OKHLA LANDFILL – LANDFILL GAS ASSESSMENT REPORT

EXECUTIVE SUMMARY

A preliminary assessment of the potential for a landfill gas (LFG) utilization or flaring only project was performed for the Okhla Landfill in Delhi, India (City) based on information provided by the City and observations made during a site visit on February 21, 2007. The landfill opened in 1994, has approximately 5.6 million tones of waste in place, and is projected to close in 2008 after reaching a site capacity of about 6.3 million tonnes.

An LFG recovery model was prepared based on waste disposal, waste composition, and climate data. The model results indicated that LFG recovery is projected to reach a maximum of approximately 1,660 cubic meters per hour (m^3/hour) in 2008 and decline after site closure. Given the projected LFG recovery rate, a preliminary evaluation of available LFG project options indicates that a flaring, direct use, or electrical generation projects may be feasible for this site. Significant income streams from emissions trading of reduced greenhouse gas (GHG) emissions and from beneficial use project revenues are possible for this landfill. Nearby markets for the LFG exist and include a cement production facility and a hospital. An electrical substation is located adjacent to the landfill which can facilitate an LFGE project that would provide electricity to the local grid. However, significant investment would be needed to construct a cap, grade the landfill, and install a gas collection and control system.

The information and predictions contained within this assessment report are based on the data provided by the site owners and operators. Neither the U.S. EPA nor its contractors can take responsibility for the accuracy of this data. Assessments and predictions presented in this report are based on the data and physical conditions of the landfill observed at the time of the site visit.

Note that landfill conditions will vary with changes in waste input, management practices, engineering practices, and environmental conditions (particularly rainfall). Therefore, the quantity and quality of landfill gas extracted from the landfill site in the future may vary from the values predicted in this report, which are based on conditions observed during the site visit.

The landfill does not have a current gas collection, flaring or utilization system. The estimated capital, operational costs, and return on investment resulting from installing such a system at the site are based on current, typical costs in America, but no warranty is given or implied on the accuracy of these data.

While all due care and attention has been given to development of this report, potential investors in landfill gas utilization projects at the landfill are advised to satisfy themselves as to the accuracy of the data and predictions contained in this report.

This report has been prepared for the U.S. Environmental Protection Agency and is public information.

INTRODUCTION

The U.S. Environmental Protection Agency (U.S. EPA) is working in conjunction with the Government of India as part of the Methane to Markets Partnership (M2M), an international initiative to assist partner countries in reducing global methane emissions. M2M promotes the beneficial use of landfill methane, while also reducing landfill methane emissions to the atmosphere. One of the key activities of this cooperative program includes identifying suitable landfills with sufficient quantities of high quality gas that can be used to meet local energy needs. To support this activity, the U.S. EPA has contracted with SCS Engineers (SCS).

Purpose of Assessment Report

The overall purpose of the Okhla Landfill Assessment Report (Report) is to perform a preliminary assessment of the amount of LFG potentially available to be collected from the landfill and 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 landfill, 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 at the landfill.
- Examine available LFG utilization options, including direct use, electricity generation, and flaring only projects.

Data Sources

The Landfill Engineer (Rajesh Paneja) provided following information which was used in preparing the Report:

- Historic waste disposal rates (in tonnes per month) from 1994 through 2007.
- Information on current and maximum waste depths, waste disposal practices, in-place waste densities, recycling and scavenging activities, site security, and potential additional sources of waste.

Additional information on electricity and natural gas costs in India was provided by Mr. P.U. Asnani based on discussions with the Mumbai Municipal Corporation. Estimated electrical and natural gas costs provided by Mr. Asnani were Rs. 3.50/kWh for residential use, Rs. 7/kWh for commercial use, and Rs. 12.00 per cubic meter of natural gas. Given the current exchange rate of Rs. 45 per U.S. dollar, this equates to approximately $0.08 per kWh for residential use, $0.16/kWh for commercial use, and $7.46/MMBtu for natural gas (assuming 1,012 Btu/ft^3 for natural gas).

Site Background

The Okhla Landfill is located in New Delhi, India, the capital city of India. The landfill is owned and operated by the Municipal Corporation of Delhi. Disposal operations began in 1994 and are expected to continue until approximately 2008, depending on waste disposal rates and site expansion capacity. The climate in the region is subtropical, with extreme heat in the late summer months. Rainfall varies seasonally, and ranges from a minimum monthly average of 3 mm in November to a maximum monthly average of over 200 mm in July and August. The annual average rainfall amount is 706 mm (28 inches). Annual average temperature is 25 degrees C (77 degrees F).[1] The population of New Delhi is 15.3 million and the metropolitan area has a population of almost 20 million.

LANDFILL DESCRIPTION

Landfill Physical Characteristics

The existing landfill property covers a total of 54 acres, which is almost completely covered with waste. There are minimal buffer zones around the outside of the waste mass and areas for the entrance, administration building, weigh station, and machinery storage and repair that are not on the waste mass. The weigh station, which is shown in Figure 1, does not always operate. The landfill does not have any liner or cover systems in place. All of the waste has been placed above ground. The local ground characteristics are a silty soil with some clay material.

Figure 1. Weigh Station

[1] Source: www.worldclimate.com

The waste mass at the landfill has an estimated depth of 20 to 30 meters, with steep slide slopes (50-60 degrees) as shown in Figure 2. This figure also shows the buildup of unmanaged leachate ponds next to the base of the landfill. The top of the waste mass is flat or gently sloping to allow for delivery of waste and management of the open face with bulldozers. This results in some standing water that, as shown in Figure 3, was still present one week after the last rain event.

Figures 2 and 3. Landfill Slopes and Standing Water

The active disposal area is shown in Figures 4 and 5. Waste is occasionally compacted using bulldozers or by trucks delivering waste. Estimated compaction for this landfill is 800 to 900 Mg/m^3 for the lower portion of the landfill and 400 to 500 Mg/m^3 in the upper portion. There are no formal recycling operations at the landfill. All recycling is done informally by a large group of waste pickers operating in the active disposal area. There are approximately 200 to 300 waste pickers that operate on the site independently from landfill management. Their presence is not legal, but there are no controls to prevent them from gaining access and working at the landfill.

Figures 3 and 4. Active Disposal Areas.

Disposal History and Estimated Future Disposal

The landfill has a scale but it is not operable all the time. Based on information received from the site engineer, the amount of waste in place is approximately 5.6 million tones. This amount of waste in place is relatively consistent with the provided data on waste disposal area, waste depth, and compaction rates. Disposal in 2007 is projected to be 461,200 tonnes. The landfill is expected to close in mid-2008 with a final waste mass of approximately 6.3 million tones.

Table 1 shows the historic and projected future disposal rates under these (base-case) assumptions.

Table 1. Estimated Waste Disposal History for Okhla Landfill

Year	Disposal Rate (Mg/yr)	Total Waste Disposed (Mg)
1994	176,270	176,270
1995	423,040	599,310
1996	430,390	1,029,700
1997	449,480	1,479,180
1998	487,980	1,967,160
1999	428,830	2,395,990
2000	454,650	2,850,640
2001	461,230	3,311,870
2002	461,200	3,773,070
2003	461,200	4,234,270
2004	461,200	4,695,470
2005	461,200	5,156,670
2006	461,200	5,617,870
2007	461,200	6,079,070
2008	230,600	6,309,670

These estimates do not account for vertical expansion of the landfill. The magnitude of possible lateral or vertical landfill expansions, and the likelihood of such expansions, is unknown. Given the lack of buffer areas around the landfill, the only expansion potential exists in vertical expansion or additional infilling in low-lying areas. However, if the landfill is targeted for LFG collection and potential end-use, the side-slopes will need to be graded to reduce the pitch and waste will have to be moved to other areas within the site which may limit future expansion.

Waste Composition Data

Waste composition is an important consideration in evaluating a LFG recovery project, in particular the organic content, moisture content, and "degradability" of the various waste fractions. For example, landfills with a high amount of food wastes, which are highly degradable, will tend to produce LFG sooner but over a shorter length of time.

Waste composition data specific to the Okhla Landfill were not available for this study. The closest landfill for which waste composition data were available was the Gorai Landfill in Mumbai. Assuming similar waste characteristics, the Mumbai waste composition data was applied to the Okhla site for purposes of LFG modeling. Table 2 shows the estimated waste composition percentages for the Okhla Landfill.

Table 2. Estimated Waste Composition for the Okhla Landfill

Waste Type	%
Metals	0.8%
Construction and demolition waste	30.0%
Wooden waste	0%
Paper	11.8%
Plastics	5.0%
Food	35.7%
Garden waste	6.3%
Rubber, leather	5.0%
Textiles	5.0%
Glass and ceramics	0.40%
Total	**100.0%**

LFG PROJECT OPTIONS

Instead of allowing LFG to escape into the air, it can be captured, converted, and used as an energy source. Using LFG helps to reduce odors and other hazards associated with LFG emissions, and it helps prevent methane from migrating into the atmosphere and contributing to local smog and global climate change.

Landfill gas is extracted from landfills using a series of wells and a blower/flare (or vacuum) system. This system directs the collected gas to a central point where it can be processed and treated depending upon the ultimate use for the gas. From this point, the gas can be simply flared or used to generate electricity, replace fossil fuels in industrial and manufacturing operations, fuel greenhouse operations, or be upgraded to pipeline quality gas.

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 would require some level of grading work, capping of the landfill, and installation of an active gas collection and control system (GCCS), including a flare to ensure combustion of all collected LFG when the methane is not being utilized. All three options also are expected to generate revenues from the sale of emission reduction credits.

To prepare the landfill for a GCCS, work on grading the landfill and constructing a cap would be needed to maximize LFG collection efficiency and prevent air intrusion. In addition to increasing gas collection efficiency, grading and capping would result in reduced gas migration and leachate generation, and improved slope stability and storm water management. Given the steep side-slopes and the minimal buffer areas around the perimeter of the landfill, it may not be practical to re-grade the waste mass to meet recommended side-slope standards and allow for installation of a geomembrane cover on the side-slopes. Operating equipment on the side-slopes is not safe or feasible, and there may not be adequate space in the interior portions of the landfill to receive all the material required to be moved to achieve proper grading of the side slopes.

The most feasible option for capping may be application of a geomembrane cover for the top of the landfill and application of low-permeable soil capping on the side-slopes. To construct a geomembrane cap, the waste mass would need to be covered with approximately 0.5 meters of soil, a non-woven geotextile mat (to protect the geosynthetic liner), a geosynthetic liner, and a cover layer of approximately 0.6 meters of soil. Seeding and mulching of the cover would also be suggested. Application of 1 meter thick low-permeable soil on the side-slopes may provide an adequate barrier to facilitate GCCS operation and limit air intrusion into the waste mass. Typical installation and material costs in the U.S. for elements of a landfill cap are as follows: $\$3/yd^3$ for landfill cover soil that would be below the geomembrane, $\$0.20/ft^2$ for geotextile material, $\$0.50/ft^2$ for geomembrane material, $\$5/yd^3$ for top cover soil, and $\$8/yd^3$ for low permeable soil for the side-slopes. Additional analysis would be needed to develop a plan and cost estimates for capping the landfill to prepare for a GCCS.

Capital costs for a GCCS will depend to a large extent on LFG flows, landfill size, and 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 approximately 7 to 10 percent of capital costs, not including electricity or system expansions. These estimates do not include costs of grading, the above-listed costs of capping of the landfill, or any additional costs that would result from operating on uncompacted waste and steep slopes. Further investigation would be needed to develop a more precise estimate of the costs for re-shaping and capping the landfill.

Electricity Generation

At most sites with LFG generation rates similar to the amounts estimated for this landfill, traditional electricity generation projects that sell power onto the grid often are difficult to justify on an economic basis. The LFG generation rates at the landfill could support approximately an 800 to 1,000 kW project for a ten-year period using reciprocating engines. Because small to medium sized electric generation projects typically have higher investment costs when compared to larger facilities on a cost per installed kW basis, these electric generation projects are typically not feasible without some kind of project “competitive advantage”. The high investment costs result from the following drivers:

- Projects require similar fixed cost investments as larger projects, including electric transmission lines and interconnection infrastructure to the closest substation.

- Smaller engine-generator units cost more per installed kW and have lower efficiencies compared to larger units.

As indicated above, some electric projects typically require some kind of project “competitive advantage” such as:

- High on-site electricity usage paying high retail rates which can be offset by the project's generation.

- Existence of a high electricity tariff, renewable tariff, or renewable portfolio standard, and the existence of markets where the renewable attributes can be sold.

- Existence of a large electricity user close by paying high retail rates which can directly take the power generated at the facility.

- Existence of an electric interconnect to the grid nearby which can be utilized with little additional infrastructure investment.

The Okhla landfill has some of the competitive advantages listed above. An electrical substation exists adjacent to the landfill and can be seen behind the leachate pond in Figure 2. Additionally, a cement production facility is next to the landfill and is expected to have significant electrical and thermal energy needs based on the observed size of the facility. The cement facility may be able to use both electricity and thermal energy from the LFG and would be an excellent facility to approach regarding the use of LFG-based energy, given its close proximity. The cement plant can be seen in Figure 5. India currently has no renewable tariff, and the retail tariff is estimated to be $0.08 to 0.16/kWh (based on information provided by the Mumbai Municipal Corporation of Rs. 3.50 per kWh). Assuming that the local utility or cement plant would pay this rate for electricity generated by a project at the landfill, this represents an attractive rate for electrical generation projects. In the U.S., electricity generated by LFG projects typically cost about $0.04 to $0.06 per kWh to generate. Therefore, estimated electrical revenues from an electrical generation project at the landfill look favorable.

<u>Direct Use</u>

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 electric 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, 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 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 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 or other large heat or power users which may be potential users of LFG were identified during the site visit and include the following:

- Cement production facility adjacent to the landfill (Figure 5)
- Hospital adjacent to the landfill (Figure 6)

Information received from the Mumbai Municipal Corporation indicates that natural gas prices are in the range of $7.50/MMBtu. This cost is similar to that in the U.S., and direct-use LFGE projects have been able to deliver fuel at a lower cost even when the cost of installation and operation of the direct-use system is considered. One of the biggest issues in developing direct-use LFGE projects in the U.S. is distance between the landfill and end-user. The Okhla Landfill appears to have to viable end-users (the cement plant and hospital) adjacent to its property boundary. Further discussion with these potential end-users of LFG is suggested to determine interest in using LFG as an alternate fuel.

Figure 5 and 6. Cement Production Facility and Hospital Near Okhla Landfill

Flaring Only

Although not a utilization option, flaring collected LFG would still produce significant environmental benefits and potential revenues from methane emissions reduction. Because emission reductions are typically the only source of revenues from a flaring only project, prices received for the emission reductions will largely determine economic feasibility. 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.

Emissions Trading

It is now 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 from solid waste disposal on land is one of the major sources of greenhouse gas emissions, 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 world wide.

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. This appears to be the case at Okhla Landfill.

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 reductions. 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.

Based on preliminary LFG modeling, the reduction of GHG emissions from a flaring, direct-use, or electrical project at the Okhla Landfill would result in the reduction of over 120,000 tonnes of CO_2 equivalent emissions between 2008 and 2012. Assuming a market value for CO_2E of $10/tonne, this could provide a potential income stream from emissions trading of over $1,200,000 for the five-year period.

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

<u>LFG Rights Ownership Issues</u>

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.

<u>Site Security and Waste Pickers</u>

The waste pickers have a long history on the site. There were a significant amount of waste pickers on the site, and they seem to be well organized. They are apparently not managed by the landfill. The site has a perimeter fence, but it been breached in several locations and waste pickers appear to come and go as they please. Site security and management of the waste pickers would be a significant issue for future investment in a LFG collection system or LFGTE project, and would need to be addressed by the landfill.

LFG RECOVERY PROJECTIONS

<u>Model Introduction</u>

SCS has developed a first-order decay model for estimating the LFG recovery potential of landfills based on annual waste disposal rates, the amount of methane a tonne of waste produces (Lo value), and the rate that waste decays and produces LFG (k value). The LFG model, essentially a modified version of the EPA's LandGEM, was developed by modifying U.S. model input variables (Lo and k) to account for landfill and waste characteristics in foreign countries. The SCS procedure for estimating model Lo and k values appropriate for international sites has been documented in pre-feasibility studies prepared for LMOP and U.S. AID for landfills in Guatemala and Mexico. Adjustments to the Lo account for the organic and dry solids content of wastes disposed. Because the Okhla Landfill has been managed as a dump site without a soil cover, a 20 percent discount to the Lo was made to account for partial aerobic conditions at the site (based on an 80% "Methane Correction Factor" that was incorporated into the Lo value). Adjustments to k value involve assigning separate k values to different waste fractions based on estimated decay rates.

Projections of LFG recovery rates can be calculated using model outputs of potential recovery and estimates of percent collection system coverage, a measure of the performance of the collection system at capturing the potentially recoverable LFG (analogous to collection efficiency). For sites without a collection system installed, future collection system coverage is estimated based on landfill configuration, disposal area sequencing, waste depth, soil cover, depth to leachate, and the presence of waste pickers.

Model Input Variables

Based on considerations of climate and estimated composition of wastes disposed at the Okhla Landfill, SCS has assigned the following values for model input variables for the LFG projections:

- Lo (regular waste) = 54 m^3/tonne (1,735 ft^3/ton).
- k (fast-decaying waste) = 0.17/year.
- k (medium-decaying waste) = 0.034/year.
- k (slowly-decaying waste) = 0.009/year.

Multiple model runs were prepared to account for a range of possible future collection system effectiveness and coverage estimates that result in low, mid-range, and high LFG recovery projections. SCS estimates that the mid-range collection system coverage estimates are the most likely to be achieved due to the condition and geometry of the existing waste mass if a LFG collection system were to be installed.

Model Results

LFG recovery projections for the Okhla Landfill are provided in Appendix A. Table A-1 of Appendix A shows the LFG recovery potential and estimated LFG recovery under the mid-range collection scenario. Figure A-1 of Appendix A shows the LFG recovery potential and estimated LFG recovery under all three collection scenarios.

Under the mid-range projections, the estimated maximum LFG recovery rate is 1,659 m^3/hour (977 cfm), which is expected to be in 2008, the year the landfill plans to cease operation. Potential LFG recovery will begin to decline after 2008 and will continue to decline over time. Review of the mid-range estimates shows that LFG recovery is expected to decline to about 507 m^3/hour (298 cfm) by 2018.

CONCLUSIONS

Overall, the physical characteristics of this landfill (amount of waste in place, waste depth, types of waste disposed) and its location provide a promising basis for an LFGE project. Based on a preliminary evaluation of potential LFG recovery and available LFG project options, an electrical generation, direct use, or flaring only project may be economically feasible for the Okhla Landfill. Its location adjacent to an electrical substation and two large potential end-users contributes to the economic viability of an LFGE or direct use project. Funding from certified emission reduction credits also increases the financial feasibility of a project at this site.

However, projected LFG recovery and project feasibility is limited by declining LFG generation rates after closure and the modest estimated LFG recovery rate (approximately 50%) from the landfill. In addition, significant work to grade and cap the landfill would be needed to stabilize the waste mass gas prior to installing a GCCS and to maximize the collection efficiency of such a system. The next steps in project development would include: (1) preparing designs and cost estimates for capping and GCCS installation at the landfill; (2) contacting the local electricity provider and the adjacent cement facility and hospital to evaluate electricity or LFG sales pricing that would be required for a project. Significant investment would be needed to realize the potential revenue streams associated with LFG utilization projects at this site, but income streams from GHG reduction credits and beneficial use of the LFG could offset those costs and make the project feasible.

APPENDIX A
LFG MODELING RESULTS FOR OKHLA LANDFILL

TABLE A-1
PROJECTION OF POTENTIAL LANDFILL GAS RECOVERY AND RECOVERY UNDER MID-RANGE SCENARIO
OKHLA LANDFILL, DELHI, INDIA

						MID-RANGE RECOVERY SCENARIO							
	Disposal Rate	Refuse In-Place	LFG Recovery Potential			Collection System Coverage	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)
1994	176,270	176,270	0	0	0.0	0%	0	0	0.0	0.0	0	0	0
1995	423,040	599,310	316	186	5.7	0%	0	0	0.0	0.0	0	0	0
1996	430,390	1,029,700	685	403	12.2	0%	0	0	0.0	0.0	0	0	0
1997	449,480	1,479,180	1,014	597	18.1	0%	0	0	0.0	0.0	0	0	0
1998	487,980	1,967,160	1,322	778	23.6	0%	0	0	0.0	0.0	0	0	0
1999	428,830	2,395,990	1,590	936	28.4	0%	0	0	0.0	0.0	0	0	0
2000	454,650	2,850,640	1,796	1,057	32.1	0%	0	0	0.0	0.0	0	0	0
2001	461,230	3,311,870	1,993	1,173	35.6	0%	0	0	0.0	0.0	0	0	0
2002	461,200	3,773,070	2,168	1,276	38.7	0%	0	0	0.0	0.0	0	0	0
2003	461,200	4,234,270	2,320	1,366	41.5	0%	0	0	0.0	0.0	0	0	0
2004	461,200	4,695,470	2,454	1,444	43.9	0%	0	0	0.0	0.0	0	0	0
2005	461,200	5,156,670	2,572	1,514	46.0	0%	0	0	0.0	0.0	0	0	0
2006	461,200	5,617,870	2,676	1,575	47.8	0%	0	0	0.0	0.0	0	0	0
2007	461,200	6,079,070	2,768	1,629	49.5	0%	0	0	0.0	0.0	0	0	0
2008	230,600	6,309,670	2,766	1,628	49.4	60%	1,659	977	29.7	2.7	0	2,416	50,743
2009	0	6,309,670	2,543	1,497	45.4	60%	1,526	898	27.3	2.5	0	4,444	93,329
2010	0	6,309,670	2,216	1,304	39.6	60%	1,329	782	23.8	2.2	0	3,871	81,301
2011	0	6,309,670	1,936	1,139	34.6	60%	1,162	684	20.8	1.9	0	3,383	71,038
2012	0	6,309,670	1,698	999	30.3	60%	1,019	600	18.2	1.7	0	2,967	62,301
2013	0	6,309,670	1,495	880	26.7	60%	897	528	16.0	1.5	0	2,612	54,855
2014	0	6,309,670	1,322	778	23.6	60%	793	467	14.2	1.3	0	2,310	48,500
2015	0	6,309,670	1,174	691	21.0	60%	704	414	12.6	1.2	0	2,051	43,068
2016	0	6,309,670	1,047	616	18.7	60%	628	370	11.2	1.0	0	1,829	38,418
2017	0	6,309,670	938	552	16.8	60%	563	331	10.1	0.9	0	1,639	34,428
2018	0	6,309,670	845	497	15.1	60%	507	298	9.1	0.8	0	1,476	30,999
2019	0	6,309,670	764	450	13.7	60%	459	270	8.2	0.8	0	1,335	28,044
2020	0	6,309,670	695	409	12.4	60%	417	245	7.4	0.7	0	1,214	25,492
2021	0	6,309,670	634	373	11.3	60%	381	224	6.8	0.6	0	1,109	23,281
2022	0	6,309,670	582	343	10.4	60%	349	206	6.2	0.6	0	1,017	21,360
2023	0	6,309,670	536	316	9.6	60%	322	189	5.8	0.5	0	937	19,686
2024	0	6,309,670	497	292	8.9	60%	298	175	5.3	0.5	0	868	18,221
2025	0	6,309,670	462	272	8.2	60%	277	163	4.9	0.5	0	806	16,935
2026	0	6,309,670	431	253	7.7	60%	258	152	4.6	0.4	0	752	15,801
2027	0	6,309,670	403	237	7.2	60%	242	142	4.3	0.4	0	705	14,797
2028	0	6,309,670	379	223	6.8	60%	227	134	4.1	0.4	0	662	13,905
2029	0	6,309,670	357	210	6.4	60%	214	126	3.8	0.4	0	624	13,108
2030	0	6,309,670	338	199	6.0	60%	203	119	3.6	0.3	0	590	12,393

MODEL INPUT PARAMETERS:

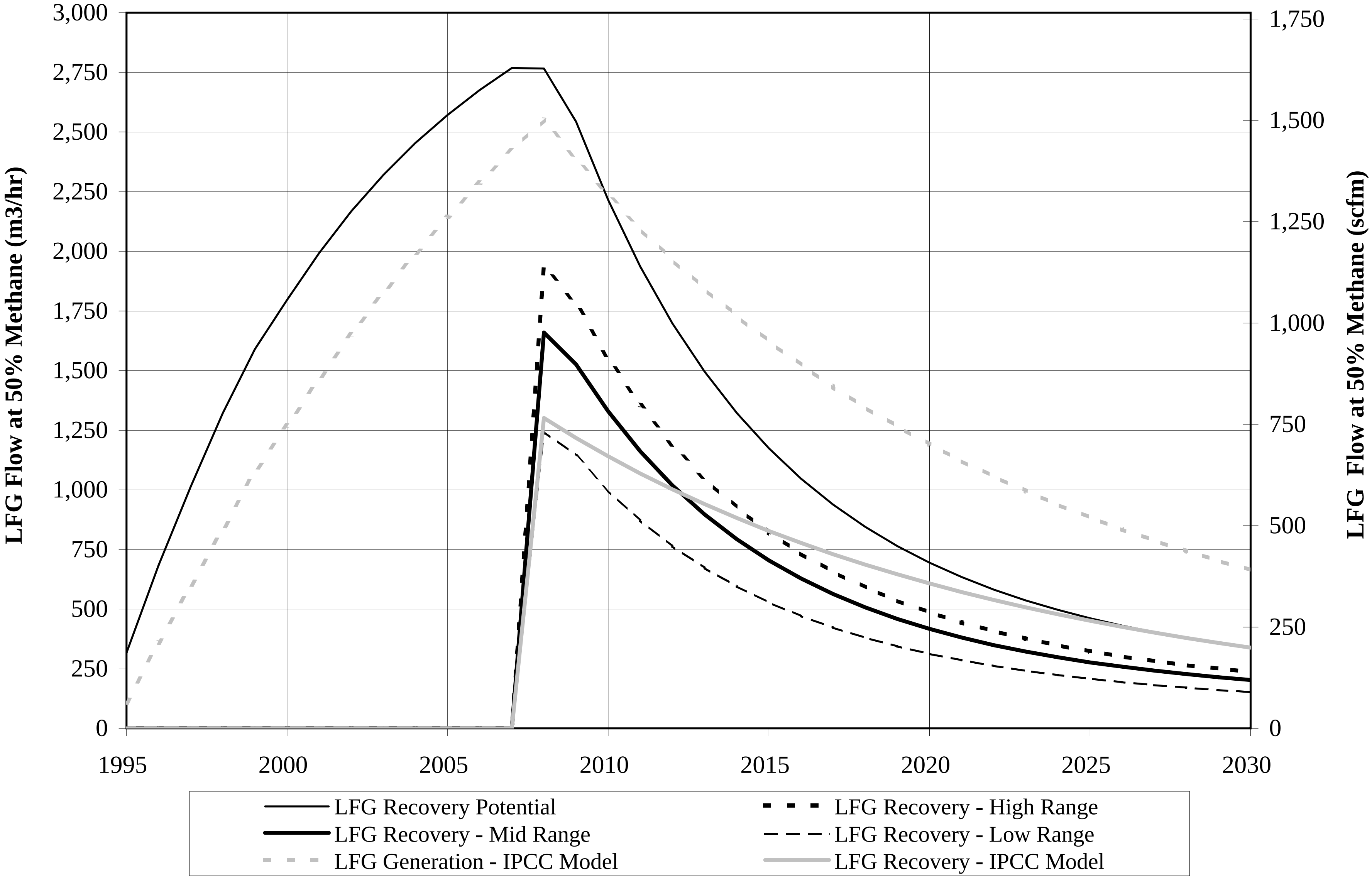
	Fast Decay	Med. Decay	Slow Decay	Total Site Lo
Assumed Methane Content of LFG:	50%			
Decay Rate Constant (k):	0.170	0.034	0.009	
CH4 Recovery Pot. (Lo) (ft3/ton):	2,390	2,390	2,390	1,735
Metric Equivalent Lo (m3/Mg):	93	93	93	54

NOTES:

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

**Emission reductions do not include electricity generation and assume system start-up on July 1, 2008.
Total estimated emission reductions for the 2008-2012 period = **129,176 tonnes CO2e**

Figure A-1. LFG Recovery Projection
Okhla Landfill, Delhi, India



5/6/2007