors. Operationally, proper management of the landfill gas will reduce the potential for landfill fires and the associated release of incomplete combustion products. Further, the driving force for subsurface migration of landfill gas and landfill gas components is minimized, protecting adjacent buildings. Generation of electricity through utilization of landfill gas further provides offset of fossil fuel generation sources common in the area, leading to lower total emissions and localized impacts.

F.2. If environmental impacts are considered significant by the project participants or the host Party, please provide conclusions and all references to support documentation of an environmental impact assessment undertaken in accordance with the procedures as required by the host Party:

There are no significant environmental impacts resulting from the project activity.

SECTION G. Stakeholders' comments

G.1. Brief description how comments by local stakeholders have been invited and compiled:

CRA is in the process of inviting all stakeholders required by the Brasilian DNA to attend a public meeting that will be held in Manaus in early January 2006, when CRA will present the project to the public and official authorities and invite questions and comments.

G.2. Summary of the comments received:

The summary will be provided when CRA receives the comments from stakeholders.

G.3. Report on how due account was taken of any comments received:

Due account will be taken as CRA receives comments from stakeholders.

Annex 1

CONTACT INFORMATION ON PARTICIPANTS IN THE PROJECT ACTIVITY

Organization:	Prefeitura Municipal de Manaus
Street/P.O.Box:	Avenida Brasil, No. 1335 – Compensa II
Building:	
City:	Manaus
State/Region:	Amazonas
Postfix/ZIP:	
Country:	Brasil
Telephone:	+55-92-3230-5033
FAX:	
E-Mail:	
URL:	http://www.manaus.am.gov.br
Represented by:	Paulo Ricardo Rocha farias
Title:	
Salutation:	Mr.
Last Name:	Farias
Middle Name:	Rocha
First Name:	Paulo-Ricardo
Department:	
Mobile:	+55-92-3675-1200 or +55-92-3675-7291
Direct FAX:	+55-92-3673-7760
Direct tel:	+55-92-3230-5033
Personal E-Mail:	

Organization:	Conestoga-Rovers & Associates Capital Limited
Street/P.O.Box:	651 Colby Drive
Building:	
City:	Waterloo
State/Region:	Ontario
Postfix/ZIP:	N2V 1C2
Country:	Canada
Telephone:	(519) 884-0510
FAX:	(519) 725-1394
E-Mail:	
URL:	http://www.CRAworld.com
Represented by:	Frank Anthony Rovers
Title:	Principal and Senior Engineer
Salutation:	Mr.
Last Name:	Rovers
Middle Name:	Anthony
First Name:	Frank
Department:	
Mobile:	
Direct FAX:	
Direct tel:	
Personal E-Mail:	frovers@craworld.com

Organization:	BGC International
Street/P.O.Box:	One America Square
Building:	
City:	London
State/Region:	
Postfix/ZIP:	EC3N 2LS
Country:	United Kingdom
Telephone:	+44 20 7894 7000
FAX:	+44 20 7894 7553
E-Mail:	
URL:	
Represented by:	General Counsel, BGC International (cc Steve Drummond, Managing Director, CO2e.com LLC)
Title:	
Salutation:	
Last Name:	
Middle Name:	
First Name:	
Department:	
Mobile:	
Direct FAX:	
Direct tel:	
Personal E-Mail:	

Annex 2

INFORMATION REGARDING PUBLIC FUNDING

There is no public funding.

Annex 3

BASELINE INFORMATION

The baseline scenario for the project activity is the uncontrolled release of landfill gas to the atmosphere and also the generation of electricity from other sources. There are presently no measures in place to reduce methane emissions and there are no current or pending regulations that would require the site to reduce emissions. The local practice to expand the electricity grid is the implementation of new thermoelectric plants.

The total estimated emissions of landfill gas to the atmosphere in the baseline scenario are estimated as 13,013,091 tonnes of CO_2e during the crediting period, as shown in Section E. The total contributions from displacement of energy from other sources is 1,232,757 tonnes of CO_2e. The table below shows the key elements used for estimate the emissions of the baseline scenario.

Year landfilling operations started	1986
Projected year for landfill closure	2015
L_o (m^3 methane per tonne of waste)	170
k (1/year)	0.05
GWP for methane	21
Methane concentration in LFG (% by volume)	50
LFG collection efficiency (%)	60
Gas engines and flare efficiencies (%)	99.99
Project Energy consumption (MWh/year)	1,051
Emission factor for Manaus current grid (tCO_2/MWh)	0.6845
Total accumulated waste from 1996 to 2015 (tonnes)	20,935,972
Unit price of electricity sold to the grid (R$/kWh)	0.08
Baseline emission factor for electricity displacement (tCO_2/MWh)	0.9656
Average capacity of Power Plant (MW)	18

Annex 4

MONITORING PLAN

1.0 Introduction and Objectives

The three primary purposes of the monitoring plan are:

- Monitor indicators of environmental impacts and sustainable development;
- To collect the necessary system data required for the determination and validation of certified emissions reductions (CERs); and
- To demonstrate successful compliance with established operating and performance criteria for the system, and to verify that the CERs have been generated.

The operational data that is collected for the system will be used to support the periodic report that will be required for the auditing and validation of CERs. The monitoring plan discussed herein is designed to meet or exceed the UNFCCC requirements (approved monitoring methodologies ACM0001 and ACM0002).

The monitoring plan for environmental impacts and sustainable development is discussed in Section 2. The routine system monitoring program required for the determination and validation of CERs is discussed in Section 3, while the additional system data that is collected to ensure the safe, correct, and efficient operation of the landfill gas management system is discussed in Section 4.

Coupled with an operations and maintenance manual that is generally developed for a system, expected performance guidelines in accordance with the data collection procedures described below will be provided with trigger levels that would be indicative of a need for any follow-up assessment and possible remedial response measures.

2.0 Environmental Impact and Sustainable Development

Environmental impacts and sustainable development factors will be assessed through a number of economic and social indicators.

Economic Development:

Job creation: an incremental number of jobs will be created at the site by the implementation of the project activity, as related to landfill gas system operations and monitoring. Monthly employment records will be used to monitor this indicator.

Income generation: an incremental wage increase will be realized by landfill gas management facility personnel as compared to alternative employment. Hourly wages will be used to assess this indicator, and this data will be compared to local employment data.

Social and Environmental Impact:

Odour: the impact of odour on neighbours is expected to decrease as a result of the landfill gas management system and will be monitored through the number of odour reports made by neighbouring residents. All odour reports will be noted and catalogued by landfill gas management system operators.

Subsurface migration of landfill gas: the driving force for subsurface (ie. through the soil) migration of landfill gases is pressure build-up in the landfill mass. Implementation of the project activity will induce vacuum in the landfill mass, inhibiting off-site subsurface migration of landfill gas. Monitoring of the migration control system aspects of the system will be undertaken by monitoring the applied vacuum at the perimeter wells of the landfill gas collection wellfield.

Landfill safety: implementation of the landfill gas management system is expected to decrease the potential for adverse landfill impacts such as landfill fires. This will be monitored by assessing the number of incidents at the landfill related to fires or other concerns.

Technology transfer: the project activity represents an example of technology transfer. Operation of the constructed landfill gas management system will complete the chief aspect of monitoring requirements for this performance indicator. During and after commissioning of the system, a bi-annual training program will be conducted to update operators on new or changing technology as related to the project activity. A further measure of technology transfer will be the communication of the project activity results at conferences or in the technical literature.

3.0 Monitoring Work Program

The landfill gas monitoring program is a relatively simple, straight forward program designed to collect system operating data required to safely operate the system and for the verification of CERs. This data is collected in real time, and will provide a continuous record that is easy to monitor, review, and validate.

The following sections will outline and discuss the following key elements of the monitoring program:

- Flow measurement;
- Gas quality measurements;
- Uncombusted methane;
- Electrical Consumption;
- Project electricity output;
- Data records; and
- Data assessment and reporting.

3.1 Flow Measurement

According to ACM0001, one flow meter will be installed during Phase 1 (flaring) on the piping, straight before the flare.

During phase 2 (electricity generation) implementation, in order to follow ACM0001, two other flowmeters will also be installed: one flow meter will be installed in the main piping straight after the blowers to measure the total LFG flow extracted from the landfill; and another flow meter will be installed in the piping before the power plant to measure the LFG flow utilized for electricity generation.

The flow of landfill gas collected by the system and subsequently utilized or flared are measured via individual flow measuring devices suitable for measuring the velocity and volumetric flow of a gas. Two such common examples are an annubar or an orifice plate. The flow measurements are taken within the piping itself, and the flow sensors are connected to transmitters that are capable of collecting and sending continuous data to a recording device such as a datalogger. The flow sensors are calibrated according to a specified temperature, pressure and composition of the gas, thus the flow actually measured must be corrected to according to actual temperature, pressure, and composition, thus density, of the gas measured. The equipment selected will allow dynamic compensation for these parameters, normalized to a standard temperature, pressure, and gas composition. For reporting purposes, the flows are generally required to be normalized to 0°C and 1 atm at standard gas composition of 50% methane and carbon dioxide each by volume.

Specific calibration procedures are dependent on the actual equipment selected, however calibration of the sensors is required on a regular basis to ensure the quality and validity of the data. The accuracy of a flow meter is dependent on the design of the equipment, and the specific type of sensor used, however equipment is available that will provide a minimum accuracy of +/-2% by volume. Again dependent on the equipment selected, the measured flow is aggregated approximately once per second.

All data that is collected will be recorded for the permanent record. Both electronic and hard copies of the data will be maintained for auditing purposes, and for use in the calculation of CERs.

3.2 Gas Quality

The two parameters that are most pertinent to the validation of CERs, as well as the safe and efficient operation of the system are the concentration of methane and oxygen in the gas stream delivered for utilization or diverted to flaring. These two parameters are measured via a common sample line that is run to the main collection system piping, and measured in real time by two separate sensors, one each for methane and oxygen, installed as per ACM0001.

Although compensation for temperature and pressure is not required for the methane and oxygen sensors, the sensors are designed to operate within specified temperature and pressure conditions. Again, specific calibration procedures are dependent on the actual equipment selected, however calibration of the sensors is required on a regular basis to ensure the quality and validity of the data. Regular calibration of the equipment is especially important, as the accuracy of the methane and oxygen sensors is greatest within the expected range of the gas stream to be measured. Equipment is readily available that will provide an accuracy of at least +/- 1% by volume. Dependent on the equipment selected, compositions are aggregated approximately once per second.

3.3 Uncombusted Methane

The efficiency of the enclosed flare will be monitored via quarterly measurement of uncombusted methane at equipment discharge. Grab samples of the exhaust gas will be obtained and sent for analysis of methane.

3.4 Electrical Consumption

Monthly electrical bills charged to the project will be monitored and considered as the actual energy consumption for the project.

3.5 Project Electricity Output

The generated electricity supplied to the grid by the project activity will be continuously measured by an electricity meter and respective data will be electronically recorded.

3.6 Data Records

Data collected from each of the parameter sensors is transmitted directly to an electronic database from which the CER quantity calculations may be carried out, and a hard copy backup of the data may be printed. Backup of the data electronically may be conducted on a daily basis, and hard copy data may be printed weekly or monthly. As a back up would be produced separate from the main recording system, no more than one day of data at a time would ever be lost due to a system malfunction. Calibration records will be kept for all instrumentation.

3.7 Data Assessment and Reporting

Assessment of the flow and composition data described above coupled with the operating hours of the engines/flare and engines/flare destruction efficiencies are used to determine the quantity of CERs generated. For electricity generation offsets, the appropriate emission factors will be monitored and applied.

The destruction efficiency of the flare is a function of the internal combustion temperature and resident holding time, which are generally measured by the flare system controller, and recorded for auditing purposes. Extensive technical documentation is available that documents the destructive efficiency of the enclosed drum flares that will be used, subject to the flow rate and combustion temperature verification. Destruction efficiency will also be assessed periodically through measurement of uncombusted methane emissions.

As discussed in Section 2.1, flow data is normalized to standard temperature, pressure, and composition for reporting purposes. The data will be compiled and assessed to produce the required quantification and validation. The annual monitoring report will contain the data required for the validation of the CERs, and additionally may contain operational data from the collection system and flaring system described below to illustrate that the system is well maintained and operating at peak efficiency. Records of regular maintenance performed will also be a component of the annual report.

4.0 Related Monitoring

Additional operational monitoring of the landfill gas collection wellfield is conducted in order to optimize the system and ensure that it is operating both correctly and efficiently. Periodic adjustments to the extraction wells will be required to optimize the collection system effectiveness. Such collection field adjustments are undertaken made based upon a review of the well performance history considered within the context of the overall field operation in order to maximize the collection of methane balanced against the minimization of any oxygen in the system which could introduce unsafe operating conditions. Monitoring at each extraction well will consist of the following parameters: valve position, individual well flow, individual well vacuum, and composition of the gas collected, i.e., methane, carbon dioxide, and oxygen, using a portable measuring device.

At such time as a landfill gas facility is designed and commissioned, a specific monitoring plan tailored to the actual utilization technology selected will be developed for this system.

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