ASSESSMENT REPORT

"Central de Residuos Vale do Aço" Sanitary Landfill
Santana do Paraiso, Minas Gerais
Brazil

Prepared for:
Fundação Estadual do Meio Ambiente - FEAM

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ASSESSMENT REPORT

"CENTRAL DE RESIDUOS VALE DO AÇO" SANITARY LANDFILL

1.0 EXECUTIVE SUMMARY

This assessment report for a landfill gas (LFG) utilization or flaring only project has been prepared by SCS Engineers (SCS), under the support of the Global Methane Initiative (GMI), the United States Environmental Protection Agency (U.S. EPA) and the Fundação Estadual do Meio Ambiente (FEAM), for the "Central de Residuos Vale do Aço" Sanitary Landfill in the Municipality of Santana do Paraíso, Brazil. The assessment was prepared based on the information provided by the Vital Engenharia Ambiental, the landfill operator, and observations made during a site visit on April 22, 2010.

The disposal site has served several cities of the valley "Vale de Aço" in the State of Minas Gerais as a sanitary landfill since 2003. The landfill had approximately 490,000 metric tonnes (Mg) of municipal solid waste (MSW) as of the time of the site visit in April 2010. Closure of the landfill is projected to occur in 2025 after it reaches its final capacity of approximately 2.1 million Mg.

An LFG generation and recovery model was prepared based on the estimated waste disposal rates, waste composition, climate, site conditions, and estimated achievable collection efficiencies. The results of the model indicate that the site may be a good candidate for an LFG capture and flaring project, and possibly a methane utilization project, although the modest potential for generating electricity makes on-site electricity generation less likely to be economically viable than other options such as direct use or flaring only. Projected emission reduction credits from LFG combustion total 470,000 metric tonnes over a 10-year period (2012 – 2021).

2.0 INTRODUCTION

This assessment report for the Vale de Aço Sanitary Landfill has been prepared by SCS Engineers (SCS) for the U. S. EPA's Landfill Methane Outreach Program (LMOP), as part of the Global Methane Initiative, an international initiative to help partner countries reduce global methane emissions in order to enhance economic growth, strengthen energy security, improve air quality, improve industrial safety, and reduce emissions of greenhouse gases.

2.1 PURPOSE OF THE ASSESSMENT REPORT

The overall purpose of the Vale de Aço Sanitary Landfill Assessment Report is to perform an assessment of potential LFG recovery rates and a preliminary evaluation of options for the utilization of the LFG. This overall purpose is achieved through the pursuit of the following objectives:

- Summarize and evaluate available information on the disposal site, including its physical characteristics, site management, and waste disposal data.
- Evaluate technical considerations for LFG project development, including estimates of the amount of recoverable LFG over the project period.
- Examine available LFG utilization options, including electricity generation, direct use, and flaring only projects.

2.2 DATA SOURCES

The following information which was used in the preparation of this report was: (1) based on observations by SCS personnel during the site visit performed on April 22, 2010; (2) provided by Vital Engenharia Ambiental S.A. (Vital) during the day of the site visit, (3) provided in completed data profile form filled out by Vital; and (4) provided by FEAM.

The data consisted of:

- Site opening date (September 2003).
- The total site capacity (3,354,655 cubic meters (m^3)).
- The size of the areas used for disposal and total area of the landfill.
- Estimated maximum current waste depths and volume of waste in place as of October 2009 (709,157 m^3).
- Annual waste disposal rates from September 2003 to April 2010 based on scalehouse data.
- Waste composition data.
- Practices for treatment and control of leachate and composting.
- Materials, equipment, and installation costs reflect the average international costs and were based on SCS' experience in this sector and the international market.
- Identification of potential LFG end-user in the vicinity of the landfill. .

2.3 PROJECT LIMITATIONS

The information and estimates contained within this assessment report are based on the data provided by Vital. Neither the U.S. EPA nor its contractors can take responsibility for the accuracy of this data. Measurements, assessments, and projections presented in this report are based on the data and physical conditions of the landfill observed at the time of the site visit. No warranty, express or implied, is made as to the professional opinions presented herein. Changes in the property use and conditions (for example: variations in rainfall, water levels, site operations, final cover systems, or other factors) may affect future gas recovery at the disposal site. The U.S. EPA and SCS Engineers do not guarantee the quantity or the quality of the available landfill gas.

3.0 LANDFILL DESCRIPTION

The Vale do Aço Sanitary Landfill is located in the City of Santana do Paraíso, in the state of Minas Gerais, Brazil. It located approximately 9 kilometers (km) north east of downtown Ipatinga and 218 km north east from downtown Belo Horizonte, capital of the State of Minas Gerais (see site location in Figure 1). The climate in the Santana do Paraíso is tropical. The 24-hour average temperature is 23.0 degrees C (73.4 degrees F). Average annual precipitation in Santana do Paraíso is 1,258[1] mm (49.5 inches), of which over 84 percent falls in the summer months of October through March.

1 http://jornaldotempo.uol.com.br/climatologia.html/SantanadoParaiso-MG

Figure 1. Location of Vale do Aço Landfill

Vital won a 30 year concession agreement in 2001 to dispose of the waste from the municipalities of Santana do Paraíso, Ipatinga, Coronel Fabriciano, Timoteo, Belo Oriente, Marliéria, and Itanhomi. These cities are located in the Vale do Aço metropolitan region with a population of over 449,340 inhabitants.[2] The main population centers are Ipatinga (241,000), Coronel Fabriciano (104,415) Timoteo (99,100) and Santana do Paraíso (24,105).[3] The Vale do Aço landfill is owned by Vital, and Vital has the environmental liabilities and responsibility for closure of the landfill. The landfill property covers 144 hectares (ha). The landfill occupies 44.38 ha; at the moment only 16.9 ha has been licensed for waste disposal.   Figure 2 shows a view of the working phase of the current waste disposal area.

2 Instituto Brasileiro de Geografia e Estatística (IBGE) (2008).
3 Ibid

Figure 2. Working Face

The remaining areas are used for composting (see Figure 3), medical waste treatment (see Figure 4), administrative offices, scale and scalehouse, access roads, parking, environmental education center, auditorium, soccer field, native tree nursery and a vast reserve are for environmental protection. Leachate is collected at the base of the landfill and is hauled off site and treated at the sewage treatment station of the Sanitation Company of the State of Minas Gerais (COPASA)[4] in the municipality of Ipatinga.

4 Companhia de Saneamento de Minas Gerais

Figure 3. Composting area

Figure 4. Medical Waste Sterilization Area

3.1 LANDFILL OPERATIONS

The site began operations in September 12, 2003. Vital has full responsibility for the operations of the landfill. Vital also has responsibility for the collection of MSW and inert waste in the municipality of Ipatinga. All waste entering the site passes through the scalehouse and is quantified and recorded by means of an integrated information system.

The landfill has a bottom liner system with the following specifications (from bottom to top):

- Layer of clay, compacted to a thickness of 60 centimeters
- 2 mm geo-membrane layer (PEAD)
- Layer of compacted clay (40 cm)

The landfill is being constructed in "layers". Each layer consists of several cells. The first layer included six cells, each with a thickness of 5 meters. The second layer will have a total of seven cells, which also are 5 m thick.. Currently, cell number 11 is being filled. Waste is deposited in 10 to 15 cm lifts on top of the working face slope, which has an inclination of 1:3 (vertical: horizontal, "VH"). The waste is pushed down the slope and compacted with a bulldozer making several passes. The landfill has three bulldozers, but only one is used to place waste due to the limited volumes. According to Vital, each cell of waste has a density of 1.0 tonne per m^3.

Low permeability clay is readily available at the site. Daily cover is applied to the working face and the top of the cell as the cell extends outward. Between each cell, a 20 – 30 cm clay intermediate cover is applied and compacted using the compactor shown in Figure 6. The intermediate layer did not appear to be removed before waste is placed on top of the cell, although Vital later clarified that is was being removed. If the clay intermediate layer is not substantially removed before placing the next layer of waste, it can: (1) create a significant barrier to leachate, potentially causing leachate lenses or small lakes on top of the clay layer, preventing the leachate from draining to the base where it can be effectively collected at the low point of the landfill; and (2) it can cause a loss of landfill air space;. These intermediate layers offer no additional landfill stability. The final cover will consist of 60 cm of clay with a layer of organic soil to support a grass cover.

Based on the drawings we received, it appears that the base of the landfill in the areas of layers 1 and 2 has a slope of over 8 percent. This slope is steep enough to cause waste and clay on top of the geomembrane to be prone to sliding when the waste is not filled up against a large barrier or "toe", particularly if the waste mass gets wet. Any slope greater than 4 percent can be a cause for concern, particularly when a smooth (non-textured) geomembrane is used. The toe or waste barrier at the bottom of the MSW landfill is to be created by the separate inerts (construction and demolition debris) disposal area. According to Vital, the inerts are being disposed of separate of the MSW, but SCS did not see the inerts being disposed in an area separate of the MSW disposal area.

Stormwater is managed using daily and intermediate cover, and canals and berms to direct stormwater away from the working face, particularly during the rainy season. However, observations of the site suggest the site is at risk of stormwater entering the landfill through the exposed leachate collection system located on the surface of the lower cell near where waste is being placed.

Figure 5. Base Layer Leachate Drains/Venting Wells

Figure 6. Base Layer - Geomembrane

The leachate is collected via horizontal and vertical drains within the landfill (see Figure 5). The first set of leachate horizontal drains were placed on the base of the landfill, on top of the liner system. The leachate drains to a lagoon, where it is temporarily stored and then transported off-site for treatment.

Figure 7. Leachate Collection Pond

The site has a passive LFG venting system and leachate drains (see Figures 5, 8, and 9) which consist of vertical wells that are connected to the horizontal leachate drains at the base of the landfill. The venting wells, which currently average about 20 m deep, will continue to be extended upward as additional layers are added. The vents are constructed with perforated concrete pipe of 90 cm diameter and have removable burners at the upper end (see Figure 9). It is possible that these integrated leachate drains / LFG vents can be modified to be active LFG wells. However, the amount of vacuum which can be applied to gas control system will likely be limited due to air infiltration that can occur through the leachate drains. Additional vertical LFG wells will need to be drilled to collect the LFG that will not be collected using the existing wells.

Figure 8. Venting Wells

Figure 9. Venting Well

3.2 WASTE DISPOSAL INFORMATION

Annual Waste Disposal Rates

The landfill reportedly began receiving in the First “Layer” in September 2003 and had approximately 494,000 tons of waste as of April 2010. The landfill receives waste from the six municipalities listed above and is open Monday through Saturday (7am to 11pm). Approximately 300 tonnes per day of MSW, 600 tonnes per day of inerts (“entulho” or construction and demolition debris), and 700 kilograms per day of medical waste are disposed at the landfill. The medical waste autoclave has a capacity of 5 tonnes. The site also receives about 10 tonnes per day of landscaping waste and organic waste from public markets, some of the green waste is composted and the rest is landfilled.

According to ABRELPE’s Brazil Panorama of Solid Waste 2009, Ipatinga produces 0.85 kg per inhabitant per day. If we assume that Ipatinga is representative of the Vale do Aço region, then we would expect that approximately 400 tonnes per day of MSW would be collected, including commercial waste. The additional 100 tonnes per day of MSW that is not received at the landfill may be going to clandestine open dumps, which have been common in the region until recently. Efforts by the State of Minas Gerais and local governments are being made to close these illegal dumping sites[5]. Since 2003, the Program "Minas sem Lixões" has supported municipalities in implementing public policies to eradicate these dumps.

The first layer covers 2.9 ha (including sideslope and is approximately 15 m deep. The second layer is on top of the first layer and has an area of 7.7 ha. The average waste depth of the two layers combined is 20 meters. When the second layer is filled, the waste in place will have a total volume of about 1.06 million m^3. As of October 2009, a total of 704,000 m^3 of landfill volume had been consumed (based on the drawings provided aerial survey data), or about 21 percent of the total site capacity of 3,354,655 m^3.

Annual historical MSW disposal rates from 2003 through April 2010 were available for this study based on scale house records. Future waste disposal is projected based on an estimated annual growth rate for waste disposal of 2 percent, which has been the average population growth in Ipatinga since 1991. Although Vital projects a site closure date of 2033, this date is not consistent with the reported site capacity and disposal rates, and does not account for the consumption of a large fraction of the available landfill space by inert waste. Based on the aerial survey information indicating that 21 percent of the site capacity had been consumed by October 2009, and considering the amount of MSW in place as of that date (446,440 Mg), the landfill has capacity for approximately 2.11 million Mg, assuming the same relative mix of MSW and inert waste will continue. Table 1 lists the historical and projected annual MSW disposal rates for the Landfill. Given the historical disposal rates and a 2 percent future growth rate, the landfill will reach its capacity in 2025.

Table 1. MSW Disposal Estimates – Vale de Aço Landfill

Year	Disposed Tonnages (Mg/Year)	Accumulated Tonnages (Mg)	Comments
2003	13,300	13,300	Reported at scale house
2004	45,730	59,030	Reported at scale house
2005	64,200	123,230	Reported at scale house
2006	82,710	205,940	Reported at scale house
2007	85,250	291,190	Reported at scale house
2008	84,850	376,040	Reported at scale house
2009	88,920	464,960	Reported at scale house
2010	92,360	557,320	Projected based on disposal data up to April 2010
2011	94,210	651,530	Projected using 2.0% annual disposal rate increase
2012	96,090	747,620	
2013	98,010	845,630	
2014	99,970	945,600	
2015	101,970	1,047,570	
2016	104,010	1,151,580	

5 Program Minas without Open Dump (Programa Minas Sem Lixões)

Table 1. MSW Disposal Estimates – Vale de Aço Landfill

Year	Disposed Tonnages (Mg/Year)	Accumulated Tonnages (Mg)	Comments
2017	106,090	1,257,670	
2018	108,210	1,365,880	
2019	110,370	1,476,250	
2020	112,580	1,588,830	
2021	114,830	1,703,660	
2022	117,130	1,820,790	
2023	119,470	1,940,260	
2024	121,860	2,062,120	
2025	49,880	2,112,000	

Waste Composition Data

Waste composition and moisture conditions in a landfill are primary considerations when estimating LFG model input assumptions. This report applies waste composition data provided by Vital Engenharia Ambiental S.A. This waste composition is based on a 1992 study conducted by Federal University of Viçosa on the MSW of the State of Minas Gerais. The estimated waste composition percentages are summarized in Table 2. The table shows that organic waste categories amount to 84 percent of the total MSW disposed. This high percentage of organics is in part due to the exclusion of construction and demolition waste, which typically is included in waste composition estimates.

Table 2. MSW Composition Data – Vale do Aço Landfill

Waste Material	Estimated %
Organic Waste*	70.85%
Paper	11.71%
Plastics	5.75%
Metals	3.62%
Glass and Ceramics	2.77%
Other	5.33%
Total	100.00%

Source: Vital Engenharia Ambiental S.A
*Note: "Organic waste" is assumed to be 90% food waste and 10% green waste.

4.0 LANDFILL GAS GENERATION AND RECOVERY PROJECTIONS

4.1 BACKGROUND ON THE SCS INTERNATIONAL LFG MODEL

SCS has developed a proprietary international LFG model that employs the following first-order decay equation for estimating LFG generation based on annual waste disposal rates, the amount of methane one Mg of waste produces (Lo value), and the rate that waste decays and produces LFG (k value).

$$Q_{LFG} = \sum_{t=1}^{n}\sum_{j=0.1}^{1} 2kL_0\left[\frac{M_i}{10}\right](e^{-kt_{ij}})\,(MCF)$$

Where:

Q_{LFG} = maximum expected LFG generation flow rate (m^3/yr)
i = 1 year time increment
n = (year of the calculation) – (initial year of waste acceptance)
j = 0.1 year time increment
k = methane generation rate (1/yr)
L_o = potential methane generation capacity (m^3/Mg)
M_i = mass of solid waste disposed in the i^{th} year (Mg)
t_{ij} = age of the j^{th} section of waste mass M_i disposed in the i^{th} year (decimal years)
MCF = methane correction factor.

The model k and Lo variables are based on estimated waste composition and local climate information. Data used for developing model input parameters are discussed in later sections of this report.

The SCS International Model uses the same input variables (k and Lo) and is generally similar to the U.S. EPA's Landfill Gas Emissions Model (LandGEM)[6]. The most significant difference between the models is the assignment of multiple k and Lo values in the SCS International Model. While the simple (single k and Lo) first order decay equation used in LandGEM is appropriate for modeling U.S. landfills, it is EPA's and SCS's opinion that LFG generation at sites in South American countries may not be adequately modeled using this approach, primarily due to the significantly different waste composition and site conditions which create different patterns of waste decay and LFG generation over time.

The SCS International LFG model employs separate modules with different k and Lo values that separately calculate LFG generation from the different waste components. This "multi-phased" first-order decay model approach recognizes that the significant differences in the types of waste disposed in developing countries require changes to the model structure as well as to the values of the input variables. A similar approach has been adopted by the Inter-governmental Panel on

6 EPA, 2005. Landfill Gas Emissions Model (LandGEM) Version 3.02. EPA 600/R-05/047 (May 2005),

Climate Change (IPCC), which released a landfill methane generation model in 2006 that applies separate modules for four different waste categories.[7]

LFG generation estimates produced by the model are used to project LFG recovery with the existing or proposed collection system based on the estimated collection efficiency. Collection efficiency, defined as the percentage of generated LFG that is recovered by the LFG extraction system, is affected by a number of factors, including: well and wellfield design, waste depth, type of liner and cover, leachate management issues, landfill management practices, and collection system operations.

4.2 MODEL INPUT PARAMETERS

Model k Values

Based on the precipitation rate (1,258 mm/year) and estimated waste moisture conditions at the landfill, SCS assigned the model k values of 0.30 and 0.06 per year for the fast and medium decaying organic waste fractions, respectively. These k values reflect a moderately wet climate and are comparable to values assigned in LMOP's Colombia LFG Model[8] for cities in this climate category. No slowly decaying organic materials (wood, leather, rubber) are being disposed at the landfill, according to the waste composition data.

Methane Correction Factor

Landfills which are unmanaged, shallow, or without soil cover will experience aerobic conditions in the topmost layers of exposed waste which inhibit the production of methane. Vale de Aço is a managed site with a good soil cover, so a "methane correction factor" (MCF) of 1 was applied (no adjustment).

Model Lo Values

Waste composition data was used to estimate Lo values for the fast, medium, and slowly decaying organic waste categories, based on the dry organic content of the disposed waste (as compared to average U.S. waste). The calculation of the Lo value for Vale do Aço from the standard U.S. "inventory" value in LandGEM (100 m^3/Mg) and the ratio of the dry organic content of Vale do Aço's waste to average U.S. waste is described in the table below.

7. IPCC, 2006. IPCC Spreadsheet for Estimating Methane Emissions from Solid Waste Disposal Sites.
8. http://www.epa.gov/lmop/international/tools.html

	U.S. Landfills	Vale do Aço Landfill	Ratio: Vale do Aço /U.S.
Organic % (dry weight basis)	Total waste: 43.5%	Fast Organics: 31.6% Medium Organics: 86.1% Slow Organics: None	Fast Organics: 0.73 Medium Organics: 1.98
L_o value	Total waste: 100 m^3/Mg	Fast Organics: 73 m^3/Mg Medium Organics: 198 m^3/Mg Slow Organics: None	Fast Organics: 0.73 Medium Organics: 1.98

Separate Lo values were calculated for the different organic waste categories resulting in the following values:

- Fast-decay waste (food and a portion of the garden waste): 73 m^3/Mg.
- Medium-decay waste (paper, textiles, and a portion of the garden waste): 198 m^3/Mg.
- Slow-decay waste (wood, rubber, and leather): none disposed.

The fraction of MSW consisting of inert materials (e.g., metals, plastics, glass and ceramics, other inorganics) was assigned an Lo value of 0 as it is not expected to contribute to LFG generation.

Collection Efficiency

Three LFG recovery scenarios were developed to reflect a range of achievable collection efficiencies that vary depending on the level of effort and amount of resources available to operate the collection systems. All three scenarios assume the following:

- The LFG collection and control system will be installed and begin operating starting in 2012.

- The collection system will be maintained and expanded annually into new disposal areas to provide relatively comprehensive coverage of all wastes within two years of waste deposition.

- A final cover will be installed in 2026 to allow the achievement of maximum collection efficiency levels starting in 2027.

The three recovery scenarios are described as follows:

- The low recovery scenario assumes that a moderate level of skill and effort is employed in the operation and maintenance of the collection system (e.g., including wellfield monitoring and adjustment about once per month). Collection efficiency is assumed to be 35 percent in 2012 and increase incrementally until 2027, when collection efficiency is assumed to reach a maximum of 60 percent following the completion of the final cover. SCS considers the low recovery estimates to be conservative and should be employed only if a large margin of safety is needed.

- The mid-range recovery scenario assumes that a moderate level of skill and effort is employed in the operation and maintenance of the collection system (e.g., including wellfield monitoring and adjustment at least 2 to 3 times per month). Collection efficiency is assumed to be 50 percent in 2012, which requires collecting approximately 70 percent of LFG generated from waste deposited through the end of 2010. After 2012, collection efficiency is assumed to increase incrementally until 2027, when it reaches a maximum of 75 percent following the completion of the final cover. SCS considers the mid-range recovery scenario to be its best estimates of likely recovery and recommends its use in an economic evaluation.

- The high recovery scenario assumes that highest possible level of skill and effort is employed in the operation and maintenance of the collection system (e.g., including weekly or more frequent wellfield monitoring and adjustment). Collection efficiency is assumed to be 60 percent in 2012 and increase incrementally until 2027, when collection efficiency is assumed to reach a maximum of 85 percent following the completion of the final cover. SCS considers the high recovery estimates to be ambitious and attainable only if the maintenance of an optimal LFG recovery system is considered to be a top priority.

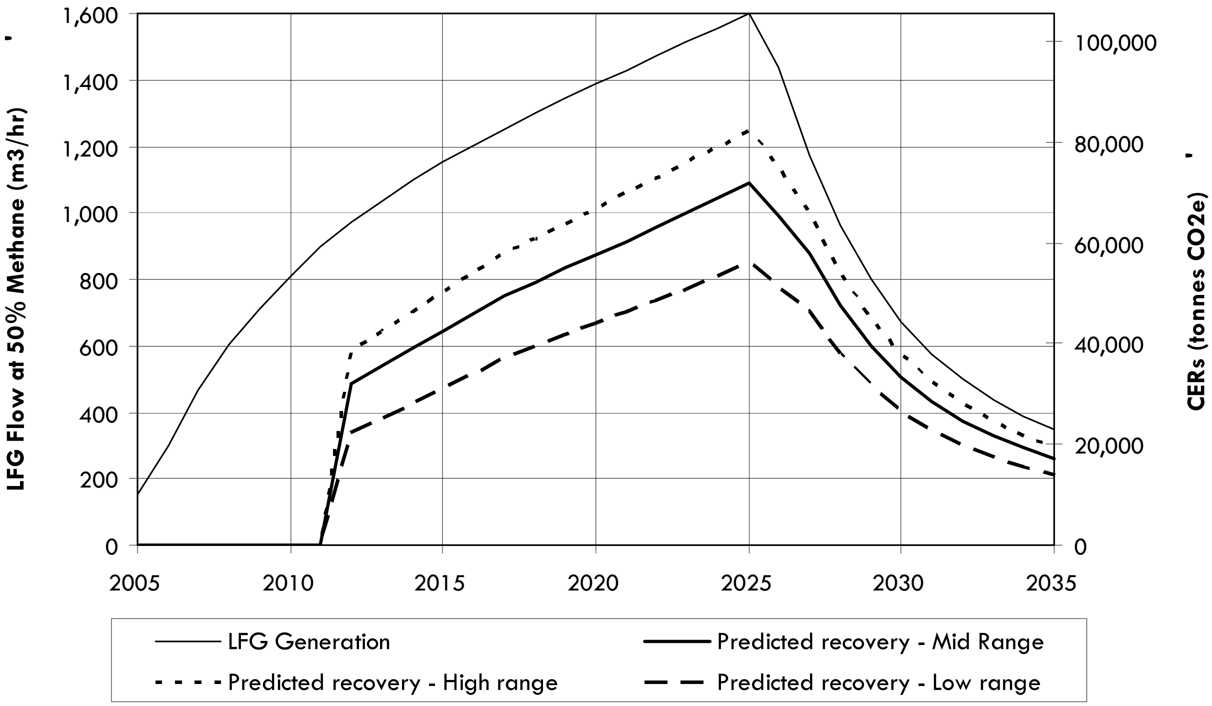
Note that, in addition to the potential variability in collection efficiency and the level of operation and maintenance, mathematical modeling of LFG is inherently uncertain Affecting the overall outcome of the estimates.

4.3 MODEL RESULTS

LFG generation projections for the Vale de Arco Landfill are provided in Figure 10 and Table A-1 in Attachment A. LFG recovery projections under alternative collection system efficiency scenarios (low, mid-range, and high) are provided in Figure 10 and Tables A-1 and A-2 in Attachment A.

As shown in Table A-1, LFG generation is projected to increase from approximately 810 m^3/hour in 2010 to a maximum of about 1,600 m^3/hour in 2025, and decline thereafter. Under the mid-range collection efficiency scenario, LFG recovery is projected to increase from about 490 m^3/hour in 2012 to about 650 m^3/hour in 2015, 870 m^3/hour in 2020, and finally reach a maximum of about 1,090 m^3/hour in 2025, after which it begins to decline due to declining LFG generation. Table A-1 also shows that the potential for power generation from LFG is estimated to be about 0.8 MW in 2012, 1.1 MW in 2015, 1.4 MW in 2020, and 1.8 MW (maximum value) in 2025. Estimated greenhouse gas emission reduction credits (Certified Emission Reductions, or CERs) to be achieved by this project through the combustion of landfill methane under the mid-range recovery projections are estimated to be approximately 470,000 Mg of carbon dioxide equivalent (CO_2e) emissions over the 2012 through 2021 period.

Figure 10. LFG Generation and Recovery Rates
Vale do Aço Landfill



5.0 LANDFILL GAS UTILIZATION OPTIONS

LFG project options examined in this study include: (1) on-site electricity generation; (2) direct use for heating/boiler fuel (medium-Btu application), and (3) flaring only. All three options require installation of an active gas collection and control system (GCCS), including a flare to ensure combustion of all collected methane when the LFG is not being utilized. All three options also are expected to generate revenues from the sale of emission reduction credits taking advantage of the United Nations Convention on Climate Change (UNFCCC) Clean Development Mechanism (CDM) or other voluntary market.

Capital costs for a GCCS will depend to a large extent on LFG flows, landfill size, and waste depth. A typical range for GCCS costs, including flare start-up, source test, engineering, and contingency costs, is about $70,000 to $120,000 (U.S.) per hectare of landfill area. Annual GCCS operation and maintenance (O&M) costs typically average from 7 to 10 percent of capital costs, not including costs of electricity or system expansions.

5.1 ELECTRICITY GENERATION

Brazil's Renewable Energy Programs

Renewable energy projects have been supported in Brazil as a means of diversifying the national energy supply. Diversifying the energy supply was one of the strategies the government sought as a consequence of the energy crisis of 2001. The other strategy was to reshape the energy model, which the government carried out by dividing energy trading markets into a regulated pool and a free-market. To promote alternative and renewable energy sources, the government created two programs, Proeolica[9] and Proinfa[10]. Proeolica was aimed at the development of wind energy. Proinfa aimed to increase the participation of energy from the renewable sources such as wind, small hydropower and biomass[11].

Proinfa was designed to be implemented in two phases. The first phase aimed to increase the power generation from renewables by 3,300 MW (1,100 MW from each of the chosen categories of renewable sources). After two public tenders in January 2006, 144 projects were contracted to deliver the 3,300 MW, but not in the same proportion as first intended. Wind and small hydro projects were to provide 79% of the capacity. The first phase of Proinfa will end with the installation of the subscribed projects, but as of 2010 there are still some projects that have faced major delays in construction and actual start-up. During the first phase no landfill-gas-to energy (LFGE) project was implemented.

Proinfa's second phase was initially projected to ensure that energy from renewable sources would supply 10 percent of the annual electric power demand of Brazil within a period of twenty years. The second phase was originally based on feed-in tariffs but was modified in 2003 in order to be based on auctions for renewables. These auctions are capped to limit their impact on the final electricity tariff. The Ministry of Energy has held a series of public auctions for renewable energy projects to obtain contracts for the purchase of energy (PPA). The latest renewable energy auction held in August 25-26, 2010. In total, 56 plants marketed their energy at this action, including 50 wind turbines plants, a biomass plant and five small hydropower plants. The plants will start supplying electricity in 2013. The average selling prices were: R$134.1/MWh for wind, R$146.99/MWh for small hydro, and R$137.92/MWh for biomass.[12]

Most renewable energy projects can also commercialize their energy in the free market environment by seeking "special consumers". Law 10,762 of 2003 created the category of "special consumers". Special consumers can be a single electricity consumer, or a group of consumers united by common interest, with a consumption load equal to or greater than 500kW. These consumers are allowed to buy electricity at any level of tension from alternatives sources of electricity within the free market environment. The alternative energy sources allowed to commercialize with the special consumers are conventional energy projects with installed

9 Programa Emergencial de Energia Eólica (CGE Resolution 24, July 5, 2001)
10 Programa de Incentivo às Fontes Alternativas de Energia Elétrica (Law 10.438 of April 26,2002)
11 Biomass refers to products that have vegetal (such agricultural products and pieces of wood), animal or human origin (urban waste). In Brazil, biomass includes sugar cane bagasse, rice husks, wood, landfill gas, etc.
12 ANEEL (http://www.aneel.gov.br/aplicacoes/noticias/Output_Noticias.cfm?Identidade=3541&id_area=)

capacity less than or equal to 1 MW and renewable energy projects (small hydro, solar, wind or biomass) with installed capacity less than or equal to 50 MW.

To provide another incentive for the development of renewable energy, the Electricity Regulatory Agency (ANEEL[13]) enacted Resolution No 77 which establishes the procedures related to the reduction of electricity grid wheeling tariffs for renewable energy sources. Renewable energy sources eligible to take advantage of this incentive include small hydroelectric, solar, wind, biomass (including biogas (LFG)), and combined heat and power (CHP), with installed capacities equal to or less than 30 MW. The resolution gave the added incentive of reducing the tariffs, of at least 50%, for access to transmission and distributions systems for the renewable energy generators. Furthermore, in order to minimize environmental impacts caused by urban waste and contribute to the guidelines of the Kyoto Protocol, ANEEL amended Article 3 of Resolution 77 to give businesses that use waste as a source of electric generation a reduction of 100% of the tariffs for use of the transmission and distribution systems. The amendment was made official in Resolution 271 in July 2007.

Vale do Aço Electric Energy Options

According to the LFG model results, the Vale do Aço Landfill could support a 1.0 MW LFGE project in 2012 running at about 80% capacity, going to full load beginning in 2014 for a period of up to 16 years (2014-2029). A 1 MW LFG-fired electric generation project is quite small, and can be challenging to make economically viable without obtaining a high price for the renewable energy. Based on the most recent Proinfa Phase II auctions, a project of this size may be difficult to implement, depending on the cost of interconnect, the technology selected, and the manufacturer of the gensets chosen. Alternatively, electricity could be sold to a qualified end user allowed under Law 10,762 where a higher price may be possible. If on-site electricity demand could be increased substantially (for blowers, leachate pumps, or other use) the 1 MW of generated electricity could be utilized to meet this on-site demand (self-generation)

Currently, the landfill is being supplied electricity through distribution lines at 34.5 kV tension and the closest substation is located about 5 kilometers from the landfill. Three phase distribution lines with a voltage higher than 12 kV typically have sufficient capacity to support an electric generation project in excess of 2 MW without upgrading the capacity of the existing distribution infrastructure. However, an interconnect study would have to be completed by the electric distributor in the region, CEMIG.

5.2 DIRECT USE

The sale of LFG for direct use at a nearby industrial facility can generate significant revenues while requiring less initial facility costs than an LFG-to-electricity facility. Unless the direct use client is located at a very short distance from the landfill, a LFG transmission pipeline will be required. If the direct use project requires transporting the LFG a significant distance to the end user, it typically requires a gas compression and treatment skid (filter, compressor or blower, and

13 Agência Nacional de Energia Elétrica (ANEEL)

de-hydration unit). LFG treatment requirements are also driven by the equipment that will utilize the LFG. Depending on the level of treatment required, the gas compression and treatment skid costs approximately \$400 to \$500 (U.S.) per m^3/hour of LFG that is treated. Pipeline construction is the largest cost item at about \$150,000 to \$175,000 per km (assuming open trenching and not including payments for right-of-way easements), so project feasibility is largely determined by the distance to end users. Annual O&M costs are about \$100 to \$150 per m^3/hour of LFG. In addition, if the LFG pipeline can be run above ground, costs can be significantly reduced.

Industries located in the proximity of the landfill that could serve as potential end-users of LFG include the following:

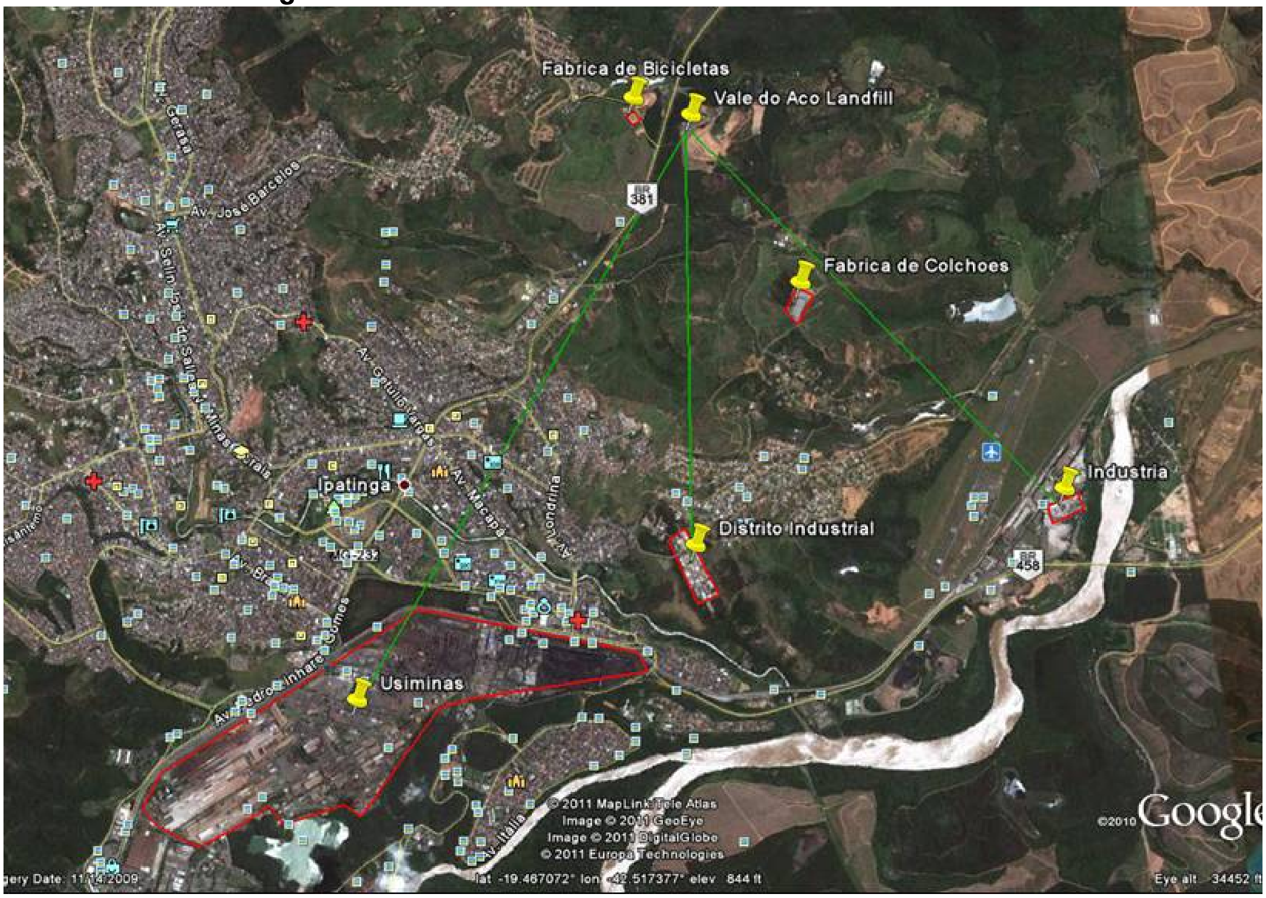
1. Bicycle factory located 0.2 km from the Landfill ,
2. Mattress factory located 1.5 km from the Landfill
3. Industrial District located 3.85 km S from the Landfill
4. Heavy industry (ies) located 4.7 km SE from the Landfill next to Ipatinga Airport.
5. Usiminas complex located 5 km S of the Landfill in Ipatinga.

It appears that the bicycle and mattress factories do not use significant thermal energy. However, it is highly likely that a suitable end user can be found at one of the other potential locations identified. The Usiminas complex is clearly a very large energy user, but the distance is relatively far for the current quantities of LFG available, and the route from the Landfill to the complex is difficult, having to pass through the center of Ipatinga. It would be necessary to evaluate the industries energy needs as well as the pipeline routes to determine if the LFG could be used at any of these facilities. In addition, there may be other industries within a 6 km radius, in addition to those identified that could utilize the LFG.

The viability of direct use project will be driven by the following key factors: (1) the end user's distance from the landfill; (2) the quality of the end user's demand for thermal energy (large and steady demand); (3) the end user's cost of current fuel (e.g. cost of natural gas,[14] coal, oil, etc in the market); (4) complexity and cost to convert existing systems to utilize LFG; and (5) quality of LFG required by the end user for its processes.

14. The cost of natural gas for an industrial user is calculated by the local natural gas distributor. The final tariff consists of fixed cost and a variable cost. The company GASMIG, a subsidiary of the state electrical utility CEMIG, is the natural gas distributor for the region. GASMIG charges large customers (>10,000 m3/day) were on average equal to US\$0.12./m^3 variable cost or about \$3.32 / MMBtu.

Figure 11. Potential Direct Use Locations



5.3 FLARING ONLY AND EMISSIONS TRADING

Because methane generated from solid waste disposal on land is one of the major sources of greenhouse gas emissions[15], its capture and oxidation to carbon dioxide results in an environmental benefit. This benefit may be measured and traded under a number of different emission reduction trading schemes worldwide, including the sale of CERs under the UNFCCC's CDM.

In order to qualify for trading of emission reductions, normally a project must be able to prove that there is no requirement under law, or mandated by waste disposal licenses or other regulations, to control the emission of the particular greenhouse gas relating to the project. SCS understands that this the case at the Valle do Aço Landfill, where under both Brazilian and State of Minas Gerais laws and regulations, it is not required to collect and destroy the LFG.

While flaring is the normal method for thermal oxidation of landfill gas, any process which prevents the emission of methane to the atmosphere would also qualify for tradable emission

15 U.S. EPA's2008 Report n the Environment

reductions (such as burning LFG in an electricity generator set). The carbon dioxide created by the thermal oxidation of methane is considered to be "short cycle" and the product of the normal carbon cycle; and therefore, does not need to be accounted for under the current methodologies for estimating emission reductions.

If electrical energy production is also included, and that power is either exported to the local distribution network or used to displace other electricity generated by the combustion of fossil fuels, it is possible to gain additional emission reductions as a result of the displacement of fossil fuel use.

Although not a utilization option, flaring collected LFG would therefore produce significant environmental benefits and potential revenues from the sale of CERs. Because CERs are typically the only source of revenues from a flaring only project, prices received for the CERs will largely determine the economic feasibility of the project. A flaring only project will produce lower revenues than the other project options but may be more economically feasible to develop at the landfill due to much lower capital investment costs. In addition, a flaring only project does not preclude a landfill from subsequently developing and implementing an LFG utilization project. A phased approach can reduce project risk by allowing for: (1) the proving of LFG quantities that the landfill can produce; (2) recover the cost of the LFG collection system (and thus not burden the utilization project with having to fund the capital for the collection system); and (3) provide a revenue base to help support the development and financing of the utilization project. If a multi-phased approach is chosen, it is very important that the concept for a second phase LFG utilization project be included in any project design document (PDD). Even if all the details are not known, a general concept should be introduced to allow for the modification of the PDD in lieu of a complete PDD resubmission.

6.0 OTHER PROJECT CONSIDERATIONS

6.1 LANDFILL GAS RIGHTS

For any LFG project to occur, the ownership of the gas rights needs to be clearly defined. Disputes over gas rights need to be settled before there can be decisions regarding proceeding with a project, contract negotiations, or revenue sharing.

The Valle do Aço Landfill is owned by Vital Ambiental and is in the jurisdiction of the Municipality of Santana do Paraíso. We understand that Vital has exclusive ownership of the LFG rights.

6.2 SECURITY AND SCAVANGERS

Security at the landfill is adequate for the development of a LFG utilization project, and the landfill does not have any scavengers.

7.0 RECOMMENDATIONS

This section presents general recommendations aimed at improving the chances of developing a successful LFG utilization or flaring only project.

7.1 SITE MANAGEMENT

The landfill is very well run and operated very well. According to site drawings, the base of the landfill has a significant downward slope, waste should be carefully placed and every effort should be made to avoid the mass from getting saturated. Waste should continue to be covered daily, and storm water should continue to be directed away from the waste mass. Every effort should be made to avoid leachate build-up in the waste mass. A larger leachate drainage system could be considered. For example, instead of just a fishbone layout of gravel drains, the company responsible for the site operations could consider covering the entire base layer with a drainage (e.g. gravel) layer.

7.2 PROJECT IMPLEMENTATION

The following are recommended next steps for implementing an LFG utilization or flaring only project:

- *LFG Rights*: confirm that Vital has the landfill gas rights. If it is not clear, work with legitimate stakeholders to equitably share the benefits and document any agreement. As a general guideline, we recommend that any benefit received resulting from the LFG should be commensurate with the level of risk incurred. For example, the entity holding the landfill's environmental liabilities should receive the majority of the project's environmental benefits (e.g., environmental/green attributes).

- *Solicit Offers:* Once the gas rights are clearly understood, the LFG rights owner (Vital) should solicit offers to develop the project. If the successful bidder is obligated to put up significant capital, then the LFG rights will most likely have to be transferred to the successful bidder in return for some kind of benefit (typically a payment based on the amount of LFG available or used). If the LFG rights owner prefers to self-develop a flaring only/GHG reduction project, then it should begin the project implementation process, including the following steps:

    - Hire a qualified entity with experience with implementation of GHG reduction projects to support with project development.

    - Prepare a design and cost budget for the LFG extraction system.

    - Prepare the Project Design Document (PDD).

    - Obtain approval from the Brazilian DNA.

  - Obtain a qualified third party entity to validate the project. And
  - Submit the project to the selected registry or GHG program for registration and approval.

- *Other Considerations*: If a phased approach is adopted, make sure the possibility of an LFG utilization project is preserved. Include the concept for a second phase LFG utilization project in the PDD. Even if all the details are not known, a general utilization project concept should be introduced to allow for the modification of the PDD in lieu of a complete PDD resubmission. Give the successful bidder a reasonable timeframe to implement the utilization project; after that period, they would lose their rights to the project. If the successful bidder does not intend to develop or is not awarded the rights to an LFG utilization project, the GHG rights owner(s) should preserve its rights to develop a utilization project in the future, along with the any environmental attributes associated with the utilization project (e.g., CERs).

8.0 CONCLUSIONS

An LFG recovery project at Vale de Arco Landfill is projected to yield a modest amount of LFG in future years, which will increase from about 490 m^3/hr in 2012 to a maximum of about 1,090 m^3/hr in 2025. Based on the LFG recovery projections contained in this report, there is sufficient fuel to run a 1.0 MW electricity generation plant from 2014 through 2029. Alternative project options include flaring only for emission reduction credits or direct use at a nearby industrial facility. Projected emission reduction credits from LFG combustion total about 470,000 metric tons of CO_2e over a 10-year period (2012 – 2021), according to the LFG recovery projections. A more detailed study is required to evaluate the specific project options identified, including a detailed analysis of revenues, capital and operating costs, financing, end user location and demand, and technology considerations, and to determine the economic viability of the various project options.

ATTACHMENT A

LFG MODEL RESULTS

TABLE A-1
PROJECTION OF LANDFILL GAS GENERATION AND RECOVERY UNDER MID-RANGE SCENARIO
VALE DO AÇO LANDFILL, SANTANA DO PARAISO, BRAZIL

						MID-RANGE RECOVERY SCENARIO							
	Disposal Rate	Refuse In-Place	LFG Generation			Collection System Efficiency	Predicted LFG Recovery			Maximum Power Plant Capacity*	Baseline** LFG Flow	Methane Emissions Reduction Estimates**	
Year	(Mg/yr)	(Mg)	(m^3/hr)	(cfm)	(mmBtu/hr)	(%)	(m^3/hr)	(cfm)	(mmBtu/hr)	(MW)	(m^3/hr)	(tonnes CH4/yr)	(tonnes CO_2eq/yr)
2003	13,300	13,300	0	0	0.0	0%	0	0	0.0	0.0	0	0	0
2004	45,730	59,030	36	21	0.6	0%	0	0	0.0	0.0	0	0	0
2005	64,200	123,230	154	91	2.8	0%	0	0	0.0	0.0	0	0	0
2006	82,710	205,940	300	177	5.4	0%	0	0	0.0	0.0	0	0	0
2007	85,250	291,190	467	275	8.3	0%	0	0	0.0	0.0	0	0	0
2008	84,850	376,040	605	356	10.8	0%	0	0	0.0	0.0	0	0	0
2009	88,920	464,960	713	420	12.7	0%	0	0	0.0	0.0	0	0	0
2010	92,360	557,320	809	476	14.5	0%	0	0	0.0	0.0	0	0	0
2011	94,210	651,530	896	528	16.0	0%	0	0	0.0	0.0	0	0	0
2012	96,090	747,620	971	572	17.4	50%	486	286	8.7	0.8	0	1,525	32,026
2013	98,010	845,630	1,038	611	18.5	52%	540	318	9.6	0.9	0	1,694	35,582
2014	99,970	945,600	1,098	646	19.6	54%	593	349	10.6	1.0	0	1,861	39,077
2015	101,970	1,047,570	1,152	678	20.6	56%	645	380	11.5	1.1	0	2,026	42,548
2016	104,010	1,151,580	1,204	708	21.5	58%	698	411	12.5	1.2	0	2,192	46,023
2017	106,090	1,257,670	1,252	737	22.4	60%	751	442	13.4	1.2	0	2,358	49,524
2018	108,210	1,365,880	1,298	764	23.2	61%	792	466	14.2	1.3	0	2,486	52,215
2019	110,370	1,476,250	1,343	791	24.0	62%	833	490	14.9	1.4	0	2,615	54,906
2020	112,580	1,588,830	1,387	816	24.8	63%	874	514	15.6	1.4	0	2,743	57,612
2021	114,830	1,703,660	1,430	842	25.6	64%	915	539	16.4	1.5	0	2,874	60,344
2022	117,130	1,820,790	1,473	867	26.3	65%	957	563	17.1	1.6	0	3,005	63,112
2023	119,470	1,940,260	1,515	892	27.1	66%	1,000	589	17.9	1.7	0	3,139	65,922
2024	121,860	2,062,120	1,557	916	27.8	67%	1,043	614	18.6	1.7	0	3,275	68,781
2025	49,880	2,112,000	1,599	941	28.6	68%	1,087	640	19.4	1.8	0	3,414	71,693
2026	0	2,112,000	1,439	847	25.7	69%	993	584	17.7	1.6	0	3,116	65,446
2027	0	2,112,000	1,171	689	20.9	75%	879	517	15.7	1.5	0	2,758	57,923
2028	0	2,112,000	960	565	17.2	75%	720	424	12.9	1.2	0	2,261	47,488
2029	0	2,112,000	799	470	14.3	75%	599	353	10.7	1.0	0	1,881	39,491
2030	0	2,112,000	674	397	12.0	75%	505	297	9.0	0.8	0	1,586	33,316
2031	0	2,112,000	576	339	10.3	75%	432	254	7.7	0.7	0	1,357	28,505
2032	0	2,112,000	500	294	8.9	75%	375	221	6.7	0.6	0	1,177	24,718
2033	0	2,112,000	439	258	7.8	75%	329	194	5.9	0.5	0	1,033	21,703
2034	0	2,112,000	390	229	7.0	75%	292	172	5.2	0.5	0	918	19,272
2035	0	2,112,000	350	206	6.2	75%	262	154	4.7	0.4	0	823	17,284

MODEL INPUT PARAMETERS:

Assumed Methane Content of LFG:	50%		
	Fast Decay	Med. Decay	Total Site Lo
Decay Rate Constant (k):	0.300	0.060	
CH4 Generation Pot. (Lo) (ft3/ton):	2,325	6,339	2,532
Metric Equivalent Lo (m3/Mg):	73	198	79

NOTES:

* Maximum power plant capacity assumes a gross heat rate of 10,800 Btus per kW-hr (hhv).

**Baseline LFG flow assumes no LFG recovery (no combustion). CERs do not account for electricity generation or use, system down-time, or methane destruction efficiency assumptions.

Total estimated CERs for the 2012-2021 period = **469,858 tonnes CO2e**

Annual average CERs over 10 year period= **46,986 tonnes CO2e**

TABLE A-2

PROJECTION OF LANDFILL GAS RECOVERY UNDER HIGH AND LOW RECOVERY SCENARIOS

VALE DO AÇO LANDFILL, SANTANA DO PARAISO, BRAZIL

	HIGH RECOVERY SCENARIO								LOW RECOVERY SCENARIO							
	Collection System Efficiency	Predicted LFG Recovery			Maximum Power Plant Capacity*	Baseline** LFG Flow	Methane Emissions Reduction Estimates**		Collection System Efficiency	Predicted LFG Recovery			Maximum Power Plant Capacity*	Baseline** LFG Flow	Methane Emissions Reduction Estimates**	
Year	(%)	(m^3/hr)	(cfm)	(mmBtu/hr)	(MW)	(m^3/hr)	(tonnes CH4/yr)	(tonnes CO_2eq/yr)	(%)	(m^3/hr)	(cfm)	(mmBtu/hr)	(MW)	(m^3/hr)	(tonnes CH4/yr)	(tonnes CO_2eq/yr)
2003	0%	0	0	0.0	0.0	0	0	0	0%	0	0	0.0	0.0	0	0	0
2004	0%	0	0	0.0	0.0	0	0	0	0%	0	0	0.0	0.0	0	0	0
2005	0%	0	0	0.0	0.0	0	0	0	0%	0	0	0.0	0.0	0	0	0
2006	0%	0	0	0.0	0.0	0	0	0	0%	0	0	0.0	0.0	0	0	0
2007	0%	0	0	0.0	0.0	0	0	0	0%	0	0	0.0	0.0	0	0	0
2008	0%	0	0	0.0	0.0	0	0	0	0%	0	0	0.0	0.0	0	0	0
2009	0%	0	0	0.0	0.0	0	0	0	0%	0	0	0.0	0.0	0	0	0
2010	0%	0	0	0.0	0.0	0	0	0	0%	0	0	0.0	0.0	0	0	0
2011	0%	0	0	0.0	0.0	0	0	0	0%	0	0	0.0	0.0	0	0	0
2012	60%	583	343	10.4	1.0	0	1,830	38,431	35%	340	200	6.1	0.6	0	1,068	22,418
2013	62%	643	379	11.5	1.1	0	2,020	42,425	37%	384	226	6.9	0.6	0	1,206	25,318
2014	64%	702	413	12.6	1.2	0	2,205	46,314	39%	428	252	7.6	0.7	0	1,344	28,223
2015	66%	761	448	13.6	1.3	0	2,388	50,146	41%	472	278	8.4	0.8	0	1,483	31,151
2016	68%	818	482	14.6	1.4	0	2,569	53,958	43%	518	305	9.2	0.9	0	1,625	34,120
2017	70%	876	516	15.7	1.4	0	2,751	57,778	45%	563	332	10.1	0.9	0	1,769	37,143
2018	71%	922	543	16.5	1.5	0	2,894	60,775	46%	597	352	10.7	1.0	0	1,875	39,375
2019	72%	967	569	17.3	1.6	0	3,036	63,762	47%	631	372	11.3	1.0	0	1,982	41,622
2020	73%	1,013	596	18.1	1.7	0	3,179	66,757	48%	666	392	11.9	1.1	0	2,090	43,895
2021	74%	1,058	623	18.9	1.8	0	3,323	69,773	49%	701	412	12.5	1.2	0	2,200	46,201
2022	75%	1,104	650	19.7	1.8	0	3,468	72,821	50%	736	433	13.2	1.2	0	2,312	48,547
2023	76%	1,151	678	20.6	1.9	0	3,615	75,910	51%	773	455	13.8	1.3	0	2,426	50,940
2024	77%	1,199	706	21.4	2.0	0	3,764	79,046	52%	810	477	14.5	1.3	0	2,542	53,382
2025	78%	1,247	734	22.3	2.1	0	3,916	82,236	53%	848	499	15.1	1.4	0	2,661	55,879
2026	79%	1,137	669	20.3	1.9	0	3,568	74,931	54%	777	457	13.9	1.3	0	2,439	51,219
2027	85%	996	586	17.8	1.6	0	3,126	65,646	60%	703	414	12.6	1.2	0	2,207	46,339
2028	85%	816	480	14.6	1.4	0	2,563	53,820	60%	576	339	10.3	1.0	0	1,809	37,991
2029	85%	679	400	12.1	1.1	0	2,131	44,757	60%	479	282	8.6	0.8	0	1,504	31,593
2030	85%	573	337	10.2	0.9	0	1,798	37,758	60%	404	238	7.2	0.7	0	1,269	26,653
2031	85%	490	288	8.8	0.8	0	1,538	32,305	60%	346	204	6.2	0.6	0	1,086	22,804
2032	85%	425	250	7.6	0.7	0	1,334	28,014	60%	300	177	5.4	0.5	0	942	19,774
2033	85%	373	220	6.7	0.6	0	1,171	24,596	60%	263	155	4.7	0.4	0	827	17,362
2034	85%	331	195	5.9	0.5	0	1,040	21,841	60%	234	138	4.2	0.4	0	734	15,417
2035	85%	297	175	5.3	0.5	0	933	19,589	60%	210	123	3.7	0.3	0	658	13,828

NOTES:

* Maximum power plant capacity assumes a gross heat rate of 10,800 Btus per kW-hr (hhv).

**Baseline LFG flow assumes no LFG recovery (no combustion). CERs do not account for electricity generation or use, system down-time, or methane destruction efficiency assumptions.

Total estimated CERs for the 2012-2021 period = **550,118 tonnes CO2e**

NOTES:

* Maximum power plant capacity assumes a gross heat rate of 10,800 Btus per kW-hr (hhv).

**Baseline LFG flow assumes no LFG recovery (no combustion). CERs do not account for electricity generation or use, system down-time, or methane destruction efficiency assumptions.

Total estimated CERs for the 2012-2021 period = **349,467 tonnes CO2e**