ASSESSMENT REPORT

Uberaba Sanitary Landfill
Uberaba, Minas Gerais
Brazil

Prepared for:
Fundação Estadual do Meio Ambiente - FEAM

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ASSESSMENT REPORT

UBERABA 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 (US EPA) and the Fundação Estadual do Meio Ambiente (FEAM), for the Uberaba Sanitary Landfill in the Municipality of Uberaba, Brazil. The assessment was prepared based on the information provided by the Prefeitura Municipal de Uberaba (PMU), and observations made during a site visit on April 13, 2010.

The disposal site has served the City of Uberaba as a sanitary landfill since 2005. The landfill has approximately 320,000 metric tonnes (Mg) of municipal solid waste (MSW) in place as of the time of the site visit in April 2010, and has an estimated remaining capacity for another 1.85 million Mg of waste, for a total of about 2.07 million Mg at closure. Based on the projected 2010 disposal rate (72,000 Mg per year) and an assumed growth rate of 4.8 percent, the site will be full by late 2026.

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 combustion 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 approximately 390,000 carbon-equivalent (CO_2e) Mg over a 10-year period (2011 – 2020).

2.0 INTRODUCTION

This assessment report for the Uberaba 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 (GMI), 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 Uberaba 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 13, 2010; (2) provided by Superintendence of Solid Waste Collection and Municipal Roads of the Municipality of Uberaba during the site visit; (3) provided in completed data profile form; and (4) provided by Superintendence of Solid Waste Collection and Municipal Roads of Uberaba in an email dated August 17, 2010 to Fundação Estadual do Meio Ambiente (FEAM).

The data consisted of:

- Estimated site opening date (2005).
- The size of the areas used for disposal and total area of the landfill.
- Estimated maximum current waste depths.
- The estimated total site capacity in cubic meters (m^3).
- Average waste disposal rates from 2006 to August 2010 based on scalehouse data.
- Waste composition data.
- Practices for treatment and control of leachate, waste recycling, 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-users 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 the Municipality of Uberaba. 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 Uberaba Sanitary Landfill is located in the City of Uberaba, in the state of Minas Gerais, Brazil. It located approximately 19 kilometers (km) south of downtown Uberaba and 494 km west of downtown Belo Horizonte, capital of the State of Minas Gerais (see site location in Figure 1). The climate in Uberaba is classified, by the Köppen method, as “Aw”, tropical hot and humid with a cold and dry winter. The 24-hour average temperature is 23.0 degrees C (73.4 degrees F). Average annual precipitation in Uberaba is estimated to be 1,570 mm (62 inches), of which over 88 percent falls in the summer months of October through April.[1]

The City of Uberaba is located in the *Triangulo Mineiro* (TM), one of ten planning regions in the state of Minas Gerais2. TM is a rich agricultural and industrial area and includes the cities of Uberlandia and Uberaba. Uberaba has a population of about 296,300 and a GDP per capita of R$18,862 in 2009, but is one of the fastest growing cities in Brazil[3.] Each inhabitant generates about 0.8 kg of MSW per inhabitant per day, as compared to 1.25 kg per inhabitant per day for Belo Horizonte.[4]

1. Source: www.worldclimate.com. Annual estimate is average of values for the closest stations with complete data (in Belo Horizonte and Araxa).
2 Portal do Governo de Minas Gerais: http://www.mg.gov.br/governomg/portal/m/governomg/conheca-minas/geografia/5671-regioes-de-planejamento/5146/5044
3 Panorama Residuos Solidos 2009, ABRELPE
4 *Ibid*

Figure 1. Location of Uberaba Landfill

The Uberaba Landfill is owned by the Municipality of Uberaba. The site property covers 45 hectares (ha), of which approximately 17 ha is expected to ultimately be used for waste disposal. The disposal area is divided into four cells or "blocks". The four hectare First Block is closed and MSW disposal is occurring in the Second Block. Figure 2 shows a view of the working phase of the Second Block.

Figure 2. Working Face

Liner systems were installed in the existing cells (Blocks 1 and 2) that consist of the following elements:

- Three layers of clay, each compacted to a thickness of 20 centimeters each.
- An asphalt (Diluted Petroleum Asphalt CM- 30) layer that was sprayed onto existing clay.
- Layer of compacted clay.

The remaining areas of the landfill contain the old unlined dump, leachate treatment ponds, administrative offices (see Figure 3), scale and scalehouse (see Figure 4), access roads, and buffer zones.

Figure 3. Administrative Offices

Figure 4. Scale House

3.1 LANDFILL OPERATIONS

The site began operations on November 30, 2005. The organization that operates the landfill is Uberaba Ambiental, S.A. It was awarded the concession contract for the operation of the landfill as well as the collection of waste in Uberaba in 2005 for a period of 20 years.

The landfill is open Monday to Saturday, 24 hours per day. The amount of waste entering the site is quantified by means of an automated scale and simple computerized recording system. The Uberaba site has available a good supply of clay with low permeability. Disposal costs are recovered from residents through a municipal tax known as "Imposto sobre o Propriadade Predial e Territorial Urbano (IPTU)", and are not based on amounts of waste disposed. Commercial entities pay about R$2.50 per metric ton.

Each of four disposal cells ("blocks") consists of eight "platforms" with a thickness of five meters that are stacked vertically. Each platform is filled laterally by pushing waste up a slope using a bulldozer which makes several passes over the waste. No compactors are used. The site has one medium-sized bulldozer and one smaller bulldozer and has access to an excavator. Intermediate soil cover about 20 cm thick is applied on top of each platform as it is extended, and is not removed. The working face is rarely covered.

Final cover will be applied over the total disposal area, 17 ha, and consists of 40 cm of clay and 20 cm of organic soil to support a vegetative layer.

Stormwater is controlled with a perimeter ditch system that includes ditches along the side of the final cover (see Figure 5).

Figure 5. Perimeter Ditch

Figure 6. Leachate Drainage Trench

Leachate is managed by using a fishbone pattern of stone trenches (parallel angled lateral trenches leading to a main trench in the middle) installed at the base of the landfill and on top of the intermediate cover over each 5-meter deep platform. The stone trenches in the base of the landfill are sloped to one point for collecting and pumping the leachate to treatment ponds. The stone trenches on top of each platform are sloped to the leachate drains (which also function as passive LFG vents), from which leachate is drained to the leachate collection system at the base of the landfill.

Differential settlement of the intermediate layers can cause the leachate drains on each platform to become ineffective due to negative slope, clogging or fracture. Due to the large amount of clay that is used in the intermediate layers, ponding or perched zones can occur on top of the clay.

An alternative solution which is commonly used in other parts of the world is completely cover the base above the impermeable layer with a drainage layer (e.g. stone), adequately protecting the impermeable layer, and sloping the base so that the leachate is collected from the low point in the base layer. Additionally, the intermediate cover should be removed prior to the next platform being installed (to the extent possible). The intermediate stone drainage grids should not be installed, with the stone being used instead in the base layer. The intermediate layers of clay offer no additional stability, and in fact, can create instability and failure points if large perched zones or ponding occurs on top of the intermediate layers.

The leachate is treated in a series of four leachate lagoons (see Figure 7). The first two, one of which is shown in the foreground of Figure 7, are smaller but quite deep (five meters deep) and are anaerobic. Leachate is then transferred to the two large aerobic leachate treatment ponds. A very amount of leachate is transferred to the final pond, and the ponds have never required pumping to remove the final treated leachate. Given the amount of rainfall that Uberaba receives, this indicates that leachate is most likely leaking out of the ponds. The ponds are unlined, but the soil in the region is a clay with a high permeability.

Figure 7. Leachate Evaporation Lagoons

The site has a passive LFG venting system that consists of venting wells that penetrate to the bottom of the waste in the First Block, having been built upward from the base layer as the waste is placed. There are vents which are constructed with perforated 90-centimeter (cm) diameter concrete pipes which are then surrounded by rock-filled cages, as shown in Figure 8 and Figure 9. About four of the wells have their tops capped with a concrete square lid that has a metal pipe in its center (see Figure 10). LFG emitting from this pipe is lit periodically to burn the LFG in order to reduce odors and the risk of explosions at the site.

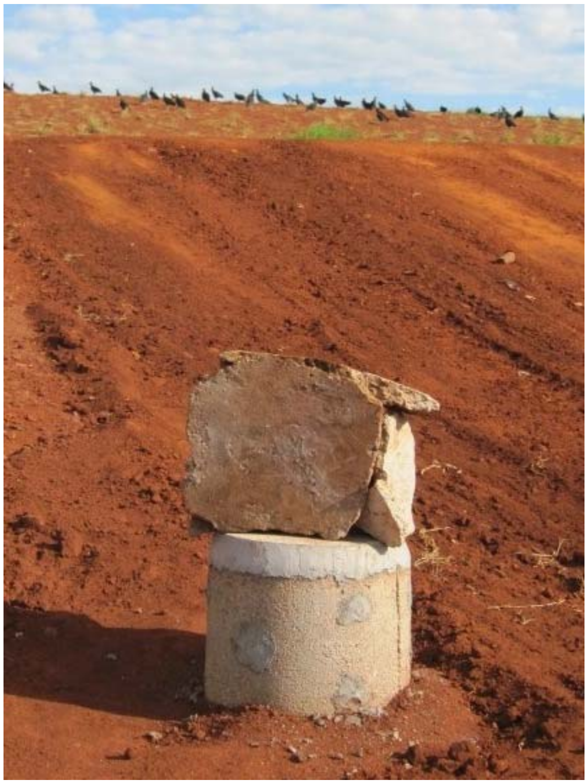

Figure 8. Venting Well in Construction

Figure 9. Venting Well with Cage

Figure 10. Venting Well with Flaring of LFG

3.2 WASTE DISPOSAL INFORMATION

Annual Waste Disposal Rates

The landfill reportedly began receiving waste on November 30, 2005 and had approximately 320,000 tons of waste as of August 2010. Total waste disposal in 2009 was 68,100 Mg. In 2010 waste disposal is projected to reach 72,000 Mg/year.

The site reportedly has a total capacity of approximately 2,958,500 m^3. In-place waste density (Mg of waste disposed / volume of waste and soil excluding final cover) was estimated to be 0.7 Mg/m^3 based on compaction and soil application practices (no data on waste density was available for this study). The resulting estimate of the waste disposal capacity is 2,071,000 Mg. The Municipality of Uberaba estimates that future annual waste disposal will grow at 4.8 percent, which will cause the landfill to reach its capacity in 2026. l. Table 1 lists the historical and projected annual waste disposal rates for the Uberaba Landfill.

Table 1. Waste Disposal Estimates – Uberaba Landfill

Year	Disposed Tonnages (Mg/Year)	Accumulated Tonnages (Mg)	Comments
2006	60,090	60,090	Reported at scale house
2007	66,610	126,700	Reported at scale house
2008	69,180	195,880	Reported at scale house
2009	68,100	263,980	Reported at scale house
2010	72,000	335,980	Projected based on disposal data up to August 15, 2010
2011	75,460	411,440	Projected using 4.8% annual disposal rate increase
2012	79,080	490,520	
2013	82,870	573,390	
2014	86,850	660,240	
2015	91,020	751,260	
2016	95,390	846,650	
2017	99,970	946,620	
2018	104,770	1,051,390	
2019	109,800	1,161,190	
2020	115,070	1,276,260	
2021	120,590	1,396,850	
2022	126,380	1,523,230	
2023	132,440	1,655,670	
2024	138,800	1,794,470	
2025	145,460	1,939,930	
2026	131,070	2,071,000	

Source: Prefeitura Municipal de Uberaba

Waste Composition Data

Waste composition and moisture conditions in a landfill are primary considerations when estimating LFG model input parameters (Lo and k values - defined below). The estimated waste composition percentages are summarized in Table 2. Some of the values were extrapolated from the site specific data provided by the Municipality and have been marked with an asterisk[5].

Table 2. Waste Composition Data – Uberaba Landfill

Waste Material	Estimated %
Food Waste*	52.2%
Garden Waste*	5.8%
Paper	17.5%
Textiles	0.5%
Wood	1.0%
Plastics	6.5%
Metals	4.0%
Glass and Ceramics	2.5%
Other Inorganics	10.0%
Total	100.0%

Source: Municipality of Uberaba

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):

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

5Organic waste” was assumed to be 90% food waste and 10% garden waste

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 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.

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6 EPA, 2005. Landfill Gas Emissions Model (LandGEM) Version 3.02. EPA 600/R-05/047 (May 2005),
7. IPCC, 2006. IPCC Spreadsheet for Estimating Methane Emissions from Solid Waste Disposal Sites.

4.2 MODEL INPUT PARAMETERS

Model k Values

Based on the precipitation rate and estimated waste moisture conditions at the landfill, SCS assigned the model k values of 0.36, 0.72, and 0.018 per year for the fast, medium, and slowly decaying organic waste fractions, respectively.

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. Uberaba is a managed site with a good soil cover over all disposal areas except a relatively small working face, 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 Uberaba from the standard U.S. "inventory" value in LandGEM (100 m^3/Mg) and the ratio of the dry organic content of Uberaba's waste to average U.S. waste is described in the table below.

	U.S. Landfills	Uberaba Landfill	Ratio: Uberaba/U.S.
Organic % (dry weight basis)	Total waste: 43.5%	Fast Organics: 31.6% Medium Organics: 89.2% Slow Organics: 80.0%	Fast Organics: 0.73 Medium Organics: 2.05 Slow Organics: 1.84
L_o value	Total waste: 100 m^3/Mg	Fast Organics: 73 m^3/Mg Medium Organics: 205 m^3/Mg Slow Organics: 184 m^3/Mg	Fast Organics: 0.73 Medium Organics: 2.05 Slow Organics: 1.84

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): 205 m^3/Mg.
- Slow-decay waste (wood, rubber, and leather): 184 m^3/Mg.

The fraction of waste consisting of inert materials (e.g., construction and demolition waste, metals, plastics, glass and ceramics) 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 2027 to allow the achievement of maximum collection efficiency levels starting in 2028.

The three recovery scenarios are described as follows:

1. 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 2028, 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.

2. 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 70 percent of LFG generated from waste deposited through the end of 2010. After 2012, collection efficiency is assumed to increase incrementally until 2028, 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.

3. 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 2028, 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.

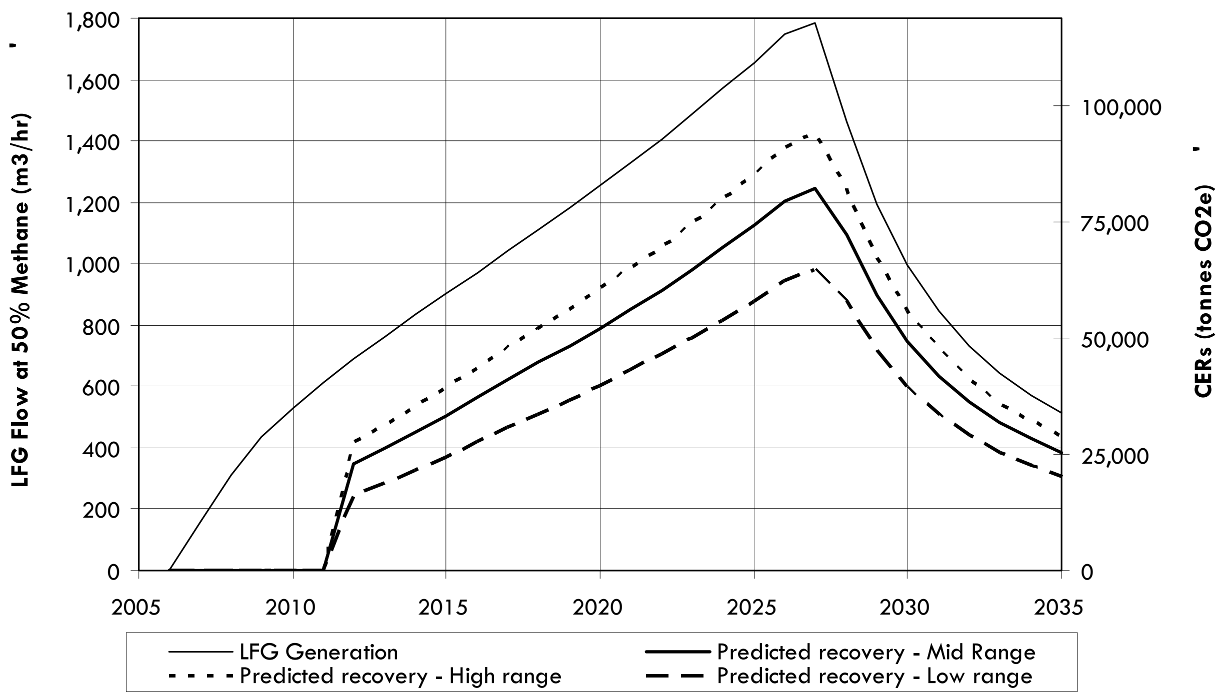
Note that, in addition to the potential variability in collection efficiency and the level of operation and maintenance, mathematical modeling of LFG is inherently uncertain affecting the overall outcome of the estimates.

4.3 MODEL RESULTS

LFG generation and recovery projections, under alternative collection system efficiency scenarios (low, mid-range, and high), for the Uberaba Landfill are provided in Figure 11 and in Tables A-1 and A-2 in Attachment A.

As shown in Table A-1, LFG generation is projected to increase from approximately 530 m^3/hour in 2010 to a maximum of about 1,780 m^3/hour in 2027, and decline thereafter. Under the mid-range collection efficiency scenario, LFG recovery is projected to increase from about 350 m^3/hour in 2012 to about 510 m^3/hour in 2015, 790 m^3/hour in 2020, and finally reach a maximum of about 1,250 m^3/hour in 2027, 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 0.6 MW in 2012, 0.8 MW in 2015, 1.3 MW in 2020, and 2.1 MW (maximum value) in 2027. 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 390,000 Mg of CO_2e emissions over the 2012 through 2021 period.

Figure 11. LFG Generation and Recovery Projections
Uberaba Landfill, Brazil



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) at a nearby industrial facility, and (3) flaring only taking advantage of the United Nations Convention on Climate Change (UNFCCC) Clean Development Mechanism (CDM) or other voluntary carbon market. 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.

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 and source test and 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. For this project, construction of a GCCS in the two existing cells will incur the following estimated costs:

- Wells
  - 9 hectares x 2.47 wells per hectare = 22.23 wells
  - 22.23 wells x US\$10,000 per well = US\$222,300
- Headers and lateral piping, valves
  - US\$9,000 per well x 22.23 wells = US\$200,000
- Flare
  - 1,000 m^3/s enclosed flare = US\$370,000
- Total GCCS capital cost = US\$792,000

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 crises of 2001. The other strategy was to reshape the energy model, and so the government created two energy trading markets, a regulated pool and a free-market. To promote alternative and renewable energy sources, the government created two programs, Proeolica[8] and Proinfa[9]. Proeolica was aimed at the development of wind energy. Proinfa aimed to increase the participation of energy from the renewable sources such as small hydropower, biomass, and also included wind[10].

Proinfa was designed in two phases. The first phase aimed to increase the power generation 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 percent 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 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 20 years. The second phase was originally based on feed-in tariffs but it was modified in 2003 in order to be based on auctions for renewables. These auctions have price caps 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 was held in August 25-26, 2010. In total, 56 plants marketed their energy at this action, including 50 wind turbine plants, a biomass plant and five small hydropower plants. The plants will start supplying electricity in 2013 and the average selling prices will be: R$134.1/MWh for wind, R$146.99/MWh for small hydro, and R$137.92 for biomass.[11]

Most renewable energy projects can also commercialize their energy in the free market environment by seeking "special consumers", a category created under Law 10,762 of 2003. Special consumers can be a single electricity consumer or a group of consumers, united by common interest, with a consumption load equal or above 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: (1) non-renewable projects with installed capacity less than or equal to 1,000 kW and (2) renewable energy projects (small hydro, solar, wind or biomass) with installed capacity less than or equal to 50,000kW.

As another means to incentivize the development of renewable energy, the Electricity Regulatory Agency (ANEEL[12]) enacted Resolution No 77 which establishes the procedures related to the reduction of these tariffs for self-generators or independent renewable energy sources. The renewable energy sources included small hydroelectric, solar, wind, biomass (which includes biogas (LFG)), or CHP, with power installed equal to or less than 30 MW. The resolution gave

8 Programa Emergencial de Energia Eólica (CGE Resolution 24, July 5, 2001)
9 Programa de Incentivo às Fontes Alternativas de Energia Elétrica (Law 10.438 of April 26,2002)
10 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.
11 ANEEL (http://www.aneel.gov.br/aplicacoes/noticias/Output_Noticias.cfm?Identidade=3541&id_area=)
12 Agência Nacional de Energia Elétrica (ANEEL)

the added incentive of tariff reductions of at least 50 percent for access to transmission and distributions systems for the renewable energy generators. Furthermore, in order to help minimize the environmental impacts caused by urban waste and promote emission reduction programs under 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 percent of the tariffs for use of the transmission and distribution systems. The amendment was made official in Resolution 271 of July 3 of 2007.

Uberaba Electric Energy Options

According to the LFG model results, the Uberaba Landfill could support a 1.0 MW LFGE project beginning in 2017 for a period of up to 15 years (2017-2031). 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 and the technology selected and 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), then 1.0 MW genset could be used to meet this on-site demand (self-generation).

Currently, the landfill is being supplied electricity through distribution lines 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

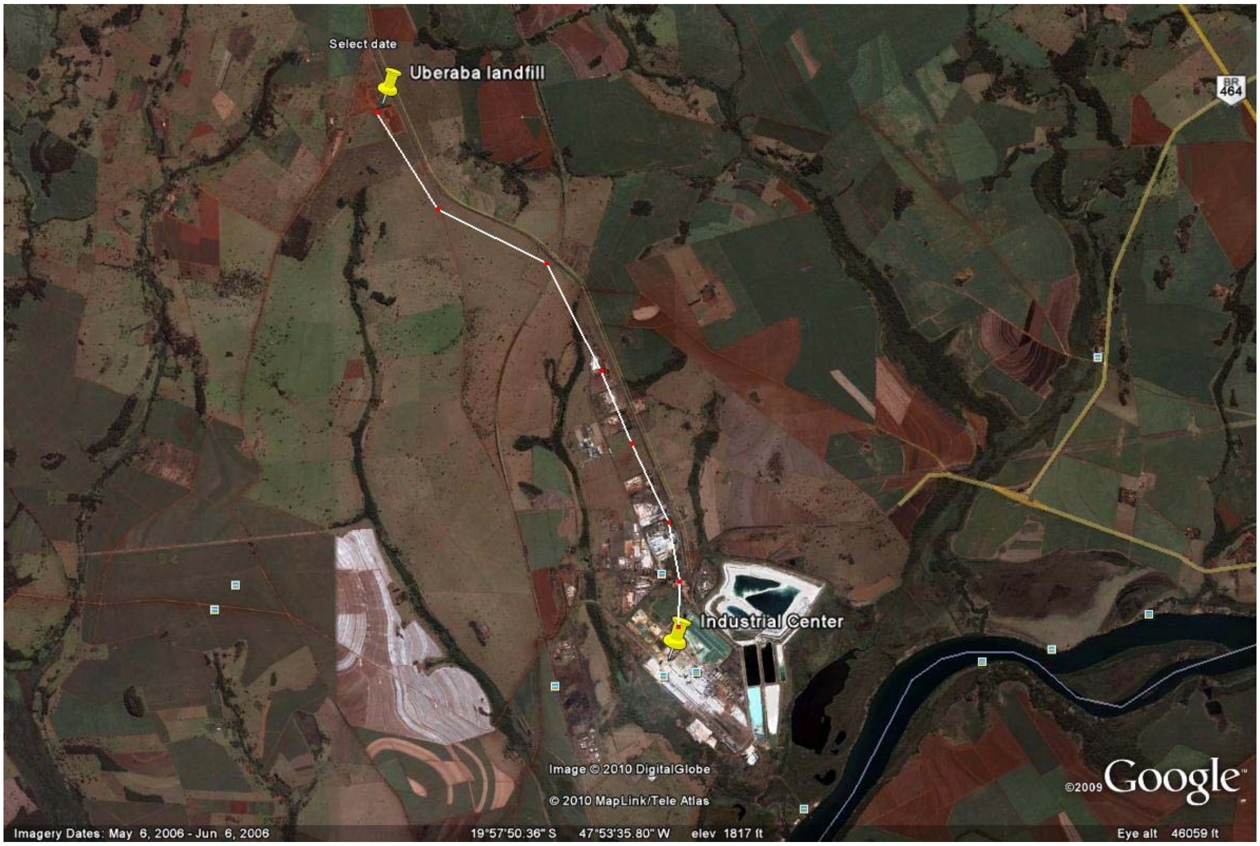
The sale of LFG for direct use at a nearby industrial facility can generate significant revenues while requiring less initial facility costs than an LFG-to-electricity facility. Unless the direct use client is located at a very short distance from the landfill, a LFG transmission pipeline will be required. 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 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 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.

About 6 to 8 kilometers from the landfill is a huge industrial chemical complex centered around the production of fertilizer. The main industry is Fosfertil, one of Brazil's largest producers of primary materials for fertilizer, but other industries located in the area include Bunge, Fertibras, Fertigram, Yara, Guarani, Ipiranga, Petrobras, and Heringer. Many of these industries appear to use large quantities of fossil fuels to produce fertilizer. The chemical industrial complex is divided into three districts. The closest district, District 3, is located about 6 km away for the landfill. A conceptual route is shown in Figure 12.

In addition, Petrobrás, in cooperation with the State of Minas Gerais through CEMIG, is planning to augment the supply of natural gas to the Industrial Center by installing a 20-inch natural gas transmission pipeline to deliver gas from San Carlos, Sao Paulo. With this significant increase in natural gas supply, it will enable an estimated investment of R$5 billion, including ammonia and urea plants, as well as investment by CEMIG in natural gas fired thermoelectric generation.

The route from the Landfill to the Industrial Center appears largely undeveloped, which would allow a pipeline to be completed relatively easily at a comparatively low cost.

Figure 12. Conceptual Pipeline Route to Industrial Center



Length of path: 4.81 miles (7.74 km)

The viability of a 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,[13] coal, oil, etc in the market); (4) the complexity and cost to convert existing systems to utilize LFG; and (5) the quality of LFG required by the end user for its processes.

The price of natural gas for industrial users is quite high. For example, the published regulated tariff for October 2010 for industrial users in the state of Sao Paolo using over 2,000,000 m^3 of natural gas per month was about R$23.34 per MMBtu,[14] and this price has been fairly constant. However, large industrial users may be able to negotiate lower terms through bilateral agreements.

13. The cost of natural gas for an industrial user is calculated by the local natural gas distributor and regulated by the state. The final tariff consists of fixed cost and a variable cost.
14 ComGas Tariffs - http://www.comgas.com.br/tarifas.asp

5.3 FLARING ONLY AND EMISSIONS TRADING

It is possible to account for and transfer the reduction in greenhouse gas emissions resulting from activities that reduce or capture any of the six main greenhouse gases. 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 Certified Emissions Reductions (CERs) under the UNFCCC's CDM. While this program is currently valid only through 2012, it is expected that an equivalent mechanism will be in place post 2012.

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 Uberaba 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 LFG, any process which prevents the emission of methane to the atmosphere would also qualify for tradable emission reductions (such as burning LFG in an electricity generator set or a boiler of an industry utilizing the LFG).

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. However, given that hydroelectric power supplies the majority of the electricity in the Brazilian grid, it is our opinion that the quantity of GHG credits created from the displacement of fossil fuel derived electricity would not be significant.

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. In addition, having two sources of revenues from GHG reductions and renewable energy sales mitigates project risk. 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

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

(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 Uberaba Landfill is property of the Municipality. The Municipality awarded the operations of the landfill to Uberaba Ambiental, S.A. under a 20 year concession contract. At the time of the site visit, the Municipality firmly stated that it had 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

Landfill Development (Phasing) Plan. In order to develop a realistic plan for the implementation of the LFG collection system, the landfill should first develop a landfill development or phasing plan. A landfill phasing plan will provide more certainty to the schedule for implementing the LFG project and expanding the collection system to all the phases of the landfill. This plan will also help to determine how collection system coverage can be maximized throughout the life of the LFG project.

Intermediate Cover. The intermediate cover should be removed prior to the next platform being installed (to the extent possible). The stone drainage grid installed at each intermediate layer could also be eliminated, with the stone being installed instead on the base layer. This approach will increase leachate removal, increase landfill air space and reduce the number of perched zones and ponding that could occur on top of each intermediate layer.

Stormwater Management. During the rainy season, stormwater that falls on the landfill surface has the potential to infiltrate into the waste mass at or near the working face and produce leachate. It is important that the landfill is designed with adequate slopes and runoff features (ditches, benches, etc.) to avoid ponding of water and excessive erosion. The active disposal area and working face should be minimized, particularly during the rainy season.

7.2 PROJECT IMPLEMENTATION

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

- *LFG Rights*: Verify and document that the Municipality has the rights to the LFG, and that the landfill operator, Uberaba Ambiental, S.A. has no claim to these rights. If there is disagreement, 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 resolved, the Municipality (or LFG rights owner (s)) 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 Municipality 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 the Municipality 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.
    - 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 Uberaba Landfill is projected to yield a modest amount of LFG in future years which will increase from about 350 m^3/hr in 2012 to a maximum of about 1,250 m^3/hr in 2027. Based on the LFG recovery projections contained in this report, there is not likely to be sufficient fuel to run a one MW electricity generation plant until 2017. Alternative project options include direct use at one of the industrial fertilizer facilities located at the nearby Uberaba Industrial Center, or flaring only for GHG emission reduction credits. If a utilization project is pursued, a phased approach should be adopted with the flaring only GHG project implemented in the first phase, followed by the utilization project once gas quantity and quality are verified. Projected emission reduction credits from LFG combustion total about 390,000 Mg 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. The municipality should consider obtaining other sources of waste materials from the agriculture, commercial and industrial sectors, particularly those waste streams which are high in organic content. These sources should be charged on an R$ per ton basis, and could form a significant source of income for the Municipality.

ATTACHMENT A

LFG MODEL RESULTS

TABLE A-1
PROJECTION OF LANDFILL GAS GENERATION AND RECOVERY UNDER MID-RANGE SCENARIO
UBERABA LANDFILL, UBERABA, BRAZIL

Year	Disposal Rate (Mg/yr)	Refuse In-Place (Mg)	LFG Generation (m^3/hr)	LFG Generation (cfm)	LFG Generation (mmBtu/hr)	MID-RANGE RECOVERY SCENARIO: Collection System Efficiency (%)	Predicted LFG Recovery (m^3/hr)	Predicted LFG Recovery (cfm)	Predicted LFG Recovery (mmBtu/hr)	Maximum Power Plant Capacity* (MW)	Baseline** LFG Flow (m^3/hr)	Methane Emissions Reduction Estimates** (tonnes CH4/yr)	Methane Emissions Reduction Estimates** (tonnes CO_2eq/yr)
2006	60,090	60,090	0	0	0.0	0%	0	0	0.0	0.0	0	0	0
2007	66,610	126,700	161	94	2.9	0%	0	0	0.0	0.0	0	0	0
2008	69,180	195,880	313	184	5.6	0%	0	0	0.0	0.0	0	0	0
2009	68,100	263,980	437	257	7.8	0%	0	0	0.0	0.0	0	0	0
2010	72,000	335,980	531	312	9.5	0%	0	0	0.0	0.0	0	0	0
2011	75,460	411,440	615	362	11.0	0%	0	0	0.0	0.0	0	0	0
2012	79,080	490,520	692	407	12.4	50%	346	204	6.2	0.6	0	1,086	22,801
2013	82,870	573,390	764	450	13.7	52%	397	234	7.1	0.7	0	1,248	26,204
2014	86,850	660,240	834	491	14.9	54%	451	265	8.1	0.7	0	1,415	29,705
2015	91,020	751,260	903	532	16.1	56%	506	298	9.0	0.8	0	1,588	33,342
2016	95,390	846,650	971	572	17.4	58%	563	332	10.1	0.9	0	1,769	37,149
2017	99,970	946,620	1,040	612	18.6	60%	624	367	11.2	1.0	0	1,960	41,152
2018	104,770	1,051,390	1,110	653	19.8	61%	677	399	12.1	1.1	0	2,126	44,645
2019	109,800	1,161,190	1,181	695	21.1	62%	732	431	13.1	1.2	0	2,299	48,288
2020	115,070	1,276,260	1,254	738	22.4	63%	790	465	14.1	1.3	0	2,481	52,100
2021	120,590	1,396,850	1,329	782	23.8	64%	851	501	15.2	1.4	0	2,671	56,097
2022	126,380	1,523,230	1,407	828	25.1	65%	915	538	16.3	1.5	0	2,871	60,296
2023	132,440	1,655,670	1,487	875	26.6	66%	982	578	17.5	1.6	0	3,082	64,713
2024	138,800	1,794,470	1,570	924	28.1	67%	1,052	619	18.8	1.7	0	3,303	69,363
2025	145,460	1,939,930	1,656	975	29.6	68%	1,126	663	20.1	1.9	0	3,536	74,263
2026	131,070	2,071,000	1,746	1,028	31.2	69%	1,205	709	21.5	2.0	0	3,782	79,429
2027	0	2,071,000	1,782	1,049	31.8	70%	1,247	734	22.3	2.1	0	3,916	82,244
2028	0	2,071,000	1,461	860	26.1	75%	1,096	645	19.6	1.8	0	3,441	72,260
2029	0	2,071,000	1,194	703	21.3	75%	896	527	16.0	1.5	0	2,813	59,063
2030	0	2,071,000	996	586	17.8	75%	747	440	13.4	1.2	0	2,346	49,265
2031	0	2,071,000	847	498	15.1	75%	635	374	11.4	1.1	0	1,994	41,879
2032	0	2,071,000	732	431	13.1	75%	549	323	9.8	0.9	0	1,724	36,213
2033	0	2,071,000	643	378	11.5	75%	482	284	8.6	0.8	0	1,513	31,783
2034	0	2,071,000	571	336	10.2	75%	428	252	7.7	0.7	0	1,345	28,249
2035	0	2,071,000	513	302	9.2	75%	385	226	6.9	0.6	0	1,208	25,370

MODEL INPUT PARAMETERS:

Assumed Methane Content of LFG: 50%

	Fast Decay	Med. Decay	Slow Decay	Total Site Lo
Decay Rate Constant (k):	0.360	0.072	0.018	
CH4 Generation Pot. (Lo) (ft3/ton):	2,325	6,564	5,890	2,679
Metric Equivalent Lo (m3/Mg):	73	205	184	84

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 = **391,483 tonnes CO2e**

Annual average CERs over 10 year period= **39,148 tonnes CO2e**

TABLE A-2

PROJECTION OF LANDFILL GAS RECOVERY UNDER HIGH AND LOW RECOVERY SCENARIOS

UBERABA LANDFILL, UBERABA, 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)
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%	415	244	7.4	0.7	0	1,303	27,362	35%	242	142	4.3	0.4	0	760	15,961
2013	62%	474	279	8.5	0.8	0	1,488	31,244	37%	283	166	5.1	0.5	0	888	18,645
2014	64%	534	314	9.5	0.9	0	1,676	35,206	39%	325	192	5.8	0.5	0	1,022	21,453
2015	66%	596	351	10.7	1.0	0	1,871	39,296	41%	370	218	6.6	0.6	0	1,162	24,411
2016	68%	661	389	11.8	1.1	0	2,074	43,554	43%	418	246	7.5	0.7	0	1,311	27,541
2017	70%	728	429	13.0	1.2	0	2,286	48,010	45%	468	276	8.4	0.8	0	1,470	30,864
2018	71%	788	464	14.1	1.3	0	2,474	51,963	46%	511	301	9.1	0.8	0	1,603	33,666
2019	72%	851	501	15.2	1.4	0	2,670	56,076	47%	555	327	9.9	0.9	0	1,743	36,605
2020	73%	916	539	16.4	1.5	0	2,875	60,370	48%	602	354	10.8	1.0	0	1,890	39,695
2021	74%	984	579	17.6	1.6	0	3,089	64,863	49%	651	383	11.6	1.1	0	2,045	42,950
2022	75%	1,055	621	18.9	1.7	0	3,313	69,573	50%	703	414	12.6	1.2	0	2,209	46,382
2023	76%	1,130	665	20.2	1.9	0	3,548	74,518	51%	758	446	13.6	1.3	0	2,381	50,006
2024	77%	1,209	712	21.6	2.0	0	3,796	79,715	52%	817	481	14.6	1.4	0	2,564	53,834
2025	78%	1,292	760	23.1	2.1	0	4,056	85,184	53%	878	517	15.7	1.5	0	2,756	57,881
2026	79%	1,379	812	24.6	2.3	0	4,330	90,940	54%	943	555	16.8	1.6	0	2,960	62,162
2027	80%	1,426	839	25.5	2.4	0	4,476	93,993	55%	980	577	17.5	1.6	0	3,077	64,620
2028	85%	1,242	731	22.2	2.1	0	3,900	81,894	60%	877	516	15.7	1.5	0	2,753	57,808
2029	85%	1,015	598	18.1	1.7	0	3,188	66,939	60%	717	422	12.8	1.2	0	2,250	47,251
2030	85%	847	498	15.1	1.4	0	2,659	55,834	60%	598	352	10.7	1.0	0	1,877	39,412
2031	85%	720	424	12.9	1.2	0	2,260	47,463	60%	508	299	9.1	0.8	0	1,595	33,503
2032	85%	622	366	11.1	1.0	0	1,954	41,042	60%	439	259	7.9	0.7	0	1,380	28,971
2033	85%	546	322	9.8	0.9	0	1,715	36,021	60%	386	227	6.9	0.6	0	1,211	25,427
2034	85%	486	286	8.7	0.8	0	1,525	32,015	60%	343	202	6.1	0.6	0	1,076	22,599
2035	85%	436	257	7.8	0.7	0	1,369	28,752	60%	308	181	5.5	0.5	0	966	20,296

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 = **457,943 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 = **248,843 tonnes CO2e**