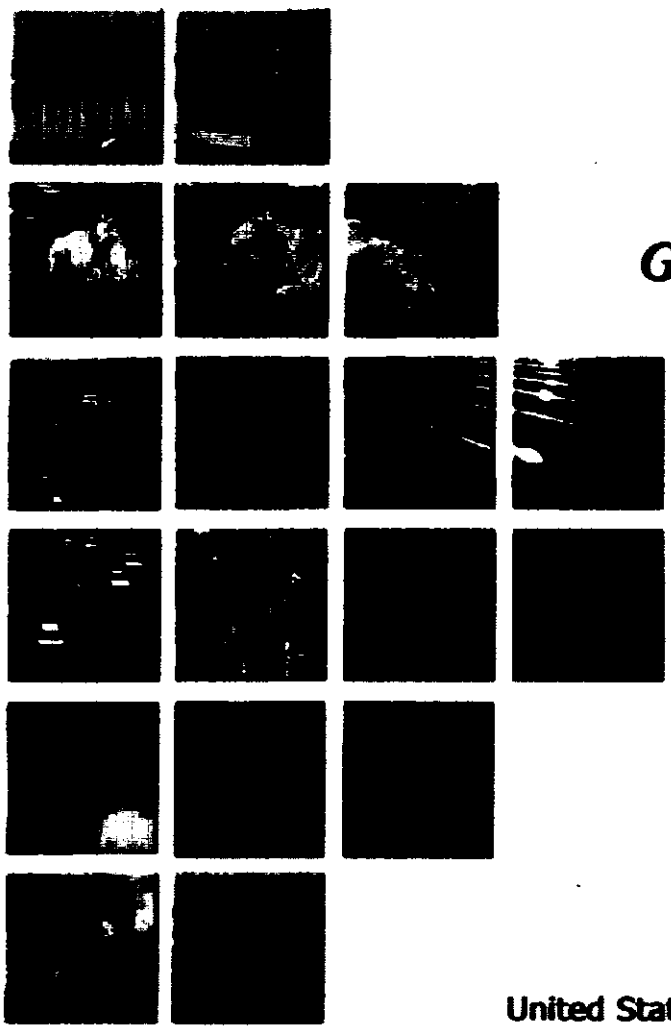
PN-ACY-126

CLIN 8: Methane Emissions and Re-Use Potential in Cities

Subtask 8.E Funding Identified and Documentation for Funding Submitted



Greenhouse Gas Pollution Prevention Project - Climate Change Supplement

A Program of the:

United States Agency for International Development / India Mission

Implemented by:

The Louis Berger Group, Inc.
Global Environment Team

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EXECUTIVE SUMMARY

I. EXECUTIVE SUMMARY

Project Background

The pressures of India's growing economy and population will result in the need for improved approaches to managing municipal solid waste. In response to public interest litigation, the Government of India passed the *Municipal Solid Waste Rules, 2000* (MSW 2000) to ensure that more effective solid waste practices are implemented in India. Among the benefits that will result from these improved management practices is the reduction of GHG emissions from municipal landfills.

The United States Agency for International Development/India Mission (USAID/India) has provided funding for the Greenhouse Gas Pollution Project's Climate Change Supplement (GEP-CCS), implemented by the Louis Berger Group Global Environment Team (LBG) to provide capacity-building and technical assistance to facilitate improvements in three sectors with significant greenhouse gas (GHG) emission impacts in India: transportation, industrial growth and municipal solid waste (MSW) management.

Under CLIN 8, the GEP-CCS project linked urban development and the rate of growth of greenhouse gas emissions with a focus on methane emissions and the re-use potential in cities. This report is the fourth in a series of four reports on this component.

Training Needs Assessment and Training Plan Developed - In February 2001, LBG/GEP-CCS with the support of Global Energy Partners conducted a training needs assessment in five cities: Pune; Chennai; Bangalore; Guntur and Jaipur. The interactions with the city authorities revealed a lack of understanding about composting and waste-to-energy projects, including landfill methane recovery and reuse and biomethanation, and also a high level of concern about ways to comply with the then recently released *"Municipal Solid Wastes (Management and Handling) Rules, 2000"* by the Ministry of Environment and Forests (MOEF). Subsequent consultations with USAID and various GoI officials confirmed that an information and knowledge gap on these issues did exist among municipal authorities. Accordingly, it was decided that the training content would provide more emphasis on the fundamentals of integrated solid waste planning and management; this would serve as a prerequisite to capturing benefits from utilizing solid waste for productive purposes, including methane gas recovery and reuse.

Training of Municipal Authorities/Urban Local Bodies Across India - Based on the TNA conducted in February 2001 and subsequent discussions, LBG/GEP-CCS designed and conducted a series of trainings entitled *"Tools for Improved Solid Waste Management and Treatment"*. The trainings were held at Chennai, Jaipur and Ahmedabad in December 2001, in partnership with the Tamil Nadu Urban Development Project (TNUDP), HCM Rajasthan Institute of Public Administration (RIPA), and the City Managers Association of Gujarat (CMAG) respectively (all three of which have strong linkages with USAID RUDO and the FIRE projects). Training was carried out for over 125 participants, predominately municipal officers, from more than 26 municipalities and 19 local urban bodies.

Concurrently with the trainings, GEP-CCS organized a National Roundtable on solid waste management and disposal practices which was attended by over 200 delegates from cities all over India.

Planning and Design of a Demonstration Project - Following the training, a representative project was required to be developed for methane recovery and reuse, including specific design aspects related to measurement, monitoring and verification of methane emissions from a selected landfill/ municipal waste site. The project was also required to explore potential funding options for the GHG emission reductions achieved.

Feedback received in the course of activities under the training needs assessment, the training series, the roundtable and the interactions with other institutional players, prompted discussions between the LBG/GEP-CCS team and USAID/India on reorienting the focus of the demonstration project assignment to suit the ground reality. The consensus that emerged was that the demonstration project would take a holistic approach looking at integrated solid waste management, with nonetheless, a clear introduction to the GHG emission reduction aspects of a MSW project.

This Report: ***Funding Identified and Documentation for Funding Submitted***

The last deliverable under CLIN 8 looks at potential funding options for the GHG emissions reductions from the demonstration project: two sites located at Kannahalli and Kyalasanahalli outside of Banagalore. The key stakeholders in the project included the Bangalore Municipal Corporation (BMC) as the lead municipal authority, in partnership with the Bangalore Area Task Force (BATF) and the Infrastructure Development Corporation of Karnataka (iDeCK).

The implementation of the Bangalore demonstration project provides the basis for this final deliverable, namely – documentation and calculation guidelines for GHG emission reductions for the purpose of potentially receiving funding through available multilateral and bilateral funding sources.

The box below details the progress of the bidding process for the Bangalore demonstration project:

Box 1.: Progress of the Bidding Process for the Bangalore Demonstration Project

Tender notification for RFQ applications	March 2003
Bids received (13)	May 2003
RFP's issued (8)	End August 2003
Pre-bids meeting	September 2003
Submission of RFP's* (3)	November 2003
Finalization of proposal selection	End November 2003 (expected)
Requisite GoI approvals	End December 2003 (expected)

** [By United Phosphorus, Ramky Engineers and Nagarjuna Constructions Ltd.]*

In consultation with AID, it was decided that, as the open bidding process and requisite reviews and approvals by State and local government agencies would proceed at a pace independent of the GEP-CCS timeline, the GEP-CCS/LBG team would provide the documentation tools for funding that could be used by either the financial institutions or the prospective landfill developer (as and when the same had been finalized). Accordingly, a calculation template has been prepared using preliminary/ assumed data for the project. As specific technical details of the landfill's operations and characteristics become known, these can be inserted into the template to arrive at a more conclusive estimate.

This report encompasses the following components, which may be used by the project developers or iDeCK, the financial institution, to monetize the emissions off-set by the project.

- *General guidance document* for quantifying and documenting GHG emission reductions.
- *Calculation template* for quantifying the GHG emission reductions.
- *DPR worksheet*[1] format which may be used by the project developer for presenting DPR information – including GHG emissions related information - in a structured format so as facilitate review by domestic/ international financiers.
- *GHG Mitigation Guidelines*, which were incorporated in the RFP documents, for bidders to use in development of their proposals for the project. These Guidelines were developed based on the reports/ reviews of the draft RFP documents, undertaken by LBG and its technical partners, in the preceding stages of CLIN 8.

Because the final selection of the developer has not been made and approved to-date, the technical details of the site's design have not been finalized. This guidance, therefore, is presented in a form that is generic enough to apply to whatever form the project finally takes.

The calculations made in the calculation template have been based on the specifications provided in the RFP for the Bangalore project, project specific technical advice from MSW specialists Global Partners, inputs obtained from iDeCK and Mahindra Acres Consulting Engineers (MACE), the design consultants on the project, as well as select assumptions made about the final nature of operations at the project. The proposed calculation approaches have been discussed extensively in collaboration with the iDeCK personnel. The LBG team has also discussed the approach with IDFC, who have been preparing similar documentation for the GHG emissions reductions and a baseline for the Lucknow project (this project was one of the first GEP-CCS pipeline projects to be funded under CLIN 3).

[1] Developed as part of CLIN 3 component of GEP-CCS.

II. GUIDELINES FOR QUANTIFYING AND DOCUMENTING GHG EMISSION REDUCTIONS

Some GHG emission reductions have the potential to be purchased by a buyer, and thus to represent a revenue stream. In many cases, the potential buyer of these reductions requires extensive information to establish the validity and, therefore, the value of these reductions prior to purchase. The purpose of the quantification process is threefold:

- Clearly establish the "baseline" levels of GHG emissions; i.e., those that would occur in the absence of a GHG mitigation project;
- Clearly establish the expected GHG emission levels that will occur as the result of the project; and
- Identify the difference between the baseline emissions and the lower emission levels that result from the project as the projected GHG emission reduction benefit of the project.

The following categories of information represent the process that typically must be completed in order to provide the basis for a potential buyer or third party reviewer to conclude whether the GHG emission reductions are valid. While the specifics of each project will be different, the documentation should be assembled with the goal of providing the reader with all the information necessary to accurately assess the validity of the GHG emission reductions.

A. Introduction/Executive Summary

Provide an overview explanation of the project: what is being built/modified; how does it work and where is it located; why is it being undertaken; who is sponsoring it; is it typical for its industry or innovative in any way; what is the timing for completion; what are its primary goals and impacts; what are its GHG impacts?

B. Legal/Regulatory/Financial Context

Identify the relevant requirements that affect the project with respect to environmental issues. Address local, state, regional, federal and international aspects; where no requirement exists, provide explicit statement to that effect. Include a cursory discussion of non-air environmental issues (e.g., water, noise, solid waste); provide detailed discussion of air-related requirements and especially any GHG/CO2 issues. Discuss any energy-related requirements that may affect the project, including energy-efficiency. Discuss the potential for future requirements at the local, state, regional, federal and international levels that might impact the project or its emissions; if none can be anticipated, an explicit statement to that effect should be made. Identify the relevant timeframe for the GHG reduction assessment that will be applied to the project.

Also characterize any programs in place that have provided financial incentives for the project. These could include low-interest loans, tax breaks, rebates, grants, donor-funding, etc.

C. Detailed Project Explanation

Provide a more technically detailed operational explanation for each component of the project, including diagrams and equations, placing the project in the context of normal operations/procedures for the industry. The purpose of this section is to present enough contextual knowledge for the reader about the project so that the subsequent sections may focus on emission-related issues without digressions into non-emission explanations. All variables and assumptions that affect the project should be introduced and generally explained in this section; their specific impacts should also be addressed in the "baseline GHG emissions" and "project GHG emissions" sections. (In practice, initial drafts of this section may be relatively short and then supplemented by information whose relevance becomes evident later as subsequent sections are drafted).

Any potential for secondary emission impacts from the project should be identified, such as "load-shifting" (in the context of affecting the dispatch of units supporting the electricity grid), emission changes due to changes in transportation or sequestration resulting from the project. Such secondary impacts may not need to be quantified and included in the actual GHG emission reduction calculation, however, they should be acknowledged and evidence should be presented to justify their omission from the calculations. The logic for the project baseline should be presented, as well as whether the baseline would be expected to change over time for the duration of the period being included.

All data gathering processes that will inform GHG calculations for the project should be explained. Relevant monitoring or measurement equipment used in the project should be described, including degree of accuracy, maintenance and calibration requirements (and records). Calculations of baseline and "with project" GHG emissions should reflect a degree of accuracy that is consistent with the least accurate measurement equipment that contributes data to the calculations.

D. Baseline GHG Emissions

Present the "business as usual" (BAU) or "without project" scenario relevant to the project. At the simplest level, this should include an activity level multiplied by an emission rate to yield GHG emissions that would occur in the absence of the impact of the project. All numbers used for calculation purposes should be as recent and as accurate as possible, specific to the activity, location, and operational parameters of the project. The source for all numbers used should be referenced and ideally will be derived from an unbiased (government) source, rather than a source that may be perceived as motivated to overstate benefits, understate negatives or overlook uncertainties. Data should be as detailed as possible and should be varied appropriately to reflect changes over the time period being included. For example, seasonal changes in temperature, rainfall, equipment operation (harvesting vs. planting seasons; tourist vs. non-tourist season variations, etc) that would affect any relevant data should be reflected.

Where information is uncertain, conservative assumptions/methodologies should be used in selecting a number for inclusion in a calculation. For example, if three data sources are available, each of which provides a different value, an average of the values could be used to apply to the project. However, the resulting value should be critically assessed to ensure that it is conservative in the specific project context. Where any uncertainty exists as to the relevance of a value, it should be adjusted in a manner that will result in understating the resulting GHG reductions that are attributed to the project. In the case of calculating a baseline, this would lead to a lower baseline emission level.

E. "With-Project" GHG Emissions

This section should include all of the elements that are addressed in the baseline emission section, providing the values expected to represent the results of project operation. Again, all assumptions should be made explicit and should be justified. Data should be as detailed as possible and all areas of uncertainty should be presented and discussed, with clear, justification for the treatment of uncertainty in the calculations. Detailed discussion should be provided about the accuracy of the operational and emission data that will be collected from the project. Contingencies that may effect actual operations and emissions for the project should be anticipated and explained, including potential interruption of primary fuel supply; seasonal operational cycles; the impact of weather extremes, such as temperature or rainfall; malfunctions or outages of equipment that are relied upon for operational or emission data used in generating relevant data. Where several operational and/or emission scenarios are possible, each should be presented and discussed. If a single scenario will be selected to characterize the "with project" emissions, the rationale for selected should be presented, with an appropriate amount of objective, credible information to support its selection.

F. Calculation of GHG Reductions

This section should present the calculation formula for both the baseline and "with project" GHG emission levels per year, with the resulting GHG reduction per year and the total GHG reductions expected for the period being evaluated. Additional detail for the data used in the calculations may be provided in an appendix if needed.

It should be noted that in all cases, assumptions and values that are obtained from outside sources should be the result of an objective, rigorous and balanced review of the relevant technical literature. In no case should a value or assumption be included that has been obtained by an employee, contractor, former employee or other entity whose perspective can be viewed as biased by a critical reviewer. It is possible that such an entity's perspective provides unique insight that is arguably more informed, and therefore more accurate, regarding the specific project, than other third-party analysis can provide. In this case, a clear justification should be made in light of the other publicly-available information. If time permits, a stronger case should be made for use of this "uniquely" known information by making it available for review by an independent third party.

G. Actual Emission Measurement and Monitoring

It is important to note that projections of GHG emissions from a project using the best information available are still merely an estimate. Until actual operational and emission data have been collected throughout the life of the project, the true impact of the project on GHG emissions cannot be known. In seeking carbon financing opportunities, it is incumbent upon project proponents to rely on the best information available to provide the most accurate estimates possible of GHG emission impacts. However, actual data must be collected throughout the operation of the project to allow for retrospective quantification of actual GHG emissions from the project, as well as any adjustments to assumptions that had been made about baseline GHG emission levels. Routine review of these factors, typically undertaken on an annual basis, provides the final assessment of valid GHG emission reductions that would qualify for carbon finance.

CALCULATION TEMPLATE FOR THE BANGALORE SANITARY LANDFILL

III. CALCULATION TEMPLATE FOR THE BANGALORE SANITARY LANDFILL

The following section discusses a calculation template developed to assess the GHG mitigation potential of the proposed MSW project. Given the absence of detailed project information (in the absence of a decision on the proposal selected), the template has been developed using a several assumptions on the facility operations. While doing the actual calculation for the project, these assumed values would need to be replaced with actual values, to the extent possible.

A. General Description of Project Activity

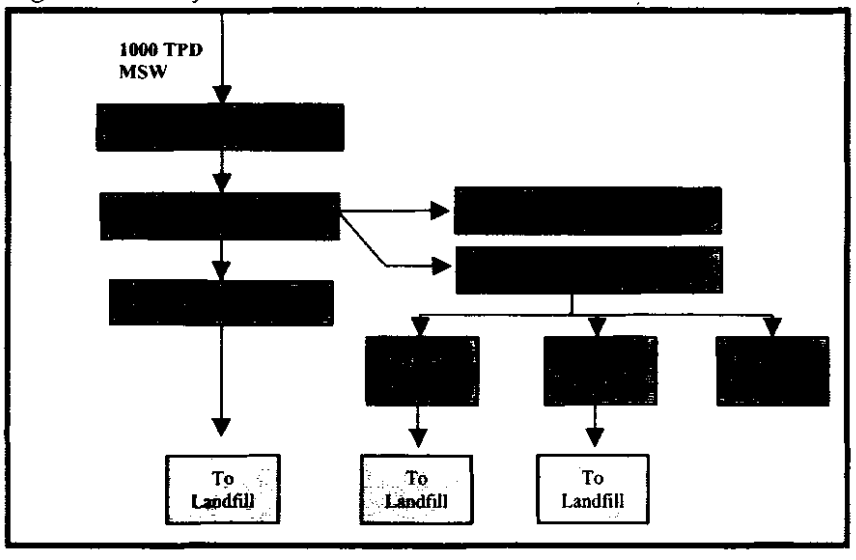
The vision for the project is to set up an Integrated Plant for Bio-conversion of MSW and Engineered Sanitary Landfill at an appropriate location on the outskirts of Bangalore city. The facility is being planned, designed and constructed as per sound engineering practices and the recommendations of the committee constituted by the Supreme Court of India and guidelines set out in MSW 2000 Rules.

The MSW 2000 Rules stipulate that the landfill will be restricted to non-biodegradable waste, inert waste, residues of waste processing facilities as well as pre-processing rejects from waste processing facilities and other waste that are not suitable either for recycling or for biological processing.

The proposed Integrated Solid Waste processing facility shall be developed in accordance with the guidelines prescribed by MSW 2000 and will have plant and machinery and support infrastructure facilities to ensure the sustained operation as per the same guidelines.

The project involves a composting plant and a sanitary landfill facility. Remnants from composting operations (largely inert waste) and unsold compost will be directed to the landfill facility. A flow chart of the facility operations is given Figure 1 below.

Figure 1. Facility Flow Chart



The project encompasses two such facilities located at Kannahalli and Kyalasanahalli on the outskirts of Bangalore. Broad parameters of the two facilities are given below.

Table 1: Features of the Bangalore Landfill Sites

Population covered	2.54 mio	1.75 mio
Waste per capita	0.315 kg/person/day	0.34 kg/person/day
Area of facility	28.65 acres	35.73 acres
Capacity	600 tpd	400 tpd

The proposed project has two separate components that result in emission reductions, namely:

- Composting of MSW resulting in reduction of methane released to the atmosphere.
- Replacement of chemical fertilizer by organic compost produced under the project.
  NOTE:- [Emission reductions under this component are however relatively uncertain. The extent of reductions would be determined by the extent to which the compost generated under the project actually results in fertilizer substitution. In some locations the compost is used as a direct fertilizer substitute, while in others it is used as a supplement that improves the soil quality. In the latter therefore it could be seen as a complement to and not a substitute for fertilizers. Project proponents would accordingly need to assess the market reality in their project's context before including this component in the offset calculations.]

The project has been developed with the coordinated efforts of the Bangalore Mahanagara Palika (BMP), Bangalore Action Task Force (BATF) and Infrastructure Development Corporation (Karnataka) Ltd. (iDeCK).

B. Baseline Identification

The current practice of management of MSW in India comprises collection of the garbage and dumping it at specified sites within the city limits. These sites are generally unused low-lying land on the outskirts of the cities. The 300 Class I cities covering a population of 250 million generate about 39 million tons of MSW every day. Only a few of these cities have initiated ways of treating their solid waste, which mainly resort to composting and land-filling. Bangalore is among the more proactive municipalities, having taken the initiative of developing an integrated solid waste facility in accordance with MSW 2000 Rules.

a. Project Boundary

The project shall encompass the city of Bangalore from where the city garbage is collected, which was otherwise dumped on open sites. The project boundary for the first stream of GHG reduction (viz. prevention of methane emissions from open dumping), is therefore the boundary of the city of Bangalore.

The compost produced in the city of Bangalore is primarily purchased by farmers from surrounding areas, including cultivators of rice, pulses, groundnut, cotton, and sugarcane. It substitutes/avoids use of chemical fertilizers like urea, di-ammonia phosphate (DAP) etc. The manufacturing process of these fertilizers leads to emissions of CO_2 and other GHGs. For the purpose of this stream of GHG reduction, it would be essential to include the fertilizer manufacturing plants in the project boundary. Ideally, all such plants should be included. However, it would be practical to consider average plants of these two and accord due weightage proportional to the consumption (by the intended users).

b. Baseline scenario

The treatment and disposal of MSW is guided by the MSW Rules 2000, as per which cities/ municipalities are required to have technically sound disposal options in place by 31.12.2003. The MSW 2000 Rules therefore represent the starting point for the development of the baseline scenario. However, since the formulation of the Rules, while some cities have started

planning for sanitary landfill facilities and composting, there has not been any noticeable change in the MSW management process across most cities. Moreover, no city in India appears to be in a position to comply with the Rules by the deadline of December 2003.

In the context of the poor enforcement of environmental regulation in India and in the weak financial health of municipal bodies, it is likely that the current practice of open dumping would continue to be the prevalent "lowest-cost-option" means of waste disposal. The baseline scenario therefore has been taken as a continuation of the current practice (i.e. disposal of MSW in open dumps), with a gradual shift over to the acceptable technical options (composting cum land-filling, land-filling with inertization, biomethanation etc.).[2]

In the Bangalore context, while open dumping is the norm, select composting operations are currently taking place. There are currently three organized composting plants, owned by:

- Karnataka Compost Development Corporation Ltd (KCDC) - 350 TPD
- Sunrays Composting – 200 TPD (capacity utilization is however, for only part of the year)
- Terra Firma – 50-60 TPD

Apart from the above, there are smaller local initiatives by some community-based organizations. Total composting operations are therefore in the range of approximately 500 TPD. This capacity is expected to remain unchanged in the baseline scenario, given that there are no plans to increase composting operations for the city of Bangalore. It is, however, expected that the municipality will proceed with installation of a waste to energy facility of about 700 to 1000 TPD capacity – which is also likely to be in place by 2010.

Total waste generated for the city is currently at 2200 TPD, which is likely to grow to approximately 3800 TPD by 2012 and 6000 TPD by 2025. Of this, part of the waste will be processed via composting and waste to energy facilities (as described above), while the rest will be directed to open dumps. The values for the latter are 2046 TPD in 2005, going up to 2738 TPD by 2009 and then declining to 2211 TPD by 2010.

c. *Duration of project activity/ crediting period*

The facility operations will commence by the end of 2004, but will stabilize for the first full year of operation in 2005. For the purpose of calculation of offsets, a period of 8 years has been taken starting from 2005 to 2012. The crediting period extends through 2012 because 2012 is the end of the first compliance period under the Kyoto Protocol, to which India is a signatory. Subsequent to 2012, it is difficult to make meaningful predictions of the domestic and international regulatory requirements for GHGs, thus, the ability to characterize the regulatory baseline for GHG emissions is extremely limited.

[2] This approach for arriving at the baseline scenario is similar to that used in the proposal for the ABIL biomethanation project in Lucknow, submitted to the Protoype Carbon Fund (World Bank) for funding.

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d. Baseline emissions calculation methodology

METHANE EMISSIONS AVOIDED

Baseline emissions would include the following:

- Methane emissions from open dumps
- GHG emissions from composting operations
- GHG emissions from WTE facilities

No data is currently available on the GHG emissions from the existing Bangalore composting operations. These can be monitored for the project, and if significant, the emission factor can be used for the baseline calculation as well. Emissions from Waste to Energy (WTE) are considered to be negligible. Therefore, for baseline purposes, only methane emissions from open dumps are included in the calculation.

The *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC Guidelines)* outline two methods to estimate methane emissions from solid waste disposal sites, namely,

i. First Order Decay (FOD) method
ii. Theoretical Gas Yield Method

First Order Decay method

The most commonly used method is the FOD method, which assumes that methane is emitted over a long period of time rather than instantaneously. The kinetic approach takes into account the various factors, which influence the rate and extent of methane generation and release from landfills. An important parameter to estimate methane emissions is the waste degradability factor, which is site specific. In countries where engineered landfills are commonly in operation, and data on methane emissions are recorded, it is possible to develop such site specific data.

In India however, no such facilities are currently in operation. Therefore although, FOD is the more realistic and sophisticated approach, due to lack of requisite data on some of the key variables, this method is not proposed for calculating emissions in the baseline scenario.

Theoretical Gas Yield Methodology

This is the default methodology under the *IPCC 1996 Guidelines* for calculating methane emissions based on:

- the amount of waste deposited at waste disposal site
- the fraction of degradable organic carbon and the amount which actually degrades; and,
- the fraction of CH4 in landfill gas

The methane emissions from landfills as per this method, are represented by the following equation:

$$\textbf{Methane Emissions from Landfills (TPD)} = MSW_T \times DOC \times DOC_F \times MCF \times F \times C$$

Where:

MSW_T	=	total MSW disposed at the landfill (TPD)
DOC	=	degradable organic carbon fraction in the MSW
DOC_F	=	fraction of DOC that actually degrades
MCF	=	methane correction factor for landfill
F	=	fraction of methane in landfill gas
C	=	carbon to methane conversion factor

Refer to Appendix A for explanations of above variables.

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In the absence of detailed site specific data, IPCC default values have been used for calculation purposes. These can be substituted with site specific data based on monitoring undertaken in the course of the landfill operations.

DOC	0.18	To be monitored.
DOC_F	0.77	This value should be used only if lignin elemental carbon is excluded from the DOC value. [Using preliminary survey data for Bangalore waste the lignin adjusted DOC value is in the range of 0.12 – 0.09. However, in the absence of reliable data, IPCC default value for DOC has been used.]
MCF	0.4	Though IPCC default value is 0.6, it advises a value of 0.4 in a context where there is a high percentage of unmanaged shallow sites (< 5m waste).
F	0.5	Usually in the range of 0.4 – 0.6
C	16/12	NA

Using above values and formula, the baseline emissions calculations may be summarized as follows:

Total waste generated for Bangalore (in 2005)	2546	TPD
Methane emissions from open dumping	76	TPD
Methane emissions from composting & WTE facilities	0 (assumed)	
Total methane emissions from MSW	76	TPD
Weighted average baseline emission rate	0.030	CH4 tons/ ton of waste p.d.
Annual baseline CH_4 emissions (Wtd avg baseline rate x project capacity x 365)	0.03 x 1000 x 365 = 10841	TPA
Annual CO_2 equiv emissions (CH4 emissions x 21, where 21 is the Global Warming Potential of CH4)	227662	TPA

FERTILIZER SUBSTITUTION

The second category of baseline calculation relates to the emissions reductions arising from replacement of chemical fertilizer by compost generated by the project[3]. The compost will replace the use of chemical fertilizers like urea, DAP, potash and super phosphates. Based on the experience of users in the area, the equivalent amount of compost to one ton of chemical fertilizer has been estimated. Based on the specific energy consumption of urea and ammonia and the average usage of these fertilizers in India, the weighted average emission factors of the chemical fertilizers can be calculated. The baseline emission reduction is the amount of emission by the equivalent amount of chemical fertilizers used.

[redacted] = [redacted] X [redacted]

NOTE: While the manufacturing process of chemical fertilizers also leads to emission of N2O, for want of precise data these were not quantifiable and hence were not accounted for in the present analysis.

The specific energy consumption of fertilizer plants in India were 12.3 Gcal/ton of ammonia, 13.5 Gcal/ton of urea, and 0.06 Gcal/ton of DAP. The consumption of major fertilizers namely, urea, DAP and SSP are 72%, 14% and 14% respectively. Based on the feedstock from which the fertilizers derive energy and the power consumption of the manufacturing process, the average emission factor for each ton of chemical fertilizer works out to approximately 2.63 tons CO_2/ ton of fertilizer.[4 5 6]

The conversion factor for compost to chemical fertilizers would vary from site to site, depending on the quality of compost generated and the use to which it is put. In the context of Bangalore, based on prior usage patterns of compost, a conversion factor of 1: 0.3 has been used i.e. 1 ton of compost should replace about 300 kg of chemical fertilizers.

[3] As mentioned earlier, inclusion of emissions reduction under this category would need to be assessed based on the market reality in the project's context i.e. the extent to which the compost generated is used as a substitute for fertilizer, versus a soil enricher.

[4] India's Fertiliser Industry: Productivity and Energy Efficiency *Katja Schumacher and Jayant Sathaye* Environmental Energy Technologies Division July 1999

[5] Energy Conservation at design stage, CII Energy Management Cell, under the ADB-ESP project.

[6] TERI Energy Data Directory & Yearbook 1999/ 2000

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DOCUMENTATION FOR GHG MITINGATION FROM BANGALORE SANITARY LANDFILL PROJECT

GHG Emissions/ Mitigation from the Project

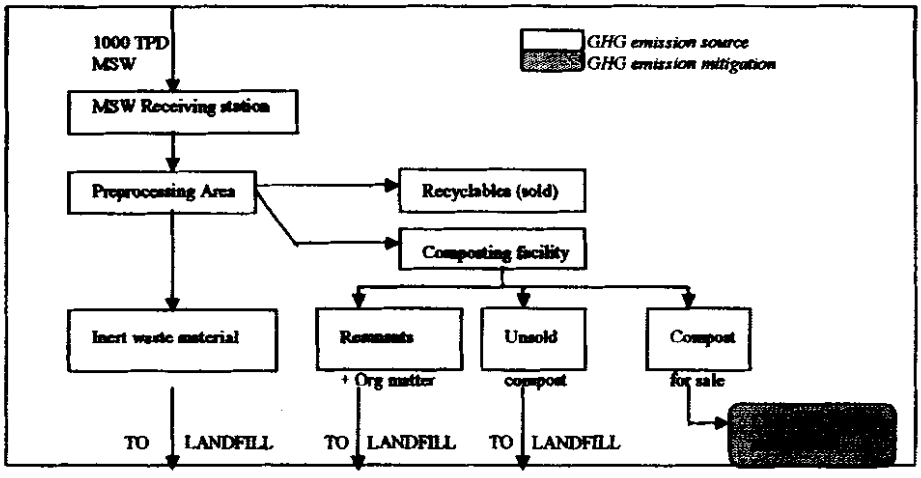
There are two potential sources of GHG emissions from the project namely,

- from composting operations, and
- from degradation of organic matter that might be land-filled along with remnants from composting operations.

In addition, there is mitigation of GHG emissions due to sale of compost generated from the project, which would substitute use of chemical fertilizer for plantations/ horticulture purposes.

Figure 2 below provides the points of GHG emission and mitigation associated with the project.

Figure 2.



a. Emissions from composting operations

As in the baseline calculations, it is assumed here that emissions from composting operations are negligible. These would, however, need to be monitored on an on-going basis, and if values are significant would need to be included in the emissions from the project.

b. Emissions from degradation of organic matter land-filled

In regard to the second potential source of emissions, under ideal composting operations, there should be no organic matter going into the landfill. This is the stipulation under the MSW 2000 Rules as well, which mandates that *"Land-filling shall be restricted to non-biodegradable, inert waste and other waste that are not suitable either for recycling or for biological processing."*

However, in actual operations it is expected that some amount of organic matter will remain even after composting, and will get transferred into the landfill along with the remnants from the composting operations.

The emissions on account of degradation of this organic matter will be calculated using Theoretical Gas Yield Formula methodology, as in the case of the baseline emission calculations. The reason for this is, again, the absence of requisite data to use the First Order Decay method. It is nevertheless expected that once the project is operational, monitoring of methane emissions will be done at the landfill facility, and these default values will be replaced with the actual emissions taking place from the facility.

$$\text{Methane Emissions from Landfills (TPD)} = MSW_R \times DOC \times DOC_F \times MCF \times F \times C$$

Where:

MSW_R	=	organic matter land-filled along with compost remnants (TPD)
DOC	=	degradable organic carbon fraction in the MSW
DOC_F	=	fraction of DOC that actually degrades
MCF	=	methane correction factor for landfill
F	=	fraction of methane in landfill gas
C	=	carbon to methane conversion factor

MSW_R can be arrived at using the following equation:

$$MSW_R = MSW_T \times Wc \times Wr \times Wo$$

Where:

MSW_T = Total MSW received at the facility (TPD)
Wc = Fraction of MSW to composting (rest going directly to landfill)
Wr = Fraction of remnants left after composting
Wo = Fraction of organic matter in remnants

Calculation of emissions for this project has been done for two scenarios, namely-

A. No segregation of waste prior to composting i.e. 100% mixed waste processed via composting.
B. Limited segregation of waste prior to composting i.e. 85% waste processed through composting facility, while the balance 15% (only inert matter) is directly sent to landfill.

It is expected that with increased compliance with the MSW 2000 Rules, segregation levels will improve, and correspondingly the situation will, over time, move towards Scenario B. Moreover, values for Wr and Wc are also likely to be affected with improved segregation and composting operations.

For the parameters in the Theoretical Gas Yield Formula, as in the case of the baseline calculations, default values have been used as per the *IPCC Guidelines*.

DOC	0.18	To be monitored using waste characterization data for MSW received at the facility
DOC_F	0.77	This value should be used only if lignin elemental carbon is excluded from the DOC value. [Using preliminary survey data for Bangalore waste the lignin adjusted DOC value is in the range of 0.12 – 0.09. However, in the absence of reliable data, IPCC default value for DOC has been used.]
MCF	1	This is the IPCC default value for managed landfill sites.
F	0.5	Usually in the range of 0.4 – 0.6
C	16/12	-

For the quantum of MSW_R two sets of values have been taken for the parameters, corresponding to the two scenarios of waste segregation. These are as follows:

Wc	100	85
Wr	30	15
Wo	15	15

Using above values, the following is the summary of the emissions calculation for the project:

Total MSW received at project site (MSW_T)	TPD	1000	1000
MSW Composted	TPD	1000	850
Remnants from composting	TPD	300	128
Organic matter in remnants (MSW_R)	TPD	45	19
Annual CH4 emissions from composting	TPD	0	0
Annual CH4 emissions from organic matter land-filled	TPA	1518	645
Total annual CH4 emissions from project	TPD	1518	645
Annual CO2 equiv emissions from project	TPA	31871	13545

c. Emissions Mitigation Due to Chemical Fertilizer Substitution

The project is also associated with emissions mitigation due to substitution of chemical fertilizers by compost generated from the project. The reductions achieved can be calculated using the following equation:

GHG Emissions Reductions o/a Fertilizer Substitution $(ER_F) = E_F \times C_S \times Y$

Where:

E_F = CO2 emissions intensity of fertilizer production (Tons/Ton of fertilizer)
C_S = Compost sold (TPA)
Y = Conversion factor from compost to fertilizer (i.e. Tons of fertilizer/Ton of compost)

Values for specific energy/emission intensity associated with the production of chemical fertilizers and the conversion factor have been discussed above. These are as follows:

E_F = 2.63 tons CO_2/ ton of fertilizer
Y = 0.3 (i.e. 1 ton of compost ~ 300 kg of fertilizer)

In regard to the quantity of compost sold, it is assumed that the project will be able to sell about 20% of the compost generated. The percentage will possibly increase over time, as pressures mount for compliance with MSW Rules 2000. The government can also be expected to take proactive measures to encourage the use of compost (e.g. adopt the use of compost for its own horticultural requirements such as plantings for municipal median strips). Accordingly, it has been assumed (based on estimates provided by the technical consultants for the project) that the proportion of compost sold will increase to about 50% by the year 2012.

The quantity of compost generated varies under the two segregation scenarios described above. Accordingly, two sets of values have been calculated for emissions reductions achieved corresponding to these two scenarios. These are summarized as follows:

		Scenario A	Scenario B
Quantity of compost sold (C_S)	=	**14600 TPA**	**12410 TPA**
ER's o/a feriliser substitution (ER_F)	=	**11519 TPA**	**9791 TPA**

GHG Mitigation potential of project

The project helps in avoiding emission of two GHGs, namely methane and carbon dioxide (due to chemical fertilizer substitution).

The project enables reduction in methane emissions by redirecting waste disposal from open dumps to composting cum landfill facilities. The composting process helps to render the waste inert and thereby reduces the methane emissions associated with degradation of organic matter in open dumps/ landfills.

Based on the calculation methodology described above, and default values used (in the absence of project specific data), the CO_2 reductions achieved due to methane emissions avoided is as follows:

Baseline - Annual CO2 equiv. emissions	=	227662 TPA	
		Scenario A	Scenario B
Project – Annual CO2 equiv. emissions	=	31871 TPA	13545 TPA
Emission reductions o/a] (ER_M) CH_4 emissions avoided]	=	195791 TPA	214117 TPA
ER's o/a fertilizer substitution (ER_F)	=	11519 TPA	9791 TPA
Total ER's o/a project (ER)	=	**207311 TPA**	**223909 TPA**

The above represents the calculation for Year 1, or 2005. Similarly, emission reductions have been calculated for the remaining crediting period, and the resulting time series data has been summarized in Appendix B.

In addition, the complete calculation methodology described in the previous sections has been provided as a calculation template in Appendix C.

Monitoring and Verification

a. M&V philosophy

Monitoring and verification (M&V) of the emission reductions from a project is key to ensure that the projected reductions indeed take place. The investors' risks from a project are addressed to a large extent through the M&V process.

The proposed project has two distinct components of emission reduction. Therefore, the M&V approach for these is designed separately.

For the solid waste treatment, the measure of reductions shall be derived from the quantity of solid waste processed at the landfill, which has a relationship with the methane generated. The proposed plant would have a measurement system for the solid waste as specified in the RFP document. The measurement of the remaining parameters would be determined by the extent of actual monitoring done, versus the use of formulae to derive the GHG emissions from the project. To the extent actual monitoring is undertaken of methane and CO_2 emissions from the composting/landfill facilities, requirement of monitoring formulae parameters, would be reduced.

With regard to the sale of compost, the measurement of the weight of compost sold would be as per the sale records of the company. This would be recorded as per the usual standards of sale of goods.

Periodic review would need to be undertaken of parameters used for baseline calculations. To this extent, the M&V system would also keep track of parameters such as the pattern of solid waste disposal in the city of Bangalore, waste characterization data, power consumption patterns for fertilizer production, fertilizer consumption in the country. The major assumptions made in the GHG reductions analysis would also be confirmed from time to time, so as to keep a track of the carbon offsets generated and also to account for any leakages that may occur.

b. M&V Protocol

The M&V protocol would need to include the following elements:

- Measure and record the quantity and composition of MSW received.
- Measure and record emissions (if any) from composting operations
- Measure and record emissions (if any) from landfill operations.

OR
- Measure and record the quantity of MSW composted, fraction of remnants, and fraction of organic matter in the remnants.
- Undertake periodic waste characterization studies to ascertain the DOC of the MSW processed.

- Measure and record the quantity of compost sold
- Keep track of solid waste management practices in the city and the country
- Keep track of energy intensity of fertilizer production, and consumption patterns of fertilizer.

DPR WORK SHEET FORMAT

Detailed Project Report (DPR) Worksheet

For GHG mitigating projects under
USAID's Greenhouse Gas Pollution Prevention Project – Climate Change Supplement

Managed by The Louis Berger Group, Inc.

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Background:

This form is for the purpose of gathering relevant project finance information for projects developed under USAID India's Greenhouse Gas Pollution Prevention Project – Climate Change Supplement (GEP-CCS). It is designed for project developers and financial institutions involved with clean energy or other types of GHG mitigating projects that are placed into the GEP-CCS pipeline.

Format: The form is designed to capture the types of projects seeking Project Finance.

Project Finance is focused on anticipated revenue streams from the project activity (or off-balance sheet financing). For example, a grid-based biomass co-generation facility would likely depend upon energy payments from a local electricity board. Much more detailed information about the project, project promoter, power purchase agreement, debt and equity sponsors and profitability and cash flow analyses are necessary to determine the relative risk and financial viability of the project.

This is a working electronic document/check-list. When each question is answered, place an electronic checkmark (√) in the left-hand box as a reference point for completion of the form.

Project Name:

Project Promoter:

Special Purpose Vehicle:

1. **Executive Summary: Project at a Glance**

---

2. Project Costs

	Plant & Machinery			
	Land & Building			
	Civil, detailed Engg			
	Erection & Commissioning			
	Preliminary & Preoperative Expenses			
	Working Capital Margin			
	Contingencies			
	Total Project Cost			

3. Proposed Means of Financing

	Total Debt Portion			
	Total Equity Portion			
	Total Project Cost			

---

4. Committed Financing (if any)

a. Committed Debt Providers

b. Committed Equity Providers

5. Estimates of Profitability

Revenue from power sale										
Other revenue										
Fuel cost										
O&M Cost										
Admn/selling cost										
PBIDT										
Depreciation										
Interest Term loan Working cap										
PBT										
Provision for Tax										
PAT										
Net Cash Flow										

6. Projected Cash Flow

Sources of Funds										
PAT										
Depreciation										
Inc. in Equity capital										
Inc. in term loans										
Inc. in bank borrowings										
Total sources										
Application of funds										
Capital Expenditure										
Inc. in Current Assets										
Term loan repayment										
Taxes										
Dividend										
Total Application										
Net Surplus										
IRR										
DSCR										
Av DSCR										

7. **Status of Finance Negotiations**

Are you in negotiations with any prospective debt providers? If yes, please specify and elaborate on expected time frame. _____

Do you plan to submit this project to a private venture capital firm or an international equity organization (e.g. REEF)? If yes identify specific fund and elaborate on negotiations.

Do you plan to submit this project to an international tender for carbon emissions reductions (e.g. Oregon Climate Trust)? If yes, please specify tender and closing date for submission. _____

8. Project Promoter Contact Information

	Name of Project Promoter	
	Address	
	City, State, Province	
	Contact Name	
	Contact Phone	
	Contact FAX	
	Contact EMAIL	

9. Project Management Team

10. Project Promoter Financial History

	What were profitability figures last 3 years?	
	Book value of firm?	
	EPS reserves and surplus last 3 years?	
	What is current business?	
	What are synergies between business and this project?	

11. Project Promoter Relevant Experience:

Briefly describe the relevant experience, if any, possessed by the project promoter. Has the promoter developed similar projects?

12. Special Purpose Vehicle Contact Information (If applicable):

	Name of SPV	
	Address	
	City, State, Province	
	Contact Name	
	Contact Phone	
	Contact FAX	
	Contact EMAIL	
	Names and shares of the promoters	
	Is a Shareholding agreement in place	
	Salient terms	

13. Project Details

	Greenfield project or involves existing equipment?	
	Is GHG mitigation achieved by Process Improvement or Clean Energy Generation?	
	Size of Project (MW)?	
	Project Location? City, Province	
	Off or on-grid?	
	State Electricity Board?	
	Technology?	
	Type of Fuel?	
	Source of fuel supply?	

14. Feasibility Details

	Was Feasibility Study prepared independently?	
	What firm prepared the Feasibility Study? List address and contact details	

15. Background on the Power Purchase Agreement (if Applicable)

	Does Project involve PPA (Yes or No) If no, skip to next heading.	
	Has a PPA been signed? (Yes or No)	
	Nature of Agreement? Take or Pay? Other?	
	Name of state electricity board or primary PPA signatory?	
	What date was the PPA signed?	
	When does it enter into force?	
	What is the length of the PPA? (Years)	
	What is the initial purchase price?	
	What is the annual % increase in purchase price?	
	Can the project sell power directly to major consumers? (Yes or No)	
	What are the securities provided for the revenues? Have the domestic lenders approved these mechanisms? Are there any special clauses, or provisions of relevance to the investors?	
	What are the terms of Payment to the project developers? Any special clauses of relevance to the investors/lenders? Have the domestic lenders approved the payment terms?	
	What are the major provisions (event definitions, treatment of the off time, etc.) of the Force Majeure clauses?	
	What is the method of fixation of tariff (two part, availability etc.)? Are there any provisions for deemed generating/penalties? What is the treatment for infirm power?	
	Have the provisions for change in law, termination, liquidated damages , etc. been approved by existing lenders/investors?	
	Would the SEB/generating utility want a share in the ownership of carbon offsets?	

16. Other Agreements (where applicable)

	Fuel supply agreement signed?	
	Water/utility supply agreement signed?	
	Shareholder's agreement been entered into between existing equity holders?	
	Special provisions of above agreements?	

17. Quantify and Describe Risks

	Risks	Low to High	Describe
	Market?		
	Country/Sovereign?		
	Regulatory?		
	Contract/counter party		
	Construction?		
	Technology?		
	Management?		
	Enforceability of Contracts?		
	Competition?		
	Exit?		

18. For risks identified in section 14, discuss Mitigation/Coverage measures

	Risks	Describe Mitigation/Coverage
	Market?	
	Country/Sovereign?	
	Regulatory?	
	Contract/counter party	
	Construction?	
	Technology?	
	Management?	
	Enforceability of Contracts?	
	Competition?	
	Exit?	

1. GHG Mitigation Applicability Macro Checklist

√		Yes	No
	Does project generate real, measurable, long-term, additional and verifiable emissions reductions vis-à-vis current baseline alternatives?		
	Are there sustainable development benefits such as increased employment and protecting biodiversity?		
	Does the project rely on ODA?		
	Has the project received host country approval?		
	Does project meet size definition ? --under 15 MW for renewables projects --under <15 giga watt hours/year savings for energy efficiency projects --under15 kilo tonnes CO2E for emissions reductions from process changes		

2. GHG Mitigation Calculations, Monitoring and Verification Checklist

√		Yes	No
	Does the project involve a discrete reduction of emissions?		
	Have the emissions reductions been estimated with an accepted methodology?		
	Has a monitoring methodology been established?		
	Has a third party verifier been contracted to verify actual emissions reductions and sustainable development gains?		
	Has clear ownership of emissions reductions been determined and documented?		

3. GHG Assessment details

	Parameter	Particulars
1	Baseline methodology	
2	Baseline Emissions tCO2 p.a.	
3	Project Emissions tCO2 p.a.	
4	Emission reductions tCO2 p.a. (2-3)	

APPENDICES

APPENDIX A

PARAMETERS USED IN THEORETICAL GAS YIELD FORMULA

APPENDIX A
PARAMETERS USED IN THEORETICAL GAS YIELD FORMULA[7]

Degradable Organic Carbon (DOC)
This is the organic carbon that is accessible to biochemical composition. It is based on the composition of waste and can be calculated from a weighted average of the carbon content of various components of the waste stream. Based on the IPCC Guidelines, DOC can be estimated using default carbon content values in the following equation:

$$DOC = 0.4(A) + 0.17(B) + 0.15(C) + 0.3(D)$$

Where:

- A = fraction of MSW that is paper and textiles
- B = fraction of MSW that is garden waste, park waste or other non-food organic putrescibles
- C = fraction of MSW that is food waste
- D = fraction of MSW that is wood or straw

The default carbon content values for these fractions can be found in the *IPCC Guidelines* (Table 6-3, Reference Manual). However, obtaining values by performing waste generation studies and sampling of different waste disposal streams at the proposed project is recommended. Survey data and sampling results should be reported and record of these should be maintained. In addition, it is important that inventory agencies exclude lignin from their DOC calculations if the default value (0.77) for DOC_F is used.[8]

Fraction of degradable organic carbon that actually degrades (DOC_F)
DOC_F is an estimate of the fraction of carbon that is ultimately degraded and released from unmanaged landfills, and reflects the fact that some organic carbon does not degrade, or degrades very slowly, when deposited in an unmanaged landfill. The *IPCC Guidelines* provide a default value of 0.77. Review of recent literature however, suggests that this may be an overestimate. It should be only used if lignin elemental carbon is excluded from the DOC value.

Methane Correction Factor (MCF)
The methane correction factor accounts for the fact that unmanaged landfills produce less methane from a given amount of waste than a managed landfill, because a larger fraction of waste decomposes aerobically in the top layers of the unmanaged landfill. The MCF is specific to that area, and should be interpreted as the 'waste management correction factor' reflecting the management aspect of the solid waste systems.

Fraction of methane in landfill gas (F)
Landfill gas consists mainly of CH_4 and CO_2. The CH_4 fraction F is usually taken to be 0.5, but can vary between 0.4 and 0.6, depending on several factors including waste composition (e.g. carbohydrates and cellulose). The concentration of CH4 in recovered landfill gas may be lower than the actual value because of potential dilution by air, so F values estimated in this way will not necessarily be representative.

---

[7] The write-up for this Annexure has been taken largely from the proposal (Annex 4) for the ABIL biomethanation project in Lucknow, submitted to the Protoype Carbon Fund (World Bank) for funding.

[8] This caveat is not stated in the *IPCC Guidelines*. It has been taken from the ABIL proposal.

APPENDIX B

TIME SERIES DATA ON GHG REDUCTIONS ACHIEVED

APPENDIX B - TIME SERIES DATA ON GHG REDUCTIONS ACHIEVED

Time series data on emissions reductions achieved during crediting period

SCENARIO A: No prior segregation. 100% mixed garbage to composting; no direct to landfill

		BASELINE EMISSIONS								PROJECT EMISSIONS		MITIGATION O/A FERT SUBSTN			TOTAL CO2 MITIGATION	
				Waste disposal					(1)		(2)			(3)	(4)	(3) + (4)
	Year	Waste	Compos-	Waste to	Open	Wtd CH4 emission	Project	Annual CH4	Annual CO2-E	Annual CH4	Annual CO2-E	Compost	Compost	Annual CO2-E	o/a CH4 emissions	
		TPD	TPD	TPD	TPD	TPD	TPD	TPA	TPA	TPA	TPA	TPA	%	TPA	(1) - (2) TPA	TPA
1	2005	2546	680	0	1,866	0.027	1100	10,876	228,397	1,669	35,058	80300	20%	12,671	193,339	206,010
2	2006	2719	770	0	1,949	0.026	1100	10,637	223,378	1,669	35,058	80300	24%	15,387	188,319	203,706
3	2007	2892	860	0	2,032	0.026	1100	10,427	218,959	1,669	35,058	80300	29%	18,102	183,901	202,002
4	2008	3065	950	0	2,115	0.026	1100	10,240	215,039	1,669	35,058	80300	33%	20,817	179,981	200,798
5	2009	3238	1040	0	2,198	0.025	1100	10,073	211,538	1,669	35,058	80300	37%	23,532	176,479	200,012
6	2010	3411	1100	700	1,611	0.017	1100	7,009	147,181	1,669	35,058	80300	41%	26,248	112,123	138,370
7	2011	3584	1100	1,000	1,484	0.015	1100	6,144	129,034	1,669	35,058	80300	46%	28,963	93,975	122,938
8	2012	3757	1100	1,000	1,657	0.016	1100	6,545	137,442	1,669	35,058	80300	50%	31,678	102,383	134,062

SCENARIO B: Limited prior segregation. 85% mixed garbage to composting; 15% direct to landfill

	Year	BASELINE EMISSIONS							(1)	PROJECT EMISSIONS	(2)	MITIGATION O/A FERT SUBSTN		(3)	TOTAL CO2 MITIGATION (4)	(3) + (4)
		Waste generated	Compos-ting	Waste disposal: Waste to energy	Waste disposal: Open dumping	Wtd CH4 emission rate	Project capacity	Annual CH4 emissions	Annual CO2-E emissions	Annual CH4 emisions	Annual CO2-E emissions	Compost generated	Compost sold	Annual CO2-E offsets	o/a CH4 emissions (1) - (2)	Total
		TPD	TPD	TPD	TPD	TPD	TPD	TPA	TPA	TPA	TPA	TPA	%	TPA	TPA	TPA
1	2005	2546	680	0	1,866	0.027	1100	10,876	228,397	710	14,900	68255	20%	10,771	213,497	224,268
2	2006	2719	770	0	1,949	0.026	1100	10,637	223,378	710	14,900	68255	24%	13,079	208,478	221,556
3	2007	2892	860	0	2,032	0.026	1100	10,427	218,959	710	14,900	68255	29%	15,387	204,059	219,446
4	2008	3065	950	0	2,115	0.026	1100	10,240	215,039	710	14,900	68255	33%	17,695	200,139	217,834
5	2009	3238	1040	0	2,198	0.025	1100	10,073	211,538	710	14,900	68255	37%	20,003	196,638	216,641
6	2010	3411	1100	700	1,611	0.017	1100	7,009	147,181	710	14,900	68255	41%	22,311	132,281	154,592
7	2011	3584	1100	1,000	1,484	0.015	1100	6,144	129,034	710	14,900	68255	46%	24,619	114,134	138,752
8	2012	3757	1100	1,000	1,657	0.016	1100	6,545	137,442	710	14,900	68255	50%	26,927	122,542	149,468

APPENDIX C
CALCULATION WORKSHEET

APPENDIX C - CALCULATION WORKSHEET

[redacted]

BASELINE EMISSIONS

Waste disposal pattern

Total MSW for city	TPD	*Value*
Disposal to (a) composting (Dc)	%	*Value*
(b) WTE facilities (Dw)	%	*Value*
(c) open dumps (Do)	%	*Value*

Emissions from

- Composting (Ec)	TPD	*Assumed zero/ Actual monitoring data*
- WTE facilities (Ew)	TPD	*Assumed zero/ Actual monitoring data*
- Open dumps (Eo)	TPD	$MSW_T \times DOC \times DOC_F \times MCF \times F \times C$

[redacted]

Total (weighted) CH4 emissions for city	TPD	*Ec*Dc + Ew*Dw + Eo*Do*
Wtd avg CH4 emission rate for city's MSW	TPD	*Wtd sum of CH4 emissions (TPD) / Total MSW for city (TPD)*
Annual baseline CH4 emissions	TPA	*Wtd avg emission rate x MSW processing capacity of project x 365*
Annual baseline CO2 emissions (Eb)	TPA	*Annual CH4 emissions x 21*

[redacted]

[redacted]

[redacted]

FERTILIZER SUBSTITUTION		
[redacted]		
CO2 Emission intensity of fertilizer prodn (E_F)	Tons/ Ton of fertilizer	$SE_F \times EI_F$
Conversion factor of compost to chemical fertilizers (Y)	Fraction	*Value*
Quantity of compost sold (Cs)	TPA	*Value*
Emission reductions o/a fertilizer substitution (ER_F) =	TPA	$E_F \times Cs \times Y$

[redacted]		
[redacted]		
[redacted]	TPA	[redacted]
[redacted]	TPA	[redacted]
[redacted]	TPA	[redacted]

[redacted]

APPENDIX D

GHG MITIGATION GUIDELINES(INCLUDED AS APART OF THE BANGALORE PROJECT REP

GREENHOUSE GAS MITIGATION GUIDELINES

CONSTRUCTION REQUIREMENTS FOR WASTE PROCESSING FACILITIES

The drainage layer needs to be highly permeable, either pea gravel or similar material of hydraulic permeability of 1 cm / sec or more. Other suitable materials for the LCRS drainage layers include chip tires. Soil is not advised because of flow resistance and susceptibility to clogging by precipitates within pores.

The coarse, high permeability layer needed for leachate drainage, while serving the drainage function, needs to contain gas and prevent exit / atmospheric emission of generated landfill gas out from the base of the landfill that would otherwise occur. Sealing around the drainage layer perimeter shall be such as to prevent such gas loss via the drainage layer. For purposes of allowing selective liquid drainage, while preventing gas flow through the liquid leachate outflow, a u-trap type of gas barrier capable of containing gas at up to 1 to 1.5 meters gauge back pressure shall be on the liquid leachate outflow.

CONSTRUCTION REQUIREMENT FOR LANDFILL FACILITIES

Gas Recovery and Greenhouse Gas Mitigation System ("GRGS")

It is recommended that the Concessionaire, in accordance with the construction and O & M Requirements, provide an adequate GRGS, which normally would consist of the following components:

- Landfill Gas Extraction System
- Landfill Gas Extraction Device Design
- Landfill Gas Collection System
- Landfill Gas Treatment System: Active Design

Landfill Gas Extraction Systems: the extraction system may be a technique, or combination of techniques that is commonly used elsewhere in the world to recover landfill gas. The system may use vertical wells, horizontal trenches, permeable layers, or geomembrane covers, or any combination thereof so long as the extraction system objectives below, of recovery efficiency and recovered landfill gas methane content, are met.

The extraction system needs to be designed and capable of being operated to meet the following objectives:

(i) Migration Control: The landfill gas extraction shall be designed and operable with the goal of controlling landfill gas migration. The migration control goal is that landfill gas concentrations remain at safe levels at the landfill property boundary or perimeter. Effectiveness of this control shall be assessed by monitoring wells, having depth at least 5 meters, unless to the depth of the water table as reasonably

GREENHOUSE GAS MITIGATION GUIDELINES

CONSTRUCTION REQUIREMENTS FOR WASTE PROCESSING FACILITIES

The drainage layer needs to be highly permeable, either pea gravel or similar material of hydraulic permeability of 1 cm / sec or more. Other suitable materials for the LCRS drainage layers include chip tires. Soil is not advised because of flow resistance and susceptibility to clogging by precipitates within pores.

The coarse, high permeability layer needed for leachate drainage, while serving the drainage function, needs to contain gas and prevent exit / atmospheric emission of generated landfill gas out from the base of the landfill that would otherwise occur. Sealing around the drainage layer perimeter shall be such as to prevent such gas loss via the drainage layer. For purposes of allowing selective liquid drainage, while preventing gas flow through the liquid leachate outflow, a u-trap type of gas barrier capable of containing gas at up to 1 to 1.5 meters gauge back pressure shall be on the liquid leachate outflow.

CONSTRUCTION REQUIREMENT FOR LANDFILL FACILITIES

Gas Recovery and Greenhouse Gas Mitigation System ("GRGS")

It is recommended that the Concessionaire, in accordance with the construction and O & M Requirements, provide an adequate GRGS, which normally would consist of the following components:

- Landfill Gas Extraction System
- Landfill Gas Extraction Device Design
- Landfill Gas Collection System
- Landfill Gas Treatment System: Active Design

Landfill Gas Extraction Systems: the extraction system may be a technique, or combination of techniques that is commonly used elsewhere in the world to recover landfill gas. The system may use vertical wells, horizontal trenches, permeable layers, or geomembrane covers, or any combination thereof so long as the extraction system objectives below, of recovery efficiency and recovered landfill gas methane content, are met.

The extraction system needs to be designed and capable of being operated to meet the following objectives:

(i) Migration Control: The landfill gas extraction shall be designed and operable with the goal of controlling landfill gas migration. The migration control goal is that landfill gas concentrations remain at safe levels at the landfill property boundary or perimeter. Effectiveness of this control shall be assessed by monitoring wells, having depth at least 5 meters, unless to the depth of the water table as reasonably

anticipated to be always less than 5 meters beneath the surface. Optimally monitoring wells should be located at perimeter spacing of 20 or fewer meters. In any event a minimum of 10 monitoring wells should be installed at the landfill. The effectiveness of the landfill gas extraction and control system shall be such that methane in wells sampled on a routine schedule (such as weekly, in the first year after landfilling, and then semiannually in years after landfilling has begun), shall in no case indicate methane over 1.25%. This upper methane concentration limit is 25% of the lower explosive limit (5% in air) for methane.

(ii) Emissions Control: Emissions through the landfill surface shall be controlled such that an integrated surface scan, consisting of a combustible gas detector with continuous sampling, moved over the landfill in (parallel sampling paths) separated by 50 meters, with sampler intake between 10 and 50 cm above the landfill, and covering the entire landfill "footprint" such that no portion of the waste surface is farther than 25 meters from a sampling path, show methane concentrations uniformly below 500 parts per million by volume.

(iii) Odour Control: Concomitant with Item (ii) above, the landfill shall be operated with the goal that no noxious odours or complaints shall be lodged by residents living nearest the landfill. If necessary landfill personnel shall be able to assess odours and to reduce odours, by a combination of walkovers (downwind) to trace odours, and recovery system adjustments such as increased extraction rate.

(iv) Cover Protection: The landfill cover shall be soil or other relatively impermeable material (in the ideal case geomembrane). This cover shall be of a nature such that breaks in the cover shall be detectable by either visual inspection, or the detection of high methane concentrations near or downwind of cover breaches, by the combustible gas scans performed for emissions control in Item (ii) above. The cover construction shall be such that breaches (as for example cracks in clay, or tears in geomembrane covers) can be patched.

(v) Energy Products Recovery: The landfill must be designed with containment integrity (i.e. relative gas-tightness) such that landfill gas recovery for energy, as widely practiced elsewhere in the world, may be rendered economically practical at a future date, according to standards practiced elsewhere in the world (examples: recovery systems in Europe, US, Hong Kong, Thailand).

Practical methane energy recovery requires containment integrity such that the large majority of landfill gas can be recovered (from 60-90% being the standard in most landfills of the world). The system design shall also be such as to reasonably assure, under actual operational conditions, that air entrainment during the desired efficient recovery, does not preclude energy uses such as engines. Thus system performance at efficient extraction (60-90% recovery) must be designed to recover methane content above 45%. Bidders may follow guidelines of systems elsewhere in the world that meet these recovery efficiency and gas purity criteria.

LOCATION AND SIZING

The sizing of the landfill gas extraction/control system could adhere to the following specifications, taking into account that reliable background information on landfill gas generation rate for the circumstances of landfills in India is scant.

(i) Generation Rate: The recovery system must be sized to control the maximum possible gas flow.

For further reference: Building on data in Vogt and Augenstein (Vogt, G. And Augenstein, D.1997. Comparison of Models for Predicting Landfill Gas Recovery: Results of a 19-Landfill Survey) the maximum landfill gas generation rate for a landfill in India is expected to peak around at most, 20 litres of landfill gas per kilogram of waste per year. This generation rate default value also builds on work by Benemann and Augenstein (for Global Energy Partners by IEM, Inc.,)

(ii) Pipe Sizing and Implications: The total pipe size serving given sections of the landfill should assume this default landfill gas recovery value and convey the expected maximum gas flow to be blower station at a pressure drop of no greater than 10 inches of water gauge.

(iii) Total Yield of Landfill Gas: The total yield of landfill gas from waste being landfilled is expected to be, at most, 100 cubic meters mixed CO_2/CH_4 per metric ton of waste. Hence over long time spans (over several years) the average gas generated would normally be some maximum waste inflow, which can reasonably be averaged over a time span of 1 month or more, multiplied by the yield of 100 cubic meters per metric tonne received by the landfill. The landfill, as specified, shall be sized for a maximum inflow of 400 metric tons (tonnes) per day. However a further safety factor of 2 is recommended. This safety factor accounts for possible effects of high rain infiltration during monsoons, possibly in combination of high temperature, which could potentially accelerate gas generation by as much as twofold compared to the long-term average. Thus the peak default gas extraction rate is (500 tonnes/day) x (yield = $100M^3$/tonne x (2 = safety factor) = 100,000 M^3/day or 4166 M^3/hour. This value will be further referred to below. It should be recognized that this is the upper range of any plausible projected gas emission range and will not be achieved in practice except possibly during short periods.

(iv) Extraction Models (Optional): Recovery may be estimated by use of predictive models. If modeling can be justified on grounds, stated by the Concessionaire, to predict recovery, the extraction and recovery model required for use shall be the "School Canyon" model, as recommended by (among others) the US EPA. This model has also given good results on European Waste as documented in work by Hans Oonk. The landfill gas yield recommended for Indian circumstances is 100

cubic meters per tonne, and recovery estimates at decay rates of 0,10 and 0.20 per year are advised.

Still, in light of present knowledge, models are at best imprecise. This is shown by much work elsewhere including in the US. (See Vogt and Augenstein. Also see Augenstein, D. and J. Pacey, 1991 Landfill Methane Models. Proceedings, Solid Waste Association of North America (SWANA) Annual Meeting October. SWANA, Silver Spring, MD). A principal value of models may come only in conjunction with needs to predict gas availability for energy uses.

(v) First Order vs. Zero Order and Other Models: Over time spans of interest the differences between zero order, first order and other modeled predictions of generation rates are not large. The safety factor incorporated in the generation model assures capacity to handle gas at the likely generation as predicted by either of these accepted models. According, it is suggested that Bidders may employ the first order model as recommended.

LANDFILL GAS EXTRACTION DEVICE DESIGN

Essentially, wells, trenches - or a surface permeable layer under geomembrane cover - may be attached to a landfill gas-piping network. Landfill gas is pulled from the well into the piping system using an adjustable rate blower, which keeps the piping system at slight vacuum. A centrifugal blower is advised because it allows extraction over a wide range of rates which may be encountered. The blower should be of material and design which has proven corrosion resistant in landfill gas applications. It should tolerate entrained liquid (usually landfill gas condensate).

Landfill design features other than the extraction system per se must be appropriate to enable high-efficiency extraction of relatively high-purity methane. Important aspects of general landfill design are as follows:

(i) Horizontal to Vertical Permeability, and Daily Cover Materials: One need is for a high ratio of horizontal to vertical permeability to gas flowing within the landfill. This can be assured by use of appropriate daily cover. The permeability of the daily cover relative to waste must be either higher (characteristic of compost, straw, sand or shred tires) or lower than waste, as would be the case with a low permeability soil. Whether the choice is high-permeability (also like gravel, rubble, tire chips) or low-permeability cover (soils), such covers assures that generated landfill gas will flow more easily horizontally than vertically, which in turn augments collection efficiency for trenches or vertical wells. The daily covers with higher permeability are favored, because they are less likely to lead to landfill "waterlogging" which interferes with gas collection. They also lead to lower extraction pressures and generally greater gas recovery well efficiency.

(ii) Waste Drainage and Leachate Collection: The waste must drain well, to avoid "waterlogging". Waterlogging, a high landfill "water table" covering the extraction zone of wells, can be fatal for gas collection inasmuch as pooled liquid around the well perforations could prevent gas collection entirely. Thus the landfill must incorporate a leachate collection and removal system (LCRS), which keeps the waste drained. Necessary components of a LCRS are appropriate base layer sloping for drainage, a reliable corrosion resistant leachate recovery sump pump and provisions for treatment of the polluted, extracted leachate after it is removed from the landfill.

The drainage layer characteristics are extremely important. The drainage layer must be highly permeable, either pea gravel or similar material of hydraulic permeability of 1cm/sec or more. Other suitable materials for the LCRS drainage layers include chip tires. Soil is not advised because of flow resistance and susceptibility to clogging by precipitates within pores.

The coarse, high permeability layer needed for leachate drainage, while serving the drainage function, must contain gas and prevent exit/atmospheric emission of generated landfill gas out from the base of the landfill that would otherwise occur. Sealing around the drainage layer perimeter shall be such as to prevent such gas loss via the drainage layer. For purposes of allowing selective liquid drainage, while preventing gas flow through the liquid leachate outflow, a U-trap type of gas barrier capable of containing gas at up to 1 to 1.5 meters gauge back pressure should be on the liquid leachate outflow.

(iii) Controllable Extraction by Individual Wells: Extraction of gas from individual areas of the landfill served by individual wells or other capture approach should be adjustable. This accommodates the likely range of varying gas generation rates of individual areas that will typify landfills.

(iv) Landfill Gas Collection From Drainage Layer: Completely gas-tight sealing of the drainage layer from the atmosphere may be difficult. An acceptable alternative or even adjunct to gas tight sealing of the drainage layer is to carry out gas collection appropriately from the drainage layer. In this case the drainage layer specifications are the same. For gas recovery from the LCRS drainage layer a perforated gas well casing or hose (necessarily horizontal and located above any anticipated liquid level) extends into the upper part (vadose zone) of the drainage layer. The pipe connects to an exterior wellhead. For recovery control the wellhead is "tuned" (see Startup and wellhead gas extraction control below). Thus extraction is controlled as with wellheads on the vertical gas wells.

The extraction system could also extract from the base leachate control (LCRS) layer, or horizontal trenches located within the waste. In particular, vertical well operation may be combined with a permeable layer" (referred to elsewhere in these specifications as a "venting layer"). For a system employing vertical wells, alone or in combination with permeable layers or other collection means, the expert opinion and best practices suggest that the Concessionaire adhere to the following specifications.

(i) Total Well Depth: Optimum (total) depth of wells will tend to be site specific depending on daily cover and other features. But in general the gas collection effectiveness of wells (volume of waste served by an individual well) increases with depth. It is recommended that the total depth of proposed wells be at least 80% of landfill depth. The effectiveness (and efficiency) of the well is also greater when the zone of gas extraction is deeper. Thus, it is recommended that the slotline in the well casing, also known as the perforated zone, be restricted to the bottom third of the gas extraction pipe casing.

(ii) Casing Material: The well casing (pipe) itself should be of a material whose reliable service is established in landfill gas recovery. This material can be plastic, of which appropriate grads of polyvinyl chloride are often preferred in many landfills worldwide. Polyethylene is much less appropriate because of plasticity. Stainless steel might be used but is expensive. Carbon steel in landfill gas service is inappropriate because it is susceptible to corrosion (to ferrous carbonate, among other compounds). The diameter of casing is not extremely critical, so long as flow resistance is low and may range from 8-20cm ID.

It is advised, especially for deeper landfills > 15 meters, that the well casing be capable of telescoping by up to 20% of the buried pipe length, to accommodate expected and normal settlement of the landfilled waste over time. Thus the casing may consist of two telescoping sleeves of pipe. The telescoping joint should be located about halfway down the well casing and surrounded by a rubber sleeve which can seal the telscoping joint. Such a sleeve can be made of rubber resistant to landfill gas and condensate (similar to the flex hose) with an elongation capacity of at least 50%.

(iii) Seals: All pipe unions and connections in landfill gas wells and piping can be assumed susceptible to flexing and strain. Flexing will occur because of landfill settlement, thermally induced expansion and contraction and for other reasons. Seals (for example where gas extraction wellhead connects to solid pipe making up the gas recovery grid), and pipe-to-pipe unions should maintain good seals during this inevitable flexing which characterizes the wellhead and gas conveyance piping. One seal method which works uses high-strength corrosion resistant flex hose, similar to

seals in automotive or other internal combustion engine coolant circulation. (see flex hose, below). Hose-to-solid pipe seals are via ring clamps holding flexible hose tightly over the solid plastic or other pipe comprising the majority of the piping run (ie majority of the total piping length).

(iv) Flex Hose: Flex hose should be of a type with demonstrated leak-free performance and acceptable longevity in landfill gas service. One flex hose type with durability and condensate component resistance is that is used to convey internal combustion (ie vehicle) engine coolant. It is preferable that such hose be resistant to vertical loads, if dictated by design (for example if buried, to bear the weight of landfill vehicles and equipment operating on the surface). Flex hose can include hose used in agricultural irrigation, providing this hose is leak free (some agricultural irrigation hose tends to leak) and resistant to condensate.

To accommodate settlement and thermal expansion/contraction of solid pipe sections, the flex hose length and "slack" should be such as to allow extensions of up to atleast 2% of adjacent solid piping.

(v) Length of Slotline Perforations in Well Casing: It is recommended that the open area of slotline perforations be large enough to accommodate maximum anticipated extraction rate (computed based on volume of waste served, below and guidelines for normalized generation, above) while maintaining minimal pressure drop across the slotline of no more than 500 Pascals. Note that this high permeability for the slotline provides a safety factor even if part of the slotline should become clogged by precipitates, or waste particulates, or should become submerged.

(vi) Well Packing and Backfilled Gas Well Seals: The cylindrical boundary around the gas extraction perforations, defined as the interface between well packing (permeable gravel, etc) and waste, should pose minimum resistance to gas flow. At the same time it must during construction prevent borehole collapse. One approach is to drill the well bore to desired depth, then inserting as quickly as possible a cylindrical outer wall of fencing wire to hold back waste from collapsing into the wellbore. The well pipe is then inserted into the wellbore. Then the annulus around the well casing is packed with gravel, shred tire or similarly high permeability material, which permits gas flow and maintains the wellbore configuration.

(vii) Barrier to Gas Infiltration in Zone Between Well Slotline and Waste Surface: Design and construction should guarantee that the well bore above the slotline has an effective gas barrier material atleast an order of magnitude less permeable than the surrounding waste. A barrier of compressed geotextile (or a non-biodegradable synthetic cloth such as

packed-down nylon or polyester) may be placed over the gravel packing described above. This non-degradable cloth or cloth-like material is in turn covered with soil of depth equal to the well bore. The remainder of the well can be filled with clay or bentonite clay. In any case any proposed seal must be such that entraining air or gas cannot "short circuit" vertically through the wellbore filled with sealing material.

(viii) Valving: Each wellhead shall be equipped with a control valve capable of controlling flow from that individual well when the pipe downstream of the well is at a constant design vacuum. The wellhead and any other valving should be of type best suitable for control; in essence the value will have flow resistance gradually changing as the valve is opened or closed. High rangeability (controllable ration of maximum to minimum flow) is essential. The maximum flow rate of the valve may be specified as the maximum gas generation calculated for the waste mass served by the well, below.

(ix) Well Bore Diameter: The wellbore is not highly critical, providing other design criteria are met. It is best that the wellbore be between 0.4 and 0.8 meters in diameter, but any wellbore attainable in a landfill by a locally available drill rig in the Indian region can be considered.

(x) Well Spacing: Because the expected horizontal to vertical permeability ratio of waste in Indian landfills is not well established, the well spacing (wellhead-to-wellhead) is recommended to be conservatively close, with well spacing no more than twice the landfill depth, or, 2.5 times the landfill depth.

The well layout may be similar or approximate to a rectangular layout (4 wells forming a rectangle) or hexagonal (any 3 wells forming a triangle). This hexagonal layout is somewhat superior on grounds of gas flow mechanics.

The conservative solution recommended here - unless more information becomes available - is to place wells on the center-to-center spacing equal to 2.5 times the total vertical well depth.

(xi) Sizing of Control Valves and Well Piping: The most important criterion for sizing these items is that the valve piping have ability to accommodate the likely maximum gas flow from the sector of waste served. With knowledge of the area, depth, and mass of waste served by each well, the default flow value for the gas recovery may be assumed as above (40 liters landfill gas per tonne of waste per year). Tonnage of waste served by given wells may be estimated by calculating the total tonnage of waste serviced by a multiple-well layout. This tonnage is safely estimated as (Cubic meters of filled waste) x 0.8. This may be the tonnage within a

triangle of a triangular well layout. Alternatively, for purposes of calculating the total per-well flow, the tonnage served by each well can be estimated as this total tonnage divided by the number of gas wells.

(xii) Radius of Influence: The "radius of influence", is defined as the lateral boundary beyond which an extraction well's influence ends. The radius of influence is mentioned as a feature of some countries' (ie USA) regulations, but it is not precisely defined, or measurable. (The shortcomings and ambiguity of the radius of influence are well recognized and are further documented in EMCON, 1982, Methane Generation and Recovery from Landfills") The well spacings recommended above in any case remove the need for estimating radius of influence.

LANDFILL GAS COLLECTION SYSTEM

(i) Collection System Location and Layout: The collection system design and layout should be such that all sectors of the landfill containing organic wastes which therefore will be generating landfill gas, are served by the collection system wells. The well spacing recommendations have been given above. The collection pipe layout will simply be the most practical and economical layout that gives the required well spacing and arrangement. For example the piping network can resemble a tree with branches terminating at wells. A variety of other layouts are used including piping around the perimeter of the landfill with lines extending inward to wells or combinations of wells.

(ii) Minimum Allowable Diameter of Pipe in Gas Collection System: A calculation of the flow per well can be based on the amount of waste served per well, and the default landfill gas generation of 20 M^3/tonne year (0.04 litres/tonne/minute). The line diameter should be calculated by standard gas flow/pressure drop correlations to give a total pressure drop due to flow of landfill gas in the well network to the blower should be no more than 25 cm of water head (10 US inches water head, or 2500 Pa). For the calculations, landfill gas can be assumed with very little error, < 5%, to have flow properties (density and pressure drop in turbulent flow) of atmospheric air at 25C. The calculated maximum pressure drop may use the maximum default generation above for the waste.

(iii) Above-Versus Below-Ground Collection Systems: It is strongly advised that an above ground gas collection system piping be used. This is due to eventual breaks in the lines, which can occur often in gas collection systems. An above-ground collection system enables these breaks to be most readily identified, observed and repaired.

(iv) Collection System Depth: This may not apply. However in the event that auxiliary gas collection trenches (gravel-filled trenches which may contain

embedded piping) are used, the trenches should be located at mid-depth (midway between the landfill final surface and the landfill bottom). The trenches may be located as deep as 3/4 of the way down to the bottom of the landfill.

(v) Minimum Collection System Slope: All runs of the as-built gas collection system should have a slope of atleast 2% to allow condensate drainage to low points. All low points in the gas collection line must also be equipped with open diplegs (also defined as u-traps) to allow condensate drainage to low points to fill and exit the u-traps and re-enter the landfill.

(vi) Collection System Materials: Polyvinyl chloride pipe, suitably fabricated for landfill gas service, is recommended. High-density polyethylene (HDPE) is difficult to join and has a high coefficient of thermal expansion. Day/night temperature changes can be a source of HDPE pipe movement and other problems. Iron or steel pipes will be corroded (to ferrous carbonate, ferrous sulfide and other salts) by the carbonic acid, dissolved hydrogen sulfide, and organic acids in condensate. Stainless steel is normally prohibitively expensive.

(vii) Timing: Filling Sequence and Initiation of Gas collection. One possible option for filling that facilitates relatively efficient gas recovery is to use a sequence of filling "cells" of relatively modest area (under 5 Ha). A vertical well gas extraction system installation should be installed and begin operation with "tuning" (see below) as soon as cells reach final grade. An even more efficient collection approach is to combine vertical wells with collection from the leachate drainage layer. With proper design and gas sealing of the collection layer, landfill gas recovery can begin as soon as the waste covers the permeable leachate collection and gas collection layer. This collection may begin as soon as the waste reaches (for example) even 20% of design depth.

ACTIVE DESIGN LANDFILL GAS TREATMENT SYSTEM

(i) Piping: Polyvinyl chloride piping, extending to the blower is recommended as noted above.

(ii) Valves: It is recommended that all valves be manual, at least for the initial system. The reason for this is that adjustments take place slowly and are easily done manually. Adjustments will be relatively few (one adjustment per week or fewer for wellhead valves, for example) and the automation of valves is not expected to be cost-effective.

(iii) Plastic Valves vs. Other Materials: Plastic polyvinyl chloride (PVC) valves are commercially available. These are recommended for the same reason that PVC piping was recommended above.

(iv) Moisture (final condensate) Removal Before Blower: Prior to entering the blower station, any remaining condensate in the landfill gas must be trapped so that it does not enter the blower and damage it. By the time the gas reaches the blower station, the maximum likely amount of water in the gas is estimated at no more than 0.01 kg/M^3 (or, 0.01 liters liquid per cubic meter of gas). A condensate tank should be sized to hold at least a week's condensate based on this value. For example, if the gas recovery rate is expected (based on default criteria above) to be 2,000M^3/hour (say) then the condensate trap capacity should be atleast 2000M^3/hr x 0.01 x 168 hours/week or 3340+ liters. This condensate trap must be capable of easy draining, or equipped with a corrosion resistant pump that can pump the condensate back for re-injection into the leachate treatment facility. Condensate flow rates are expected such that small inexpensive tubing or inexpensive commercial hoses (costing ca. Rs.100/meter) should suffice for conveying condensate to treatment.

(v) Blower Size: There are uncertainties in the gas generation rate due to factors including waste inflow rate, weather factors, waste composition, and other variables. To be conservative in light of uncertainties, the blower should be sized to handle the highest default rate of landfill gas generation stated above. Blower housing and all parts contacting gas should be corrosion resistant. The blower should be capable of providing a total pressure drop (essentially the total vacuum) of at least 100 cm water gauge (10,000 Pa). The blower should be located just before the gas flare station (or energy use if this should be installed later).

(vi) Flame Arrestor: The flame arrestor should be of any standard type recommended for landfill gas service. Arrestors suitable for pipeline "natural" gas service will also be satisfactory. The arrestor size should be suitable for the maximum landfill gas flow calculated above.

(vii) Accessories: The inlet and exit lines from the blower should be equipped with temperature sensors. A high temperature shutoff is strongly recommended. This is incorporated in case gas flow to the compressor becomes completely or nearly completely blocked. In such a case, the compressor energy expended on the gas in the compressor can quickly elevate temperature to the point of severe damage unless there is such a high-temperature shutoff mechanism.

An inlet pressure sensor should also be included giving automatic blower shutoff if inlet pressure to the blower falls below a predetermined set point. This precludes the hazardous situation where a pipe break upstream of the blower leads to a combustible air/gas mix entering the blower station and flare.

An oxygen sensor, activating blower shutdown, is also recommended. This shuts down the blower if oxygen reaches as much as 5%, a level indicating a serious leak in the landfill gas piping system, which can lead to explosive gas mixes in the system, burn back in the landfill gas flare, etc.

(viii) Flare: For initial operation a shielded, candlestick flare is recommended. One significant uncertainty is posed by the fact that gas recovered and conveyed to the flare station, initially quite small on start of operations, may vary, increasing over time by an order or more of magnitude. Because the variation in capacity of flares is limited, it is recommended that the initial flare be small - about 10% of the calculated maximum default gas recovery capacity - and that a second flare of tenfold this capacity be installed in parallel. Gas flow should be enabled to either or both flares by manual valving. The flare(s) should be equipped with automatic igniter(s).

(ix) Instrumentation Control: It is recommended that the control of the system be manual during initial operation (first several years) and that personnel become experienced in all manual operations of the system.

(x) Electrical Equipment Supply: Electricity must be supplied according to manufacturers' requirements for each electrically powered equipment item (such as the blower, condensate pumps and any instrumentation). This electrical supply must be equipped with standard breakers, and other control switches as needed. It is essential that the electrical controls including switches along with other sensitive instruments and meters (for example temperature readout) be located in a shed or shelter which keeps equipment dry. The shelter should, however, be well ventilated to limit heat buildup.

(xi) Condensate Handling System and Air Compressors: The condensate system was described above, and need for an air compressor, at least as part of the landfill gas control/recovery system, is not anticipated.

OPERATIONS AND MAINTENANCE REQUIREMENTS FOR LANDFILL FACILITY

(i) Methane / CO_2 Content Monitoring: Gas composition monitoring will be essential. Monitoring may be carried out by either of two types of meters. The most accurate meters for field use are the handheld infrared (IR) based measuring units such as sold by Landtech or Mine Safety Appliances (in the United States). For well adjustment and monitoring purposes, thermal conductivity based meters such as sold by Gastech, California, USA are often satisfactory. These units cost less than the IR based units. The "Gastech" model, like the IR based instrument, can also

detect low levels of methane using a catalyst-based detector. Equivalents of these units are sold worldwide and either of these types of unit would be satisfactory.

(ii) Startup and Wellhead Gas Extraction Control: Once the gas system is installed, the individual gas wells must be adjusted ("tuned") to maximize methane recovery. Typical tuning involves gradually increasing extraction form wells over time, by gradually opening wellhead valves. This continues until falling wellhead methane levels indicate that air entrainment through the landfill surface, and into the collected gas, is significant. (Too much air entrainment limits gas extraction since it can alter methane generation rates unpredictably and undesirably, reduce gas usability for energy because of dilution, or even cause the landfill to catch fire, usually a disaster). If methane content falls too far, such as below 45%, the well is throttled. The lag time between adjustment and attainment of the final equilibrium composition is significant, and "overshoots" and "undershoots" are common enough, that tuning must continue until several interstitial void volumes of gas are extracted, or for several months.

(iii) Monitoring Wells/Probes: The monitoring wells are simply vertical or near-vertical sampling pipes inserted into the ground (described earlier). These allow methane content sampling through tubing extending from their lower terminus to the surface. The monitoring may be either by IR or thermal conductivity type meters, but the meters should be capable of detecting levels of methane down below 1% by volume to catch undesired methane migration. Monitoring wells can assure that offsite migration is not occurring. Monitoring checks may initially be frequent (weekly). If methane migration is absent, as demonstrated by absence of methane in the monitoring wells, the measurement frequency may be reduced to monthly, then even less often as deemed acceptable by landfill operators and/or their regulators.

(iv) Blower/Flare Station Components: Most major problems should be forestalled by the high temperature controlled and low-pressure controlled and oxygen content cutoff mechanisms. Generally, blower maintenance instructions should be followed carefully. The blower should be monitored initially at least twice as often as recommended for "known" (i.e. European and US) landfill gases for which blowers have been operated for many years and corrosion behavior is known.

(v) Gas Detection System Components: Several gas-monitoring components were mentioned above. One component that has not been mentioned is a flame ionization detector that is capable of monitoring the landfill surface to assure that the surface concentration does not exceed a set standard (assumed above to be 500 PPM). While sensors are sold specifically to

detect the low levels of landfill methane according to the 500 PPM criterion, instruments used to check natural gas (pipeline methane, and also propane/butane) can serve this function. Units used for propane or butane need to be calibrated with methane standards.

The surface leak detection can be carried out at intervals typical of other jurisdictions (European Union, USA) - Monthly early on, quarterly if the landfill section in question is compliant (<500 PPM) after one year, and semiannually thereafter.

Leak detection and sealing: Elevated oxygen in the collected gas usually indicates a leak in the collection pipe. When oxygen concentrations over about 1% are observed, the leak is traced back by checking the pipes through which higher oxygen content is detected.

(vi) Condensate Blockage Elimination: Sudden falloffs in gas recovery at the flare station, or gurgling noises in gas lines may indicate condensate blockages. These often occur when gas lines have settled to create low points that have no drainage. When this occurs, either condensate drains must be installed, or else (often more conveniently) the line must be restored to a slope suitable for draining by traps and drains.

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