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Global Energy Partners LLC
AN EPRI, GRI, DMJM COMPANY

METHANE RECOVERY AND RE-USE POTENTIAL IN INDIAN CITIES

TRAINING NEEDS ASSESSMENT REPORT

—Final Report—

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EXECUTIVE SUMMARY

ES.1 Project Background

Global Energy Partners (Global) was assigned by Louis Berger (LBG) to conduct a methane recovery and re-use assessment as part of Berger's CLIN 8 activities under the GEP project for USAID. This assessment identified the current characteristics of municipal solid waste management in India by way of extensive data review and site visits to representative cities in India. Cities were selected using a set of data characteristics that best represented the current and future conditions that would make methane recovery and re-use a practical option for Indian cities to consider in combating the greenhouse gas and global warming problems brought about by methane emissions. Other considerations in city selection related to the level of interest cities have expressed to USAID in connection with its various urban infrastructure and greenhouse gas emission reduction initiatives. Based on these factors, the following five cities were included in the assessment:[1]

- Pune
- Chennai
- Bangalore
- Guntur
- Jaipur

Once the cities were selected, a delegation from the GEP project (USAID, LBG and a methane expert from Global) traveled to each of the five cities to conduct a training needs assessment (TNA) that included data collection, interviews and assessments of methane recovery and re-use potential. The information gathered as part of this effort contributed toward the development of a detailed training plan that provides the framework for appropriate next steps and the tools and techniques necessary for the respective municipalities to move forward on potential implementation.

ES.2 Solid Waste Management in India

According to a report prepared by the Indian Central Pollution Control Board in Delhi (2000), "Management of Municipal Solid Waste," annually over 48 million tons of municipal solid waste is generated in India. It is also estimated that the current urban municipal solid waste generation is about 0.49 kilogram per capita per day. This is two to three times more than the waste generation rate in the rural areas. In year 2025 the urban municipal solid waste generation will reach 0.70 kilogram per capita per day.

In 1997 the urban population of India was estimated to be 247 million. The country's annual overall population increases by about 2 percent. The estimated urban population increase is more than 3.5 percent per year. This has resulted in yearly increase of solid waste of 5 percent.

There are about 20,200 hectares of land used as disposal areas for municipal solid waste. Annually methane emission from these disposal sites is estimated to be around 7×10^5 tons CH_4. India is among some of the lowest paper consuming countries, but as the urban population increases, paper consumption and packing waste will also increase and the estimated emissions from these disposal sites will increase. Waste management practices must be modernized to address these changes in handling and control of future increase in landfill gas emissions.

[1] Note that seven cities were originally scheduled for site visits during the TNA mission however due to the catastrophic earthquake in the Gujarat state and logistical problems during the mission, it was not possible to conduct visits at Baroda and Noida.

ES.3 Key Issues Concerning Solid Waste Management in India

Several critical issues related to solid waste management in India are noted:

- *Insufficient Funding Mechanisms:* Fees for local solid waste collection, transportation, treatment, and disposal range from Rs. 500 to Rs. 1,500 per ton. About 60 to 70 percent of this is spent on collection labor and 20 to 30 percent on transportation. Only 5 percent of the funds are spent on disposal of waste. With this funding scheme, monies for improvements to the waste disposal processes are not nearly sufficient.
- *Funds are Difficult to Access:* Revenues derived from fees are typically deposited in the general revenue accounts which make it difficult to determine the income and expenditure that is directly related to solid waste management activities.
- *Potential Agency Overlap:* There is no single agency responsible for solid waste management in India. There are multiple ministries for different aspects of solid waste management in India which is a challenge in coordinating and aligning the efforts of the various ministries and research institutes.
- *Waste Composition:* Due to the nature of the waste that disposed into Indian landfills, the composition of organic waste does not lend well to high yield/high quality methane gas necessary for cost-effective recovery and re-use.
- *Poor Disposal Methods:* Waste appears to be dumped anywhere that is available, without consideration to potential land use conflicts, groundwater contamination, and health hazards. Due to rapid urbanization, fill sites are often located in close proximity to residential and business districts. Transportation of the waste is accomplished using trucks that are outdated and unreliable.
- *Insufficient Landfill Planning:* Landfills in India are not designed in a manner that is conducive for ultimate recovery of methane gas. Little if any emphasis is given to long-range planning that might ultimately bring about cost-effective recovery and re-use.

ES.4 Summary of TNA Mission Findings

A summary of the key findings from the February 2001 TNA mission are provided below for each of the five cities visited. More detailed findings will be found in Annexes A-E of this report.

PUNE (Annex A):

- Total tons disposed per day of 800 (150 aerobic composting by CICON, 650 anaerobic composting)
- Population of 2.2 million
- NGO collecting waste in some areas
- Transfer stations
- Site adjacent to residential areas
- Anaerobic composting for methane and aerobic composting contracted
- Methane recovery planned

CHENNAI (Annex B):

- Total tons disposed per day of 3,000 (600 gasification by EDL, 400 aerobic composting, 2000 dumping)
- Population 4.75 million
- Some waste transported by private sector

- Disposal site in marshy areas
- Site adjacent to residential areas
- Tonnage measured by weight bridge on site
- Gasification project awarded and sanitary landfill construction project in bidding process

BANGALORE (Annex C):

- Total tons disposed per day of 2,200 (900 aerobic composting by KCDC, 240 aerobic composting by Sunrays, 1,000 dumped)
- Population 4.13 million
- Informal support by municipal corp. to rag pickers
- Existing compost plant near one dump site
- Private sector transport about 52% of waste generated
- Tonnage measured at the composting site (KCDC)

GUNTUR (Annex D):

- Total tons disposed per day of 350 (280 pelletization by SESL, 70 dumped)
- Population 0.75 million
- Waste transportation partially privatized
- Waste disposal site is adjacent to residential area
- Bulk density (0.4-0.6 MT/Cu. M.) reported
- Pelletization and gasification contracts awarded

JAIPUR (Annex E):

- Total tons disposed per day of 1,000 (600 gasification by EDL, 400 dumped)
- Planned awareness campaign
- Sandy silt on-site soil
- Waste disposal site at storm watershed
- Medical waste is disposed with municipal solid waste
- Gasification project awarded

ES.5 Recommended Training Action Plan

Based on the review of each site and analysis of the available information, a seven-topic training program is recommended, and it shall be administered over a two-day period. The seven topics include:

- Solid waste management overview
- Physical and chemical characteristics of municipal solid waste (MSW)
- MSW transformation technologies
- Significance of methane from MSW
- Technology options for methane recovery and re-use
- Operational issues
- Landfill methane project development

The training program will combine classroom lectures, video clips of various projects and technical topics, and class exercises. The aim of the program will be to train participants on the most important aspects of methane recovery and re-use projects, both from a technical and implementation point of view.

1.0 INTRODUCTION

1.1 Study Objectives

Methane is currently the second most important greenhouse gas in the atmosphere, with emissions expected to reach those from carbon dioxide by 2025. After remaining constant in the atmosphere during the past 10,000 years, the concentration of methane has doubled during the last century. This has accelerated during the last two decades when atmospheric concentrations have been increasing at the annual rate of 0.9% per year. Although methane gas has a shorter lifespan in the environment, it has a greater heat-trapping characteristic than carbon. The current estimate of methane emissions in the atmosphere is 575 million tons, of which 75% is anthropogenic. The primary natural sources of methane are wetlands, oceans and freshwater; anthropogenic sources include coal mining, biomass burning, landfill of organic wastes, incomplete combustion of fossil fuels, enteric fermentation in domestic animals, and rice cultivation.

The increasing urban dumpsites in India have been a growing source of uncontrolled methane emissions. However, there is no current procedure to evaluate the impact of methane emissions from urban locations, or the more important aspect of capturing and utilizing this valuable energy resource. The control of methane emissions and re-use potential is essentially urban solid waste management. Solid waste management is a major problem for the heavily urbanized Indian cities wherein growth rate of solid waste is much greater than the availability of landfills and the associated management of landfills.

The purpose of this study is to provide a framework by which Indian cities can begin the process of implementing solid waste management practices that ultimately control and minimize the alarming volume of methane emissions. At the same time, based on practices in other countries, this study identifies ways in which that methane gas can be recovered and re-used for energy production, thus potentially helping to solve another major infrastructure issue in India—chronic power shortages.

The objectives of the project are two fold:

- To develop a comprehensive Screening/Selection criteria to identify 5 viable Indian municipalities as sites for the development of an outreach strategy and training program targeting methane recovery and re-use.
- To assess, design and develop a comprehensive training plan to train municipal authorities on the proper tools and techniques to assess their methane emissions and technology options for re-use potential during the entire cycle of waste management.

1.2 Overview of Landfill Gas Recovery and Re-Use

To provide the overall context for this assessment, it is necessary to first review the basic principles behind landfill gas recovery and re-use. The sections below provide a very general overview of the recovery and re-use process—the benefits, the gas extraction and collection, technologies employed, economic issues, and the typical criteria employed when evaluating projects.

1.2.1 Benefits of Landfill Gas Recovery and Re-use

Recovery and energy use of landfill gas has many important global and local environmental benefits as well as energy and economic benefits. Landfill gas-to-energy reduces methane emissions, and VOC emissions, as well as displacing other pollutants associated with fossil fuel use. Landfill gas when vented or flared is a wasted low-cost energy supply that can reduce dependence on fossil fuels. Some of the benefits are discussed below:

- *Energy Benefits*- Landfill gas is a renewable energy source that can be used as a constant source of energy. Since organic waste is continuously being produced and decomposing waste produces landfill gas, then landfill gas-to-energy recovery projects are a constant source of energy. With the population increase in India and the high organic content of waste this would be a great renewable resource for production of electricity.
- *Economic Benefits*-This low cost source of renewable energy will create jobs related to the design, construction, and operation and maintenance of theses facilities
- *Environmental Benefits*- one ton of methane emitted into the atmosphere is 24.5 times more damaging in its "greenhouse potency" to the atmosphere than a ton of carbon dioxide. Methane's potency and its rapid cycling through the atmosphere contribute greatly to the global warming problem, and, also now, to stratosphere ozone depletion. Another benefit is the reduction in VOC emissions and odor of the landfills. Generating electricity from fossil fuels such as coal and oil also increase the sulfur dioxide emission, which is a major contributor to acid rain. In contrast, using landfill gas will displace the use of fossil fuel and reduce these sources of air pollution and adverse climate effects.
- *Political and Social Image Benefits*- One of the benefits of using landfill gas-to-energy is the improvement of any municipality's image by turning a current liability into an asset. This could not only provide a low-cost source of renewable power for the community but also mitigate global warming. Landfill gas, even in low concentrations is explosive and can result in fires and explosions damaging to humans and property. The beneficial use of this landfill gas will be protective and reduce the risk of landfill gas explosions. Landfill gas-to-energy when operated properly virtually eliminate the risk of injury and property damage by collecting and combusting landfill gas before it can accumulate to dangerous concentration levels in spaces within or adjacent to the landfill.
- *Attraction of New Industries*- municipalities can attract new industry to the area by providing a low cost source of fuel. Industries that can use large quantities of medium Btu gas may want to locate a plan near the landfill since this could be a cheap source of energy.
- *Landfill Owner and Operators*- Landfill owners and operators are being mandated to control and destroy landfill gas. Revenues from a landfill gas project can offset the cost of landfill gas collection and control system that are mandated by law. In many cases the projects could even generate profit as world energy costs continue to rise.

1.2.2 Landfill Gas Generation

When organic waste decomposes through a natural process, it is transformed by the action of microorganisms into simpler organic gasses . This landfill gas is produced through an anaerobic (without oxygen) decomposition process. Typically, byproduct gases are made of about 45 percent carbon dioxide, 50 percent methane, and 5 percent of other gases including mainly nitrogen (from entrained air), and small amounts of hydrogen sulfide and volatile organic compounds. Methane is the primary constituent of natural gas and therefore can be used as a fuel. The amount of gas generated and (to a slight extent) the quality of methane produced are dependent upon the quality and type of waste-in-place, climate, and other site-specific factors.

The production of landfill gas normally begins from six months to a year after waste is placed in a landfill. Depending on the site conditions and climatic factors, landfill gas generation may continue at a significant rate for many years after landfill closure. This holds for most landfills as now operated. However technology to improve the situation by accelerating, controlling and more rapidly completing generation is being successfully demonstrated with very promising results.

Methane is combustible in concentrations between 5 to 15 percent by volume in air. Methane is flammable at atmospheric pressure and ambient temperature. Methane can migrate through the soil to significant distances. Landfill gas can migrate through sand, silt or clay soil as long as there are continuous voids. The rate of gas movement is dependent upon density and permeability of the soil as well as driving pressure.

1.2.3 Landfill Gas Collection

Landfill gas collection systems are necessary because landfill gas has the potential to cause property damage, death and injury as a result of explosions and landfill gas fires. Landfill gas can be collected using either horizontal trenches, permeable layers beneath an impermeable liner or vertical wells drilled into the landfill at selected points. Well spacing depends on site-specific variables, but it typically lies between 100 to 300 feet spacing between wells. The horizontal trenches and vertical wells are connected by piping to a central point where a motor/blower is used to provide vacuum for removal of the landfill gas. In an effectively designed and constructed system, methane recovery efficiency could be as high as 85 percent without impermeable final cap and as high as 95 percent when a impermeable liners are used.

1.2.4 Technologies for Landfill Gas Utilization

Landfill gas can be collected and used as an energy source for various applications. These include: direct use of medium-Btu gas for industrial boilers-burners, co-generation (heat and electricity), on-site space heating and or hot water heating, lighting, industrial processes. Process landfill gas can also be used to fuel vehicles. Methane is either consumed or converted to a non-greenhouse gas that reduces emissions to the atmosphere. In addition, using landfill gas to produce electricity will reduce use of fossil fuel, which also reduced carbon dioxide emissions.

If raw landfill gas is used for space heating or hot water heating, only condensate water and particulate matter removal, and sometimes keeping the gas relative humidity somewhat below 100% is necessary. Such uses do not require highly elaborate and expensive processing and are well suited to many smaller landfills across India. Pipeline quality gas can also be used for any application where natural gas is normally used. In this option, moisture and particulate removal is necessary in addition to removal of carbon dioxide. Off-the-shelf technologies are available for such applications but these requires large capital expenditure.

Electrical power generation projects in United States has been extensively demonstrated to be reliable and economically viable method of landfill gas utilization. Over 70 percent of the US landfill gas utilization projects generate electricity. Over 60 percent of the landfill gas to electricity facilities use reciprocating engines. About 24 percent of landfill gas utilization projects sell medium-Btu gas to direct user, while 4 percent upgrade their gas pipeline quality (close to 1,000 Btu).

Electricity Generation: Landfills that can generate landfill gas at more than 1 million cubic feet per day can utilize the gas to generate electricity in a cost-effective manner (presuming recent

enormous wholesale electricity price escalations in the US electrical grid). There are several proven technologies that are available for generating electricity from landfill gas namely:

- Reciprocating Internal Combustion Engines (IC)- typically ranging from 250 kW to 1 MW in size. More than one engine could be installed. These have the advantages that their manufacturers, sales and maintenance is available worldwide, and they are very efficient relative to other (present) options.
- Gas Turbines- higher capital cost than IC engines per kilowatt of installed capacity, but at larger landfills they have lower cost of electricity. Landfill gas volumes of more than 2 million cubic feet per day are required for this to be economically feasible. They also have lower NO_x emissions than IC engines since large quantity of air is used. They are less efficient, giving about two-thirds the power per unit of landfill gas burned but better adjustment to fluctuations in heat values of the landfill gas.
- Rankine Cycle (Steam) Turbines- used where gas flow rates are very high. Reasnablly high thermal to electrical efficiencies can be achieved with lowest pollutant emissions of any present technology. These need sufficient landfill gas for 10 to 20 MW of power.

Gas Delivery System- Landfill gas can be processed and sold as gaseous fuel through dedicated pipes or to connect to natural gas pipelines. There are two types of fuels:

- Sale as a Medium-Btu Fuel-When a utility power or an industrial user is located within an economic distance, situation-specific but of the order of a few miles of a landfill, a variety of commercial applications, such as firing boilers and space heating can be fueled via dedicated pipelines. A guide is that the user should usually be within 5 miles of the landfill and has constant demand for gas. Projects can be feasible at small landfills. Economies of scale increase with size.
- Sale as a High-Btu Fuel-Landfill gas must be upgraded to pipeline quality, which is generally very high in cost. The process involves removal of water, carbon dioxide, hydrogen sulfide, hydrocarbons, and on some cases nitrogen. A natural gas pipeline must be located fairly close (one to a few miles) to the site. Other options such as fuel cells, compressed natural gas (CNG), liquid natural gas (LNG) are promising emerging technologies that have recently been in successful demonstration phase.

1.2.5 Economics of Landfill Gas to Electricity Project

Table 1 shows representative cost data for a range of landfill project sizes. The cost data were derived from statistical analyses of existing projects (U.S.EPA 1993) in United States (U.S.). Gas generation potential for each ton of waste in India is different than in the United States since India's waste characteristics are much different than those in the United States. India's waste has less than 5 percent paper compared to U.S. waste, which is about 25 percent paper. Therefore, waste in the U.S. produces more methane than waste in India. Other factors should also be considered such as collection efficiency and moisture content of the waste and the average annual rainfall. Detail analysis and site specific investigation should be performed at each site to determine the maximum gas flow since the composition of waste and climate in India is much different than in U.S. This exhibit is provided only as a tool to demonstrate the relative costs for each possible case. Project analysis should use engineering cost estimates based on the individual site characteristics and project configuration and consider possible factors that are discussed next.

Care must be taken when reviewing projections such as those in Table 1, to realistically take into account several issues. Landfill gas yield and recovery predictions have been refined recently, with original EPA gas availability projections for US waste somewhat lowered. A recent 19-

landfill study (Vogt, W.G. and D. Augenstein, 1997, *Comparison of Models for Predicting Landfill Gas Recovery SWANA, Silver Spring, MD*) has shown a best US fit with maximum recovery rates as much as 30% lower than recoveries assumed in Exhibit A. Also, there is landfill-to-landfill recovery variation, moderate irregularity and unpredictability in recovery, and long-term trailing off of recovery. These result in problems of part-load operation of energy equipment as they are encountered. (Nonetheless, there are promising improvements under investigation to address all these issues.) Also, rather limited studies in third world countries suggest that because of lower paper content, ragpicking and the like, that developing countries' waste methane yield may be on the order of half that of the US. The present situation, nonetheless, still leaves very considerable opportunity for successful projects and a significant landfill gas contribution (e.g., of the order of 1% of US and world electrical supplies. See for example Eam-o-Pas, K., Wetherill, T., Panpradist, B. 2000 *Landfill Gas Generation and Recovery in Thailand.* Proceedings, Second International Methane Mitigation Conference, Akademgorodok, Novosibirsk, Siberia, Russia, co-sponsored by Russian Academy of Sciences [hosting], US EPA, US DOE, Canada Natural Resources, International Energy Agency, Chinese [PRC] Academy of Sciences with several other agencies).

The cost of a landfill gas recovery system includes the capital cost of gas collection system which includes the vertical or horizontal gas collection system, the well header system, the gas blower or gas compressor, and the condensate handling system. In addition to the annual operation and maintenance (O & M) costs, a stand-by flare may be required. The capital cost for the utilization system will depend on the particular option. For a typical electrical generation system, it would include the installed cost of an on-site engine generator, engine controls, gas-processing equipment, and electrical grid interconnection equipment. For the option of direct use of gas the major capital cost will be the construction of a gas pipeline from the landfill to the user, additional compressors, and any required gas processing equipment or end-user equipment modification. The annual O & M costs include direct cost, labor costs, and indirect costs including insurance, overhead, and administration.

TABLE 1:
Representative Landfill Energy Recovery System

Landfill Size	Max. Gas Flow[a]	Engine Cap.[b]	Collection System ('000 US$)		Flare System ('000 US$)		Generator System ('000 US$)		Total ('000 US$)	
(10^6 metric tons)	(m^3/ min)	(MW)	Capital	Annual O & M	Capital	Annual O & M	Capital[c]	Annual O & M	Capital	Annual O & M
0.25	1.6	0.3	155	55	68	4	360	34	583	93
0.5	3.2	0.6	269	60	72	4	720	67	1,061	131
1	6.3	1.1	468	68	79	4	1,320	123	1,867	195
5	29.4	5.2	1,698	117	130	7	6,240	581	8,068	705
10	51.8	9.1	2,956	167	180	10	10,920	1,016	14,056	1,193
20	96.6	17.1	5,146	255	280	15	20,520	1,910	25,946	2,180

[a]estimated using a statistical model based on existing landfills that recover methane, assuming a collection efficiency of 85 percent.
[b]Engineer capacity must be sufficient to utilize the estimated peak sustainable gas flow.
[c]Assuming engine generator cost US$1,200,000 per MW of installed capacity.
[d]Assuming engine generator O & M rate of US$0.015 per kWh.

Source: Reproduced from "Opportunities to Reduce Anthropogenic Methane Emissions in the United States", Report to Congress, October 1993.

1.2.6 Typical Screening Criteria for Evaluating Projects

The following criteria have been developed for evaluation and selection of a site with future landfill gas recovery and re-use potential:

a) Site with at least 1,000,000 tons of waste-in-place, to make landfill gas recovery project economical.
b) The site receives more than 100,000 tons of waste annually, all waste must be available for anaerobic composting and landfill gas recovery.
c) The waste has high organic content (more than 50 percent) by weight and moisture content of 25-50 percent by weight.
d) There is a water source available on site.
e) There is sufficient land available to continue landfilling for the next 10 to 20 years within the existing site
f) Site is located at least one to two kilometers away from a residential area and the site is fenced to protect the facility from trespassers.
g) There is either sufficient low permeability clay cover soil on the existing waste or if not covered, there is enough low permeability clay soil available on site to cover waste to allow landfill gas recovery and prevent oxygen intrusion in waste.
h) Recovery tests confirm adequate gas availability and methane content both when the landfill is modeled, and a gas recovery system is installed.
i) There is at least 3-5 meters separation from the bottom of the landfill and the highest groundwater.
j) Landfill is located at a suitable site for construction of a sanitary landfill.
k) There are personnel available to be trained in the maintenance, monitoring, and adjustment of landfill gas wells in the field.

l) The site is near a facility that could use landfill gas or is close to a high voltage grid for electric line interconnection.
m) There is sufficient funding or the ability of the municipality to manage large capital infrastructure projects.

1.3 Project Steps

The following activities have been undertaken to support this assignment:

- *Phase I—Development of a Municipality Screening/Selection Criteria:* In November 2000 when Global was assigned the task by LBG, a list of selection criteria was drafted and then subsequently discussed with USAID and LBG staff and partners. The list was based on a review of current USAID Regional Urban Development Office (RUDO) documents, combined with the project team's experience in municipal solid waste issues and Global's international experience in this area.
- *Phase II—Present Case Study at USAID/RUDO Conference:* One (1) Global technical expert traveled to India during December 5-10, 2000 to present at the USAID/RUDO conference "Cities and Climate Change," in Hyderabad, India. The presentation shall was entitled "International Experience-Case Study of Landfill Methane Utilization." A copy of the presentation is included in Annex F. At that time, the Global expert networked with authorities from various Indian cities to gauge their interest level in participating in future training sessions related to municipal solid waste management and methane recovery techniques. Finally, a grouping of five cities was recommended based on the information received and the feedback obtained during the mission.
- *Phase III—Conduct a Training Needs Assessment:* A methane expert from Global traveled to India in early February (February 12-21, 2001) to participate in a training needs assessment. Under the organization of USAID/RUDO, the LBG team traveled to five Indian municipalities to meet with officials and gain a better understanding of their current solid waste management programs.
- *Phase IV—Develop a Detailed Training Plan:* This plan, contained in Chapter 5 of this report, provides the framework of appropriate next steps and the tools and techniques necessary for the respective municipalities to move forward.

2.0 CURRENT KNOWLEDGE OF METHANE RECOVERY AND RE-USE

2.1 Overview of Current Solid Waste Practices in India

In India, the urban and local government authorities (similar to county and urban government authorities in U.S.) are generally responsible for solid waste management systems. In some urban and local districts, similar to the US, private organizations are involved in collection, recycling, processing and disposal of solid waste. Unlike the US, in India, as reported by the Central Public Health and Environmental Engineering Organization Manual (2000), about 30 to 50 percent of the total municipal staff are involved in solid waste management. Funds spent for local solid waste collection, transportation, treatment, and disposal range from Rs. 500 to Rs. 1,500 per ton. About 60 to 70 percent of this amount is spent on collection labor and 20 to 30 percent on transportation. Only 5 percent of the funds are spent on disposal of waste.

The funds generated from the solid waste management activities are normally deposited in the general revenue accounts. This makes it difficult to determine the income and expenditure that is directly related to solid waste management activities. This also makes it difficult for the decision-makers to know the actual operating, capital costs, project revenues, and establish appropriate collection and disposal fees. Similar to the systems in the US, there should be a full cost accounting system. This setup could incorporate a separate fund, such as an enterprise fund, separately tracking waste-related income and costs.

In the US, typically, the solid waste received at the landfill site is already segregated or will be segregated into hazardous, non-hazardous and bulk waste. The non hazardous waste is further segregated into paper, plastic, metal, etc. In India, most of the valuable materials for recycling, such as paper, plastic, rags, etc. is already handpicked. Only the remaining material, primarily food waste mixed with dirt reaches the disposal site. The method of disposal is simply dumping of waste on land without any type of lining system to protect the groundwater from leachate or any landfill gas control system to control air pollution. Almost all sites are left uncovered and at some sites waste is burned by the local rag pickers for reclamation of metals from the disposal site. Minimal attention is given to the health and safety of the staff working at the landfill site or the residents living in slum communities adjacent to the landfill. Rapid urbanization has also made it difficult for many of the local bodies to secure proper disposal sites for waste disposal. Therefore, waste is often disposed within close proximately of the collection points within the urban area.

Inadequate planning and inefficient equipment for waste collection and transport have limited house-to-house waste collection in India. Collection of waste from slums, narrow lanes and high traffic areas is also a problem. Much of the collection and loading of the waste is done manually. In many low-income areas waste is not even collected. A study by National Institute of Urban Affairs reports that most cities face issues of labor health impact and labor union agitation. It is estimated that the collection efficiency could range anywhere between 25 to 90 percent of the solid waste generated depending on the location. The balance of this waste is unattended and dumped in many different locations. Indian municipal authorities with the assistance of USAID/RUDO are developing new systems and methods to improve the collection and disposal of solid waste. With this assistance in place, it is expected that the solid waste management practices will improve substantially over time.

The transportation of waste to the disposal site is done using outdated trucks, tractors, tippers ad refuse collectors. Poor maintenance, continuous breakdown of vehicles and inadequate fleet size prevent proper and timely collection of waste. Transportation modes used in the smaller cities

include bullock carts, three wheelers and tractors. In some cities front-end loaders are also used for waste collection.

Proper collection and disposal of sanitary waste is the most critical aspect of solid waste management among all cities. The Central Pollution Control Board in Delhi reports that 94 percent of cities dump domestic, commercial, industrial and medical waste in low-lying areas, which leads to ground and surface water contamination by leachate and uncontrolled landfill gas. Air pollution due to burning of open dumps is also common among cities. Presence of actinomycetes/fungi and other microbes in air samples from the landfill sites have also been documented. The Central Pollution Control Board in Delhi has identified 14 towns and cities where closure of the existing open disposal sites is a priority in India. These sites are at Hyderabad, Ahmedabad, Surat, Bangalore, Mumbai, Pune, Bhopal, Jaipur, Chennai, Kampur, Luknow, Agra, Calcutta and Delhi. Currently there is a USAID study under way to determine the degree of water and air pollution at each site.

In January 1998, under the direction of the Supreme Court of India a committee was formed to review the solid waste management condition in cities in India. In September 1999, the Ministry of Environment and Forests issued draft rules for municipal wastes management and handling. In September 2000, the final rule was adopted that lays out procedures for waste collection, transportation, segregation, storage, processing and disposal. Under this rule all cities are mandated to set up suitable waste treatment and disposal facilities by December 31, 2001 or earlier. The rules also specify standards for compost quality, leachate control, and management and closure of landfill sites.

In accordance with Supreme Court directions, the Ministry of Urban Development (Government of India) is to set up a Technology Advisory Group for improving solid waste management in the country. This advisory group is expected to assist the improvement of solid waste management practices over a period of next five years.

In the US, the Environmental Protection Agency (EPA) is responsible for regulating solid waste management practices. There is no single agency responsible for solid waste management in India. There are multiple ministries that are responsible for different aspects of solid waste management. This fragmentation of authority partially hinders implementation and poses a challenge to local authorities in coordinating and aligning the efforts of the various ministries and research institutes.

Some cities have begun to explore a variety of resource recovery techniques such as composting, vermi-composting; waste-to-energy projects that include incineration, pelletization, bio-methanation, and recycling. Some examples include a methane generation facility in Pune and an incineration plant at Timarpur (Delhi), which was set up in 1987 using Danish technology. It did not and could not operate because the waste used had too low a calorific value for the technologies and quantities of waste supply were inadequate. The facility at Timarpur is currently owned by MNES and is managed by DESU. Some governmental agencies have opposed revival of this incineration of waste to energy because of environmental hazards. In May 2000 tenders were invited but no bids were submitted. Since no bids were received and the facility is almost 14 years old the ministry is now considering the option of dismantling and selling the facility.

Recently work is underway for setting up a plant for generation of approximately 5.4 MW of power through landfill gas-to electricity in Nagpur (Maharashtra). Project developers are CICON and ENBEE Infrastructure Ltd. They have entered into a separate Power Purchase Agreement with Madhya Pradesh Paper Ltd. and Nav Bharat Papers Ltd. The city of Nagpur will provide 10

acres of land on a lease basis and guarantee supply of 520 TPD of raw material to the plant. This would be the first such facility in the country. The project is being executed on Build, Operate and Own (BOO) basis. The initial agreement will be for a period of 30 years and can be extended for an additional 30 years.

Very few cities in India are familiar with landfill gas to energy projects and their cost-effectiveness compared to other available technologies. The urban authorities do not have the technical knowledge and resources available to evaluate the feasibility of these technologies for their waste stream and for heir site conditions. Clean waste-to-energy projects are proposed by the private sector without adequate justification of the cost effectiveness or demonstration of their success given the characteristics of Indian waste. The Ministry of Non-Conventional Energy Sources has recognized the importance of energy recovery from waste as a renewable energy resource.

Considering these factors, we nevertheless estimate the potential benefit from methane recovery projects to be about 1000 MW of power from urban and municipal waste and about 700 MW from industrial wastes in India. The time required to realize this potential is highly uncertain. However, with reasonable assumptions, we estimate that this potential could be reached in 10-20 years given the large issues that face municipal authorities in terms of waste management infrastructure development.

2.2 Institutional Mechanisms in India to Facilitate Future Potential

The primary ministries and organizations capable of assisting the development of the energy and environmental projects discussed above are:

- Ministry of Environment and Forests (MOEF)
- Ministry of Non-Conventional Energy
- Ministry of Urban Affairs
- Ministry of Finance
- World Bank and its affiliates (such as Global Environment Facility)
- US Agency for International Development (USAID)

These organizations will be key in the development of regulations, tax incentives, infrastructure development and initial technical and financial support for the development of these projects. With respect to potential methane recovery and re-use operations, each organization has a particular role to play in the development process. MOEF is instrumental in setting and enforcing environmental regulations related to waste handling and landfill disposal practices. The Ministry of Non-Conventional Energy oversees the disposition of the non-conventional methane gas energy resource. The Ministry of Urban Affairs oversees the practices related to waste collection, management, recycling initiatives, and land-use planning. The Ministry of Finance would oversee any project-related development activities that involved public finance. The World Bank and its affiliates play a role as catalyst to spur the resource development. Finally, USAID plays a key role in technical transfer and assistance to enable more favorable development of the resource and the minimization of greenhouse gases.

Local authorities from urban areas have clearly expressed their interest and need. Without proper political and financial support from the above organizations, enthusiasm and eagerness of local authorities to incorporate new technologies will fade.

2.3 Current Barriers/Gaps

Several barriers/gaps to implement methane recovery projects at solid waste landfill sites have been discussed in earlier sections. The major barrier is the lack of a single coordinating and implementation agency in India, similar to the US-EPA. Current organizations under MOEF, CPCB and MOU are developing an ambitious set of regulations. However, the implementation and coordination of these regulations have become a major problem. To overcome this problem, in addition to technical, financial and infrastructure support, political will and support from federal and state ministries are needed.

The first and foremost action needed is in the area of collection, segregation and transportation of solid waste. USAID, CPCB and MOU are working in this area. Next is an integrated planning of storage, processing and disposal at selected landfill sites. With USAID, CPCB, MNES and MOU's assistance an economical and environmentally beneficial demonstration project has to be developed. The major barrier at the current stage is to develop funds and organization for a responsible agency or task force to implement a technology demonstration project.

Technical and economical gaps are associated with the quality of the waste and the site selected. Although, these may pose significant barriers to the development of this technology, they can be overcome or minimized in most of the cases with further development.

3.0 TNA SELECTION PROCESS

3.1 Selection and Data Collection Criteria

When considering a methane recovery and re-use operation there are several factors that must be taken into account as outlined below. While it is not expected that all of these questions can be answered a priori, these are the important characteristics that must go into siting a methane recovery and re-use operation. Prior to the TNA mission, a detailed questionnaire was developed highlighting many of these points. The questionnaire was sent to several of the municipalities that attended the Hyderabad conference (December 2000).

1. Geographic Characteristics: Perhaps the most important attribute considered for the landfill is the physical geography at the site. A variety of factors influence cost-effective methane recovery and re-use operations. Several of these factors are noted below.
   a. Topography: Flat areas require excavation to properly construct structure while a canyon is ideal with minimal excavation.
   b. Soil type: The ideal is clay at the top and silt lower down with clay at the bottom; other soil types require more site preparation such as plastic liners, etc.
   c. Depth of groundwater: Ideally a minimum depth of 10 meters between the lowest level of the landfill and the groundwater is needed to minimize problems related to fluid leakage and gas loss.
   d. Potability of groundwater: If nearby well water is used for residential and agricultural consumption and if location of landfill is nearby then lining of landfill is very critical.
   e. Amount of rainfall: Arid locations require a water source to add to landfill while wet areas require more control systems for liquid containment and recovery.
      - Maximum and average summer daily rainfall
      - Maximum and average winter daily rainfall
   f. Average annual temperature: Extreme temperatures will influence the productivity of the methane gas.
      - Maximum and average summer daily temperature
      - Maximum and average winter daily temperature

2. Landfill Characteristics: It is our understanding that in India landfills are largely open dumps overflowing with waste, with no proper methods for waste segregation and final disposal. This fact influences the feasibility and timing of a methane recovery and re-use operation. Data needed include:
   a. Volume of waste: The higher the volume the better due to scale economies.
      - Daily waste flow (Tons/day)
      - Annual waste generated (Tons)
   b. Composition of waste flow: The percentage of organic material that is flowing in will have a significant bearing on the cost feasibility and cost-effectiveness of the project.
   c. Fill characteristics: Is the waste filled into separate and independent modules and if so what are the sizes.
   d. Landfill practices: How is the waste currently managed once it arrives at the site
      - Is it buried or capped?
      - Is the waste compacted and if so what type of compacting equipment is used?
   e. Physical dimensions of the existing landfill:
      - Total area (footprint) of waste now landfilled
      - Height of landfill
      - Depth of waste
      - Topography of landfill

f. Age of waste (date of opening, fill history and other pertinent documentation)
c. Stability of waste (stream flow and contamination)
d. Moisture content of the waste
e. Type of waste and percentage by weight
f. Potential methane gas volume and efficiency
g. Chemical characteristics of leachate (pH, alkalinity, nutrients, etc.), if present
h. Other competing methods of waste management and methane recovery
   - Anaerobic digestion and fertilizer re-use
   - Presence of ragpickers

3. Location Characteristics: The location of the landfill will be very critical to the success of the recovery and re-use operation. Several factors play a role:

   a. Activities around the landfill. If the landfills are located in a highly dense neighborhoods, there may be negatives due to increased odor, noise and health hazards associated with the activities necessary in siting a methane recovery and re-use operation, particularly if the municipality goes to more advanced recovery and re-use techniques such as "bioreactor" landfills. Landfills that are located close to industrial facilities might be positive in the sense that waste is readily generated and can easily be moved over to the facility. However, it is critical to consider the types of industries as certain industries such as food processing and textiles are more conducive to generating the necessary organic waste that would make for more promising methane recovery operations.
   b. Location of the electric grid: Since the main purpose of the recovery and re-use operation is to generate electricity, it is critical to understand whether there is an electrical infrastructure in place close to the proposed site. This is due to the fact that the methane gas generated does not contain the pressure needed to be transported over long distances. Because of this, the electrical generating equipment is typically located within 1-2 km of the landfill. Usually, the equipment is hooked up to a medium or high voltage electrical transmission line or the power serves industrial facilities or neighborhoods located nearby.
   c. Land for future expansion: Since methane recovery and re-use operations require a significant capital investment (our review of US projects has shown the capital cost ranges from $1.8 million to over $6 million), it is important that the productive capability of the landfill be maximized. In order to facilitate this, there must be enough land allocated at the disposal site to accommodate future landfilling, that will lead to additional recovery and re-use operations.
   d. Traffic handling capacity: With a full recovery operation in place, it is essential that a proper transport infrastructure be in place, to handle the dump trucks and other vehicles that would be accessing the landfill on a daily basis.
   e. Availability of water: Wastewater or some other source of water will be necessary for the operation of the methane recovery system. It is important to know the distance between the source and the landfill site and whether there is any infrastructure (e.g., pipelines or canals) to transport the water.

4. Social and Economic Conditions: An influential factor in a methane recovery and re-use operation relates to the social and economic conditions for the municipality. These factors have a bearing on the volume and composition of the current and future solid waste streams. Factors include:

   a. Current city population and projected growth: Obviously, a larger city will generate higher aggregate volumes of waste that is beneficial for the project economics.
   b. Industrial mix:

- Higher concentrations of food processing and textile waste yield useful organic waste to improve the methane gas quality and quantity
- Large financial sector (offices) yields higher volume of paper which is useful organic waste

5. Politics of the Region: The ultimate success of a methane recovery and re-use project depends on the will of the local political leaders. Understanding the following factors will shed light on whether there is strong support for such a project.

   a. Support of new ideas and initiatives
   b. Ability of municipality to implement public projects
   c. Capabilities to relocate displaced workers
   d. Ability to deal with public relations and perceptions resulting from project and potential reallocation of workers and residences
   e. Climate for public/private partnerships

6. Existing Regulatory Mandates or Incentives: It will be critical to understand the regulatory structures that are in place at the local, state and federal levels. It is expected that the municipal officials will know the answers to the local and regional regulatory schemes however it will be necessary during the TNA mission to obtain insights and perspectives from regulators at the federal level including the Central Pollution Control Board (CPCB), the Ministry of Non-Conventional Power, and the Ministry of Environment. The types of questions asked would include:

   a. What are the existing regulations that would influence the success of a project?
   b. Support for project at the state and federal levels.
   c. Are there currently mechanisms in place to encourage better waste management practices and methane emission reduction through recovery and re-use operations?

7. Personnel Capabilities: A key factor in the potential for methane recovery and re-use projects is the ability of the staff to carry out such projects. Our TNA mission attempted to answer these questions so as to make a qualitative judgement as to whether the municipality has the capability to develop a project and if not, will identify the requirements for successfully implementing such a project. The types of questions asked would include:

   a. Skill of on-site staff (operations)
   b. Availability of qualified technical management and staff
   c. Availability of local universities to form partnerships and alliance for tapping into skilled labor pool

3.2 Recommended Cities

As a result of the application of the above screening criteria, combined with our December 2000 discussions with USAID, seven cities were selected to be part of the February 2001 TNA mission. Based on the findings of the TNA mission and the recommendations from this report, these cities may be part of the GEP project CLIN 8 for future outreach strategy for development and training related to methane recovery and re-use operations.

As indicated previously, a brief questionnaire was sent to several cities covering the criteria listed above. Unfortunately, none of the cities provided their responses prior to the TNA mission. Given the limited data available from the cities, it was not possible to answer many of Questions 1-7 above in time to be useful as a tool for screening candidate cities for the TNA mission.

USAID/RUDO had already studied the quality and quantity of Indian municipal solid waste. Hence, LBG, Global and other project partners assembled a matrix of selection criteria using data attributes that were largely available, either through their own research or through information assembled by USAID/RUDO. The matrix profiled each of 17 cities (included as part of RUDO's "FIRE" project) from the perspective of connectivity, waste volume, waste composition, waste handling, waste management, initiative and municipal administration. Based on these data points and selection criteria decided by the project participants, scores of 0 to 10 were attributed with each factor receiving an equal weight (except initiative and municipal administration which were scored on a scale of 3-8). Based on this assessment, the following eight cities were selected:

1. Pune
2. Vijayawada
3. Ahmedabad
4. Baroda
5. Hyderabad
6. Bangalore
7. Mumbai
8. Chennai

While the present analysis was thorough and well reasoned, it gave limited insight to some of the cities that expressed an interest in participating in the TNA visits based on the short survey that was distributed at the Hyderabad conference. Fortunately, there is a significant amount of cross-over between the list of eight given above and the cities who expressed an interest at the Hyderabad conference. Out of the original list of 17, there is only one city that expressed interest in participating but is missing from the above list, Tiruppur. Two other cities expressed interest (Guntur and Cochin) but were not on the original list of 17.

No representatives from Mumbai completed the survey. In studying the conditions of Mumbai (data provided by USAID/RUDO), this city is not attractive from an implementation point of view, however, it may be an attractive candidate simply from the perspective of its significant volume of waste. Due to the city's enormous heterogeneous population, its relatively poor waste composition and the uncertainty of its administration to cooperate in this type of project, we recommend that Mumbai *not* be included in the complete list of possible TNA visits.

Representatives from Tiruppur completed the survey during the Hyderabad conference. However, they were not able to provide data regarding the city's waste composition or its waste management practices. Nevertheless, this city was considered in place of Mumbai based on the following information:

- This city's economy revolves around the manufacturing of hosiery and cotton products; with such an industry mix it is reasonable to assume that the organic waste is conducive to methane recovery and re-use operations.
- The financial health of the city would indicate that they can implement projects effectively.
- We understand that USAID/RUDO is working closely with the city to implement projects related to water treatment and sewerage.

Based on our assessment of the above analysis and the review of data and insights gleaned from the Hyderabad conference, we recommend the following eight cities for top consideration for the TNA visits:

1. Pune
2. Vijayawada
3. Ahmedabad
4. Baroda
5. Hyderabad
6. Bangalore
7. Chennai
8. Tiruppur

After presentation of this list to USAID, several additional factors were considered by USAID and LBG and the final selections are shown on Table 2.

TABLE 2:
Final List of Cities for TNA Mission

1. Pune
2. Baroda
3. Chennai
4. Bangalore
5. Guntur
6. Jaipur
7. Noida

Note that for two cities included in the final list (Baroda and Noida) site visits were canceled due to the catastrophic earthquake in the Gujarat state (Baroda) and logistical problems encountered during the mission (Noida).

4.0 INTEGRATED TRAINING RECOMMENDATIONS

4.1 Proposed Training Outline/Curricula

At the conclusion of the TNA mission, a training outline was prepared in collaboration with USAID/India, for all cities, based on the interviews conducted with the individual city commissioners, the staff, and field observation of the existing practices and institutional knowledge. In addition, input from the Ministry of Environment and Forest Notification S.O. 908 (E) was included to ensure that the training needs were assessed with consideration of the requirements and standards that are currently mandated by the Government of India.

Our proposed two-day training program recognizes that while many of the practices and techniques that are in place in developed countries can and should be transferred to the Indian context, it may not be possible to rapidly accelerate a process that will take several years to develop. Steps to be taken must be methodical and careful, with a vision toward a sustaining long-term solution. Solutions should be geared toward addressing many urban solid waste issues at one time—methane emission and greenhouse gas reductions, improved health and safety, aesthetic qualities, and chronic power shortages.

Our training program highlights seven key technical topics that are outlined in the training curricula presented in Figure 1. These topics are based on our assessment of the current needs and capabilities from the TNA visits. Each area is designed to address the important technical, managerial and planning topics necessary for developing an Integrated Waste Management approach to solid waste management. The program will include an appropriate mix of classroom lectures, video clips of best practices, and class exercises. To maximize efficiency, the video clips would be pulled from the team's existing library and might include the following:

- Low-permeable clay or silt base--clay placement operation
- Base geomembrane lining
- Operations layer placement
- Waste placement at typical working face
- Waste compaction using compactor
- Well drilling operations
- Television reports of US waste to energy projects

In addition, each participant will receive a reference manual that will contain background materials related to methane recovery and re-use. This would include any relevant technical reports, articles/journals, website listings, and US/international case studies. These materials will be drawn from a number of sources available to the trainers including:

- Electric Power Research Institute
- Gas Technology Institute
- US Environmental Protection Agency (Landfill Methane Outreach Program and others)
- Solid Waste Association of North America (SWANA) Conference Proceedings
- University of Central Florida, College of Engineering
- University of Wisconsin, Madison, Department of Engineering

FIGURE 1:
Annotated Training Curricula

A) Policy review and solid waste management overview
- Overview of methane correlation to greenhouse gas problem
- Current practices in India and comparison to world standards
- Collection, transfer, transportation, recycling, hygiene
- Optimal landfill structure
- B) Physical and chemical characteristics of municipal solid waste (MSW) composition
- Methane gas production process
- Lifecycle and decomposition

B) MSW transformation technologies
- Biological processes-Anaerobic, aerobic, and vermi-composting
- Thermo-chemical processes-Pyrolysis, gasification, and incineration
- Present status: Incineration, aerobic and vermicomposting working for waste disposal. Pyrolysis and gasification, severe obstacles up to now, worldwide
- Advanced bioreactor technology developments
- Incineration and landfill gas maximize energy recovery

C) Significance of methane from MSW
- Emission from dumpsite, sanitary landfills during active life and post-closure
- Migration of landfill gas and hazards
- Control of landfill gas
- Economic benefits of landfill gas methane recovery and use
- Climate change impacts

D) Technology for landfill gas methane recovery and re-use
- Engineered landfill gas collection system (active and passive)
- Uses of landfill gas methane-Power generation, thermal uses, LNG and methane and carbon dioxide uses, fuel cells
- Analysis of the production potential
- Economics and project selection

E) Operational issues
- Overview of main features of operating landfill with properly filled waste
- Gas collection and transport system
- Electrical infrastructure and access to power grid
- Methods to calculate production potential

F) Landfill methane project development
- Site selection and stakeholder involvement
- Waste characterization, gas potential estimation
- Gas collection system and use identification
- Plant and machinery selection
- Project cost estimation
- Approvals, license, agreements, studies, etc.
- Project structure selection process
- Bid documentation and bid process management
- Selection, construction, and operation
- Risk analysis
- Carbon offsets (World Bank and UN Concern; basis for loan support)
- Organization resources and networking
- Project financing and potential funding sources

4.2 Potential Training Partners

Three individuals with experience in landfill gas, bio-energy, solid waste management energy recovery, and project development have been selected to assist the cities in this training and evaluation of the sites for a demonstration project (see chart below). The first member of the team is Mr. Greg Wikler. Mr. Wikler is a project director from Global Energy Partners and is overseeing this project under the direction of LBG. He has over 16 years experience in the energy field and has been instrumental in project development addressing many of the mechanisms needed to ensure successful implementation. He also has conducted several training courses for international participants. Mr. Wikler will have overall responsibility for the training program, including the development of presentation materials, reference materials, and onsite facilitation during the training.

The second team member will be Mr. Don Augenstein. Mr. Augenstein is currently an advisor for this project, having provided assistance during all phases. He is the technical director of IEM (Institute for Environmental Management, Inc.) in Palo Alto, California. He is a chemical and biochemical engineer with 28 years of experience. His has been involved in: development of improved models for projecting landfill gas recovery; providing engineering and technical services for renewable energy projects with landfill methane enhancement project; conducted environmentally studies to address potential climate change implications of U. S. landfill methane emissions and developed preliminary assessments of cost effectiveness of landfill methane abatement and greenhouse gas mitigation. Mr. Augenstein has published and presented numerous technical papers over the past 28 years. He will be the lead trainer and will have responsibilities to present the technical materials as well as spur discussion among the participants.

The third team member will be Mr. Ramin Yazdani. Mr. Yazdani is an integral member of this project, having represented the Global Energy Partners team during the February TNA mission. He is a professional Civil Engineer licensed in the State of California with a master's degree in civil engineering over ten years of experience in the field of solid waste management. As an Assistant Director of Public Works Department is responsible for planning, permitting, design and operation of a large municipal landfill in California. He has been involved in all aspects of integrated waste management projects, methane to electricity facility and has conducted research in finding better ways to manage and reduce solid waste in Yolo County, California. His work has been recognized in the US as well as abroad. He has worked with the local, state, federal officials and well as the local citizens of Yolo County to achieve obtain regulatory approval of a full-scale demonstration project to enhance methane production and reduce greenhouse gas emissions. His work has brought the cooperation and financial support of state and federal agencies as well as the interest of many private and public sectors worldwide. Mr. Yazdani has been teaching part-time for the past seven year. He will be an assistant trainer and will provide technical review of case studies and the data presented by the participants related to the homework assignments.

The second audience will be technical managers and people involved with day-to-day landfill operations. Based on our assessment from the TNA visits, we found that this group is in need of the same information as the first audience. In addition, they require technical specifications that will enable them to think about effective methods for implementing a landfill management and methane recovery and re-use operation in their jurisdiction. The remaining time for the training program will be targeted primarily to this audience.

4.3.2 Course Organization

The training module plan will be in two parts. The first part will focus on the basic waste management practices. This is to establish a basic understanding of the best practices and the Integrated Waste Management approach to solid waste management. It will cover some the key issues that are important for managers and administrators to understand.

The second part of the training will focus on the science of sanitary landfill and the energy use options and in particular the re-use of methane from landfill as a renewable source of power. The importance of methane emission reduction and ways to economically use this renewable resource to reduce cost and generate revenue will be emphasized. Various technology options will be discussed so that each of the attendees can make informed decisions about methane re-use project potential. Evaluation and economic viability of various landfill gas-to-energy will be the focus of this part of training. The goal is that the individuals will walk away with the capability to use their knowledge to evaluate options and technologies to use landfill gas at their landfill site. Examples of various projects will be made available. Real life examples of landfill projects will be used for classroom discussion. This is to ensure interaction between the participants and to facilitate a hands-on learning experience for all attendees.

After the first day, a homework assignment will be given to the participants so they may apply their own knowledge of the waste management practices from their cities to prospective methane recovery and re-use projects. This assignment will focus on completion of the selection and data collection criteria presented in Section 3 of this report. During a group discussion on the following day, the trainers will assist in estimating the gas production potential and power production potential. The purpose of the homework assignment and group discussion is to enable the participants to develop a systematic "blueprint" in evaluating the potential options in methane re-use technologies and strategies.

4.3.3 Training Program and Mock Agenda

There are two options for providing the two-day training course. In the first option, training would be provided to each city individually at each city. The second option is to conduct two-training sessions in two cities and invite other cities to attend.

The first option would allow more staff to attend since there would be no travel required for the municipalities. This would also reduce the financial burden for the municipality and ensures higher enrollment for the training. The second option will require additional travel time and cost for some of the municipalities but lower training cost for USAID. The location of the training could be selected such that site visits could be made to gather facts and data for possible sites for a methane recover and re-use demonstration project.

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The overall course agenda may be structured into the following mock agenda:

- Day 1:
  - Solid Waste Management Overview
  - Basic Waste Management Practices
    - Physical and chemical characteristics of municipal solid waste
    - MSW transformation technologies
  - Methane and Energy Production
    - Significance of Methane from MSW
    - Technology Options for Methane Recovery and Re-Use
  - Operational Issues
  - Homework Assignment:
    - Complete baseline characteristics profile
    - Assess key parameters for methane project opportunities
- Day 2:
  - Evaluation of Participant's Sites
    - Group discussion (comparison/contrast)
  - Project Development
    - Technical assessment
    - Economic analysis
    - Project financing
    - Timing
  - Specific Demonstration Project Discussions

4.3.4 Training Schedule

The training package will be designed and developed by July 2001 and could be delivered to the municipalities as soon as August 2001. Immediately after the training sessions, meetings will be held with USAID and various municipalities that have initiated the process of consideration for possible demonstration projects.

ANNEX A:
TNA SITE ASSESSMENT—PUNE

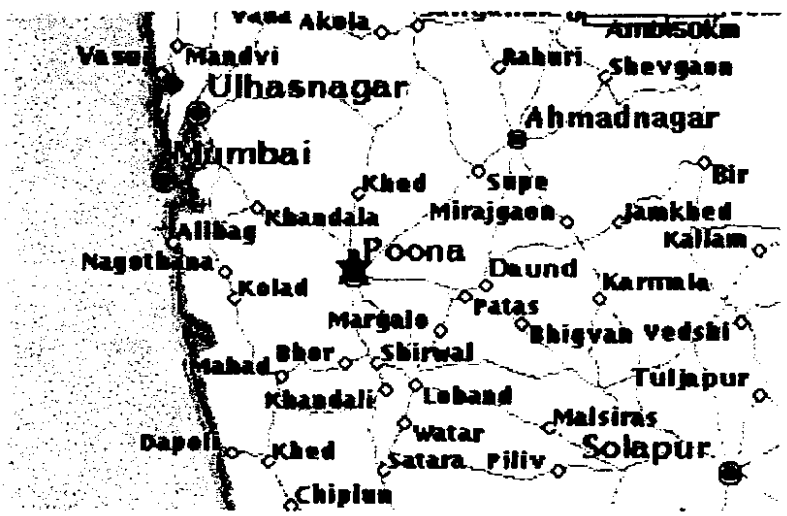
25a

TNA REPORT
METHANE RECOVERY AND RE-USE POTENTIAL IN INDIAN CITIES

CLIN 8—GEP PROJECT
GLOBAL ENERGY PARTNERS

Prepared by: Yazdani Consulting
Ramin Yazdani
for Global Energy Partners

Date: February 12, 2001



1. TNA SITE ASSESSMENT—Pune, India

   a. **Current Solid Waste Management**
   Pune is the second largest city of Maharashtra. This city is an important military center of India and is known for it's educational institution and research centers. The area of jurisdiction of the Pune Municipal Corporation is 139.90 sq. kms. The population of the city is about 2.2 million people.

   On February 12, 2001 interviews were conducted with two representatives from the Pune Municipal Corporation, Mr. A.V. Deshpande, Municipal Commissioner and Dr. R.R. Pardeshi, Deputy Medical Officer of Health of the Pune Municipal Corporation. Below is the summary of the interview.

   Waste Handling and Separation, Storage and Processing
   The health office is responsible for solid waste management in various wards. The solid waste management system of Pune has been decentralized such that the city is divided into 10 elector wards and 124 wards. Each ward is responsible for 124 staff that are responsible for sweeping of about 35,000 to 50,000 sq. ft. per worker. The sweepers use wheelbarrows to move the dirt and trash from each area to a location where 3.5 cubic meter open top containers called tippers are is stored. There are 1,400 such tippers throughout the city. There are 90 collection truck vehicles that are used to haul and

empty containers. The city also owns 8 compactors. House to house waste collection is also provided to the residences weekly. There are about 6,000 to 7,000 rag pickers. The rag pickers often sort through these 3.5 cubic meter containers for paper, and other recyclable material. Kitchen waste is collected from the hotels and restaurants regularly. Hospital waste is collected and incinerated at three waste incineration sites. Two incinerators are used for private hospitals and one for the public hospital. Starting in December of 2000 these incineration sites began operation. All waste except the hospital waste is dumped at a site that is about 3.5 km. from the city. The disposal site currently in use is called Bevachi-uruli, which is about 3.5 km. from the major transfer station. The collected waste from each tipper is dumped in a compactor truck that is further transported to either of the four transfer stations. There are two major and two minor transfer stations. The city owns eight compactors to reduce the volume of waste before it's transported to the dumping site at the transfer stations. The waste volume is reduced by compaction in trucks before it is dumped at the disposal site.

Waste Generation and Composition

The waste generated is estimated to be 800 TPD. Waste characterization is reported to be as following: a) Combustibles, 60%; b) paper 9%; c) plastics-less than 1%; d) recyclables 10%; e) earth 28%; f) misc. 2%.

Land Method of Solid Waste Disposal

There are two major disposal sites within the city and one site just outside of the city. Two other major disposal sites within the city limits where the waste used to be taken are currently closed. Disposal of waste began at the Devachi Urvi site in 1992, shortly after the other two sites were closed.

Below is a photograph of one of the two old disposal sites that was visited, called Paud. This site was used for waste disposal for over 45 years (see photo below). At this old site, waste was placed on top of the existing ground without any compaction. The height of the waste was estimated to be as high as 10 to 20 meters high in an area of about 40 hectares. This site is in the residential and commercial portion of the city.

Currently 800 TPD of waste is disposed at the site just outside of the called, the Devachi Urvi disposal site. This site used to be a quarry site before it was used for waste disposal. It is about 18.2 hectares in size with a footprint of about 250 meters by 728 meters. This quarry is about 21 meters in depth. Since 1992 20% of the site has already been filled. The closest community from the landfill is about 1.5 km. Trucks dump waste at the site and workers spread waste with shovels. No compaction of waste is done after dumping. No cover soil is used to control odor or vectors. According to Dr. Pardeshi the bottom of quarry is rocky and during rainy season rains infiltrates into the ground quickly.

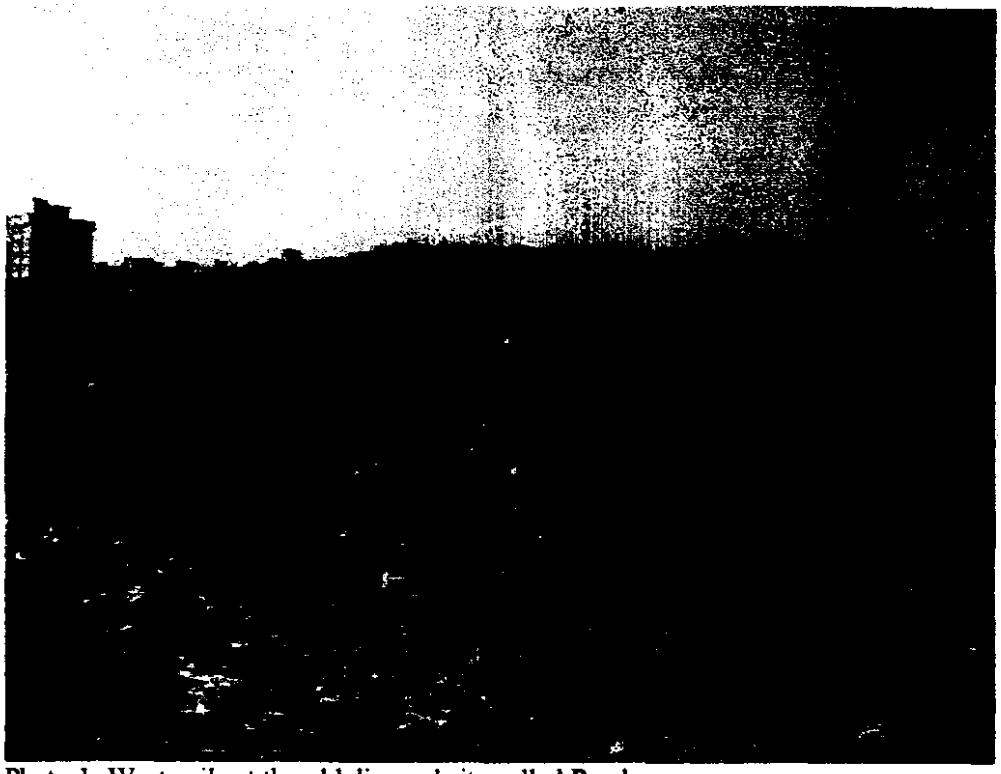


Photo 1- Waste pile at the old disposal site called Paud.

Photo 2- Property adjacent to the waste disposal site at Paud

Other Methods of Waste Disposal

The city has recently awarded a contracted to CICON for anaerobic digestion of about 400 tons per day of waste for a biogas plant. 150 tons of waste will also be composted either through vermi-composting or aerobic composting.

Climatic Conditions

The average rainfall in the area is about 76 cm.

Composition and Characterization of the Solid Waste

During the interview the following estimated waste characterization information was verbally provided: 45-50% organic waste; 20% plastics; 10-15% paper and cardboards.

Based on a report prepared by Kirloskar in 1987 the following waste compositions were reported: 60% combustible; 8.74% paper; 0.72 plastic; 0.58% glass; 10.04% recyclable; 28.33% earth; 1.63% miscellaneous.

Distance to Power Grid

2 to 3 km. from the site to power lines of 33 to 66 KVA.

Requested information by the municipality:

During the interview the following issues were identified to be of interest by the municipality: a) how do we take out the plastic in the waste and find market for its use? ; b) How do we take care of liquid waste from public toilets and the solid waste? ; c) How do we control methane gas and fires in landfills? ; d) How does landfill gas impacts the groundwater contamination near the landfill? ; e) Interested in partnership with a project to explore the liquid and solid waste disposal; f) How do we recycle the water from the toilets and reuse it for flushing toilets?; g) How do we construct a sanitary landfill to minimize the impact to the environment and comply with the new regulations?

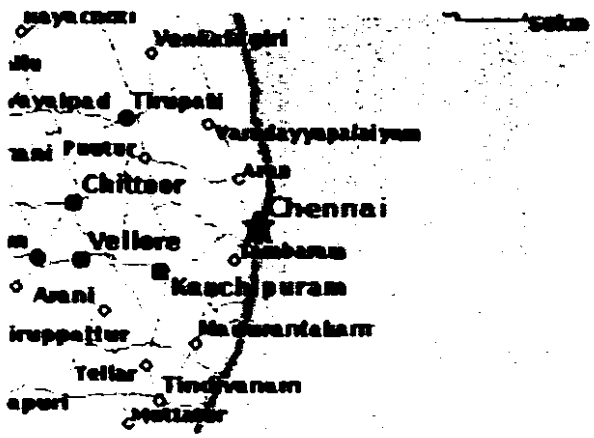
ANNEX B:
TNA SITE ASSESSMENT—CHENNAI

TNA REPORT
METHANE RECOVERY AND RE-USE POTENTIAL IN INDIAN CITIES

CLIN 8—GEP PROJECT
GLOBAL ENERGY PARTNERS

Prepared by: Yazdani Consulting
Ramin Yazdani
for Global Energy Partners

Date: February 13, 2001



1. TNA SITE ASSESSMENT—Chennai, India

   a. **Current Solid Waste Management**
   Chennai is the fourth largest port of India and the capital of the state Tail Nadu. The jurisdiction of Chennai Municipal Corporation is spread over an area of 174.56 sq. km. Population of the city is estimated to be 4.75 million people.

   On February 13, 2001 interviews were conducted representatives from the Chennai Municipal Corporation staff and Kampsax consultants. Chennai Municipal Corporation, Dr. Chandra Mohan, Deputy Commissioner-Health & Solid Waste Management, and Kampsax India Limited Consulting Engineers and Planners, Mr. Vijay Padmanabhan, Senior Manager and Mr. A.S. Harinath. Below is the summary of the interview.

   Waste Handling and Separation, Storage and Processing
   The city provides a variety of receptacles such as concrete or masonry dustbins, small structures used for storing waste with a capacity of about 10 cubic meters, or compactor bins. The waste is transported to a nearby transfer station or to a collection point on tricycle, autos, etc. Some door-to-door collection service is practiced by NGOs, such as Exnora, Guild of Service, etc. This type of service is only common among middle and high-income areas of the city. The streets are cleaned by street sweepers that use wheel-barrows to transfer the waste to the collection points. In some areas waste is dumped on to the sides of the roads. The waste generated at the hotels and restaurants are collected and transferred directly to the disposal site using heavy motor vehicle.

Collection vehicles used include mini-tippers, autos (1 tonner), heavy motor vehicles (9.5 tonner), and light motor vehicles (3 tonner). There are eight transfer stations within the city. Waste is transferred to a higher payload vehicle for haulage to the disposal sites. Recycling of the materials are mainly done by rag pickers either at streets or at the transfer stations and at the dumpsites. Based on a report by ERM consulting company there are 371 ragpickers at the transfer station (125) and dumpsites (246) recover about 10 TPD and 18 TPD respectively. There are also about 10,000 street rag pickers collecting about 200 to 300 TPD from homes and from open dumps on the street sides. Approximately 150 TPD of waste disposed is construction demolition, concrete, silt, dirt, and bricks.

Waste Generation and Composition

In 1995 Environmental Resources Management India estimated Chennai's waste generation to be as following: a) residential (66%), 1,750 TPD; b) commercial (14%), 371 TPD; c) hotel, restaurants, etc. (4%), 106 TPD; d) vegetable and fruit markets (12%), 318 TPD; e) hospitals (2%), 53 TPD; f) construction (2%), 53 TPD. The current estimated waste generation is estimated to be 3,000 TPD.

The average chemical analysis of Chennai city waste is reported to be as following: a) Moisture content (% by weight), 27.61; b) pH value of 7.68; c) Organic Content (%) of 39.06; Carbon Content (%) of 21.53; d) Nitrogen Content (%) of 0.73; e) Phosphorous Content (%) of 0.65; f) Potassium as K2O (%) of 0.63; g) C/N ratio of 31.01; h) Calorific Value in kJ/kg of 4,595.

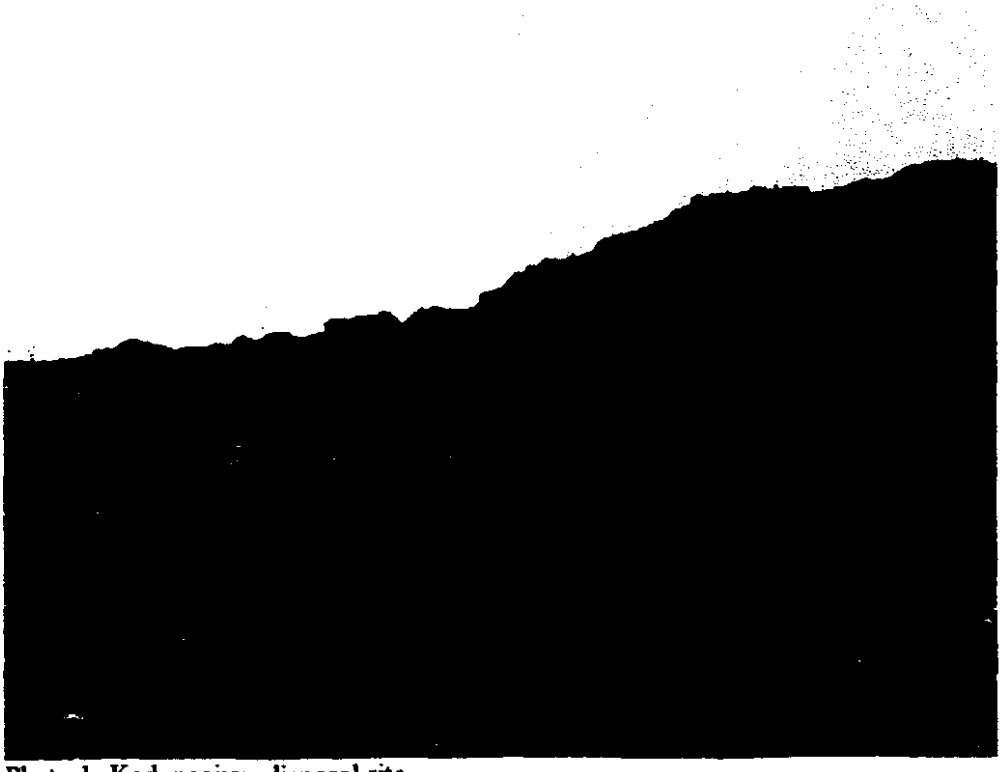


Photo 1- Kodungaiyur disposal site

Land Method of Solid Waste Disposal

There were two major disposal sites in Chennai, namely Kodungaiyur to the north and Perungudi to the south. Each site receives about 1,500 TPD of waste. Tonnage is measured by weight bridge on site. Both of these sites are situated in the marshy area, which has had flooding problem during monsoon seasons. The Kodungaiyur site is located next to the Metrowater's Sewage Treatment Plant. The site is 350 acres. 65 acres is owned by C.O.C., and 285 acres is owned by CMWSSB. Based on a topographic survey in April of 1998 the filled land occupies approximately 64 hectare. This site has been in use for the past 20 years and it's within one km from neighborhood.

The Perungudo site is located outside of the city and it is also situated close to Metrowater's Sewage Treatment Plant. This site is within 0.5 km from the neighborhood. The site has been receiving waste for the past 13 years. Total of 800 acres is owned by CMWSS Board Waste. The filled up land area is about 45 hectare.

Photo 2- Newly constructed all weather access road at Kodungaiyar site

Other Methods of Waste Disposal

The corporation is considering alternative waste treatment technologies: a) generation of 14.85 M. W from 600 TPD of waste on B.O.O. basis at the Perungudi site has been awarded to EDL; b) generation of compost from 500 TPD of waste at the Perungudi site.

Climatic Conditions
The average rainfall in the area is about 100 cm. Average maximum and minimum ambient temperature is 40 C and 20 C respectively.

Distance to Power Grid
25 km from the site to power lines.

Requested information by the municipality
During the interview the following issues were identified to be of interest by the municipality: a) various technology options for landfill gas use; b) capital cost and operation and maintenance cost of the projects; c) financing options and carbon credits to assist in project financing; d) bid document processing and review for construction of sanitary landfill.

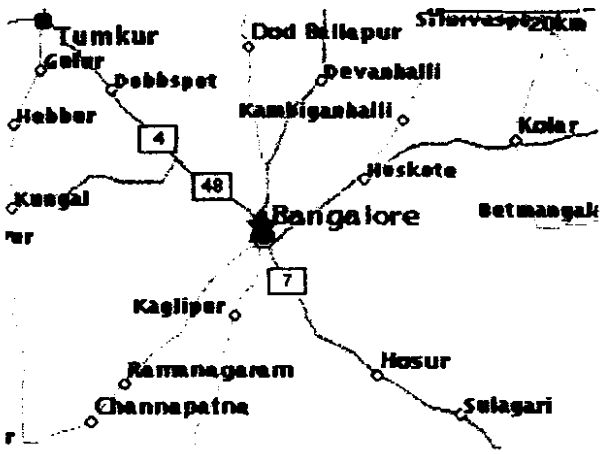
ANNEX C:
TNA SITE ASSESSMENT—BANGALORE

TNA REPORT
METHANE RECOVERY AND RE-USE POTENTIAL IN INDIAN CITIES

CLIN 8—GEP PROJECT
GLOBAL ENERGY PARTNERS

Prepared by: Yazdani Consulting
Ramin Yazdani
for Global Energy Partners

Date: February 14, 2001



1. TNA SITE ASSESSMENT—Bangalore, India

   a. **Current Solid Waste Management**
   Bangalore is the fifth large largest city in India and is the capital of Karnataka. The jurisdiction of Bangalore is spread over an area of 225 sq. km. The population of the city is estimated to be 4.5 million people. 20% of the population lives in about 460 slum sites.

   On February 14, 2001 interviews were conducted with representatives from the Bangalore City Corporation officials. These included Bangalore Health officer, Dr. S.U. Kumaraswamy, Bangalore Special Commissioner, Mr. Ashok Dalwai and Mr. S. Ramesh, Executive Engineer. Also the Karnataka Compost Development Corp. was visited and Mr. H.R. Suresh, Assistant Manager was interviewed. Below is the summary of the interviews.

   <u>Waste Handling and Separation, Storage and Processing</u>
   There are two departments involved in the management of municipal solid waste, namely, the health department and the engineering department. There are 6 zones and each zone is managed by the assistance of the senior or junior health officer. There are about 6,670 sweepers that collect over 2,000 tons of waste from the streets and bins in Bangalore. There are 20,000 to 25,000 rag pickers working in addition to official employees for segregation and recycling of paper and plastic waste. The Corporation helps the rag pickers in performing this work by providing them with pushcarts.

Currently Wastewise, a private contractor, is conducting a study to determine the needs of this operation. The Corporation intends to recognize the services provided by rag pickers and institute some welfare measures for the rag pickers.

The Corporation and private companies transport waste from streets and bins to the disposal sites. In 40 areas of Bangalore private contractors collect waste from bins and transport to the disposal sites. The corporation staff transports 50 percent of the waste to the disposal sites. The collection of waste from households is estimated to cost around Rs. 80 crores. The corporation is planning to charge the households for collection and thus generate around Rs. 30 crores.

The corporation is planning to improve the transportation infrastructure for waste and is hoping to receive financial support for part of this from HUDCO. They also plan to construct modern sanitary landfill and one major transfer station in addition to a few minor transfer stations.

Waste Generation and Composition

The total waste generation for the city of Bangalore is 2,200 TPD. This is a mixture of municipal solid waste, hospital waste, and industrial waste. In addition, they received 300 TPD of inert material. No waste composition data was provided during the interview. The previously gathered waste composition adapted from data by the School of Planning in Ahmedabad is as follows:

> Composition about a) Combustible material 30 %; b) Paper 3 %; c) Plastic 3 %; d) Metal 2 %; e) Glass 2%; f) Recyclables 20%; g) Rock and dirt 30%; h) Misc. 10% The moisture content of waste is reported as being 40% with a density of 420 kg per cubic meter.

Land Method of Solid Waste Disposal

There are nine small dumping sites in the city. One of these sites is for municipal solid waste disposal and the rest are used for construction demolition waste. Total waste received at the site is about 400 TPD of construction demolition waste in addition to 2,200 TPD of other waste. The Banglore Municipal Corporation is planning to start 6 sanitary disposal sites covering a total area of 52 acres. The Corporation has acquired 111 acres of land for disposal of waste but only half of it could be used since the rest is too close to the airport and would require clearance form the airport authorities. Currently hospital waste is disposed at the same site as municipal disposal site, however, the corporation is negotiating with a private firm for setting up an incinerator on B.O.O.T. basis. They are also looking to purchase additional land for future sanitary landfill site. Much extra land will clearly be needed needed since 2,200 tons/day will result (for example) in a waste height of 100 feet in only about 10 years

At one of the existing disposal site of about 100 acres of land the soil condition is gravel and some clay. At another site with 29 acres of land the soil is sandy/clay type. Based on the visual observation of the staff, leachate is generated from the site. There have been complaints about odor and birds at the sites. The groundwater table is about 200 feet below the surface. There are no groundwater testing data available for the site. The topography of the site is composed of rolling hills and flat areas. There are drinking water wells around the landfill. The site accepts waste seven days per week. At one site there are five homes within 300 meters of the disposal site.

Other Methods of Waste Disposal

There was no disposal site visit arranged. We requested to see the composting operation of the corporation. The landfill site is near the composting facility but no staff were available to assist in site visit.

The corporation has had a contract with the Karnataka Compost Development Corporation (KCDC) since 1979 for aerobic composting of waste at about 350 tons per day (TPD) at the Bomanhalli site. They use a 15-acre site, which is provided to them by the corporation to do composting (See photos below). Currently they are working on expanding this operation to 600 TPD. The corporation will provide them with an additional 14 acres of land for processing of this additional 250 TPD. KCDC will have 29 acres of land to process 600 TPD of waste at this site.

The corporation has also contracted with Sunrays Composting Facility which will aerobically compost 200 TPD of waste at another location. A total of 900 TPD of waste will be processed aerobically. The reject material will be transported to the disposal site.

Based on the interview conducted with KCDC manager the following information items were provided:

- Cost to process compost per ton — Rs. 750
- Sale price of compost per ton — Rs. 900
- Sale price of enriched compost per ton — Rs. 1,600
- Sale price of vermi compost per ton — Rs. 3,000

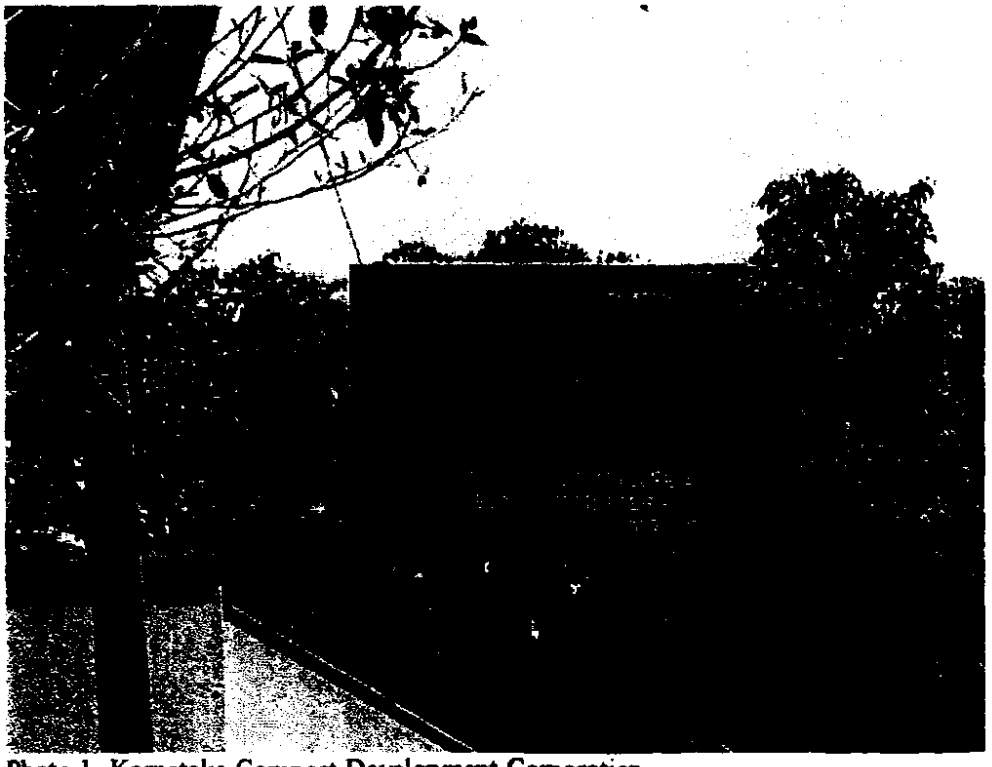


Photo 1- Karnataka Compost Development Corporation

Photo 2- Windrows of municipal solid waste and caw manure slurry used in composting for 45 to 60 days and piles are turned every 6 to 8 days

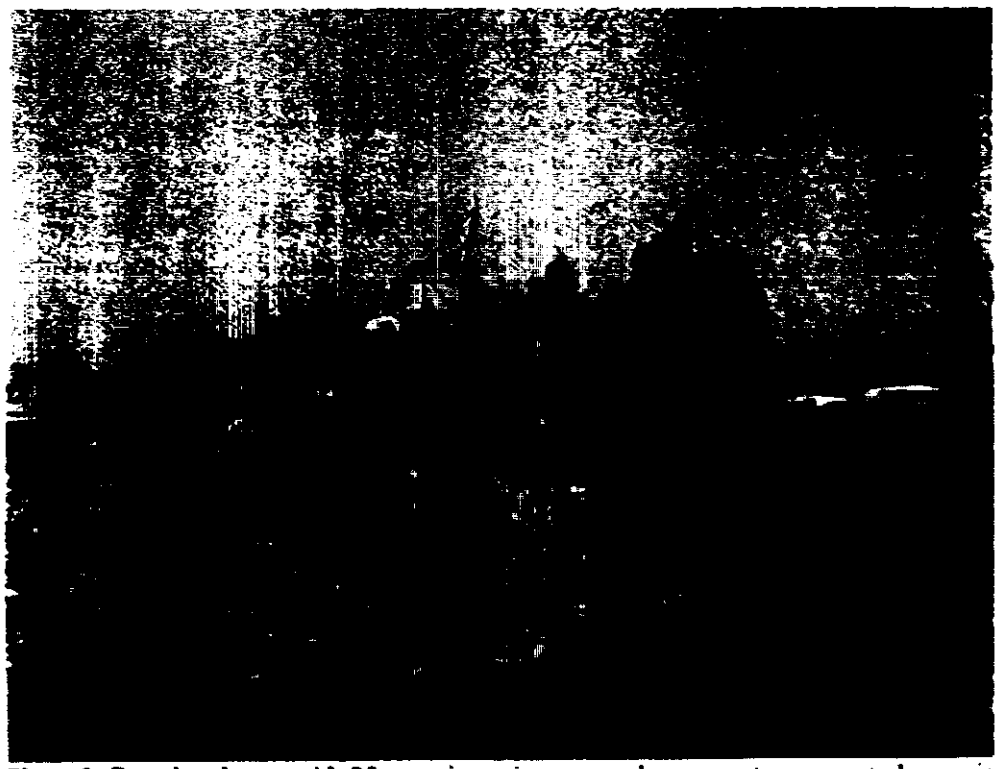


Photo 3- Rotating drums with 25 mm sieve size are used to separate composted organic waste from plastics and other contaminants

Photo 4- Rotating drum with 4 mm sieves are used as secondary processing of composted waste to remove rocks and other large particles

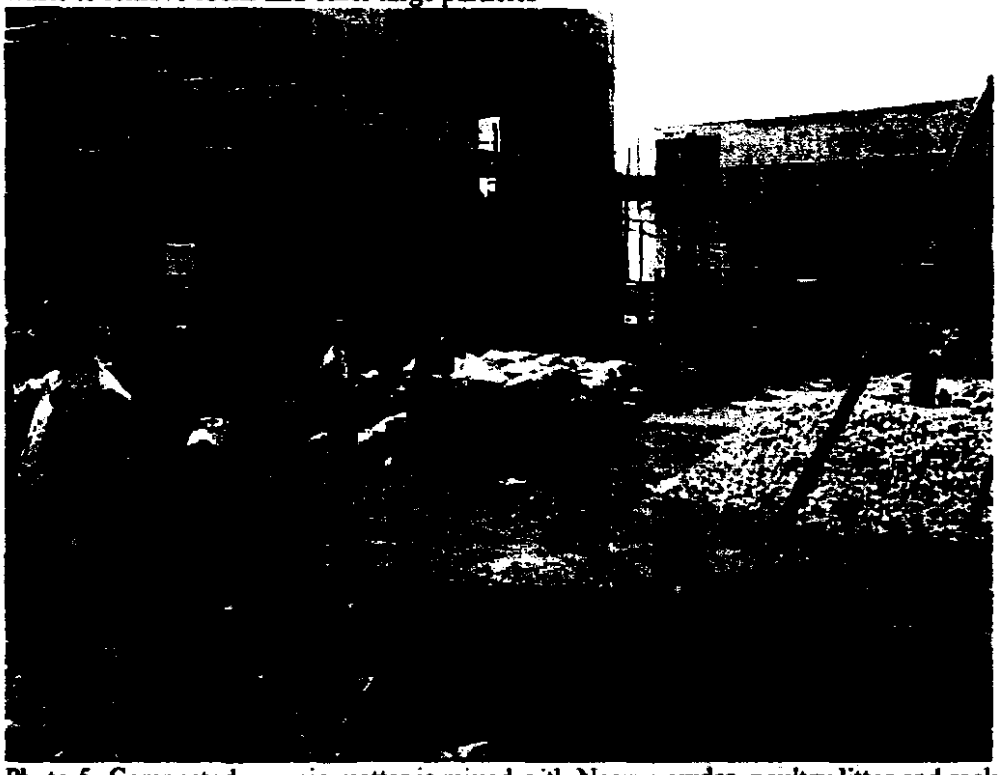


Photo 5- Composted organic matter is mixed with Neem powder, poultry litter and rock phosphate for enriching the compost and bagged for distribution for Agriculture, Horticulture and Floriculture Department of Government of Karnatakas

Photo 6- Vermi-composting produces high quality compost for agriculture use

Climatic Conditions

The average annual rainfall in the area is about 1200 mm. Maximum average daily ambient temperature is 36 C and minimum of 11 C.

Distance to Power Grid

The distance to the power grid is about 2 kilometers.

Requested information by the municipality

During the interview the following issues were identified to be of interest by the municipality: a) needs for assistance in determining best methods for transportation and disposal of waste; b) they are interested in learning more about landfill gas-to-energy options; c) they would like technical assistance with the management of municipal and commercial solid waste.

ANNEX D:
TNA SITE ASSESSMENT—GUNTUR

TNA REPORT
METHANE RECOVERY AND RE-USE POTENTIAL IN INDIAN CITIES

CLIN 8—GEP PROJECT
GLOBAL ENERGY PARTNERS

Prepared by: Yazdani Consulting
Ramin Yazdani
for Global Energy Partners

Date: February 15, 2001

1. TNA SITE ASSESSMENT—Guntur, India

   a. **Current Solid Waste Management**
   Guntur is divided into eleven zones and there are 49 wards for tax collection purposes. The jurisdiction of Guntur is spread over an area of 45.7 sq. km. The population of the city is estimated to be 479,000 people. 34% of the population living in slums and urban poor areas. There are 112,000 households in the city.

   On February 15, 2001 interviews were conducted with Mr. Praveen Prakash, commissioner for the Guntur Municipal Corporation. Listed below is the summary of this interview.

   <u>Waste Handling and Separation, Storage and Processing</u>
   The city has 2,800 cylindrical bins for trash collection that are made of 4 foot diameter concrete pipe. They also have 500 fiberglass containers that they have recently purchased (see photo below). The city produces 350 TPD of solid waste. The city uses 32 tractors and one moving compactor to collect and haul waste. There are no transfer stations in the city.

   Waste disposal sites within the city are used to dispose trash without having to use a transfer station. City cleaning and waste collection and transportation has been done through a few local Self Help Groups that employ sweepers. The Swarn Jayanti Shahri

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Rojgar Yojna provides loans to these groups for buying facilities like wheelbarrows and tractors for transportation of waste. The photo below shows such tractors used for the collection and transportation of waste to the disposal site near the city. The corporation provides guarantees for these groups thus helping them to get the loans.

Photo 1- New fiberglass Donald Duck containers container in the background used in the city

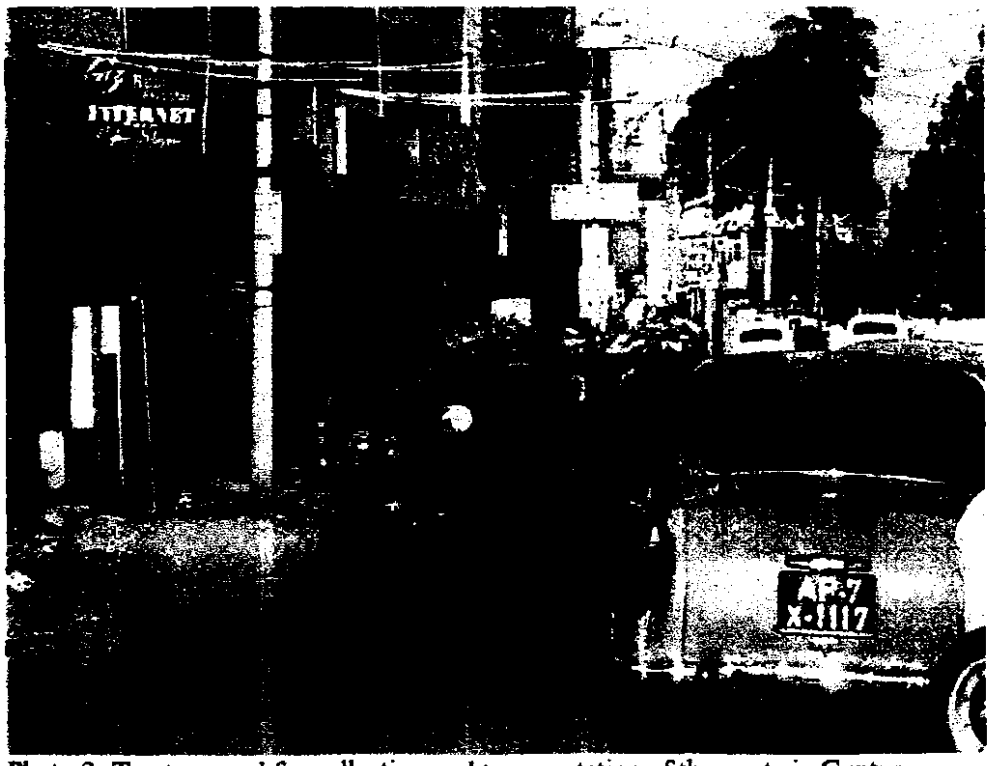


Photo 2- Tractors used for collection and transportation of the waste in Guntur

Waste Generation and Composition

The total waste generation for the city of Guntur is 350 TPD.

This is a mixture of municipal solid waste, hospital waste, and industrial waste. Based on estimates of the city engineer the waste composition is: a) organic waste 60%; b) rags 10%; c) glass and inerts 10%; d) metals 5%; e) plastics 3%; f) leather and rubber 5%; g) misc. 7%. This was not based on any scientific sampling of waste but rather observation of the waste.

Based on a report that was prepared by the Water and Environment Section of Civil Engineering Department of the Regional Engineering College, Warangal, the following waste composition was reported: a) Plastic (hard) 0.11%; b) Plastic (soft) 3.15%; c) glass 0.13%; d) metal 0.08%; f) paper 3.54%; g) textile 3.54%; h) wood 0.47%; I) leather 1.4%; j) rubber 0.49%; k) soil 29.70%; l) stones 4.17%; m) misc. 0.01%. The moisture content of the waste was reported to range between 35 to 40%.

Chemical analysis of waste was also reported as follows: a) Volatile matter 36.22-68.14; b) non-volatile matter 31.86-63.78; c) Kjeldhal Nitrogen 0.18-0.54; d) Total Nitrogen 0.47-0.69; e) Carbon Content 12.5-26.61; f) pH 6.2-8.30; g) Calorific Value 1,641.74-3,750.11; h) Potassium 0.34-0.79; i) Phosphorous 0.36-0.70; j) Moisture content 25.09-55.57%.

Land Method of Solid Waste Disposal

There are two waste disposal sites. No sanitary landfills exist in this city, so waste is simply dumped. The largest disposal site is Etkur road site that is about 6.5 acres in size (see photo below). This site currently receives 110 TPD of waste, except hospital waste. This site has been in operation for the past 70 years. The other 3 sites are less than 2 acres in size and are within heavy populated area of town. The groundwater table is about 10 feet below the surface.

The second disposal site, 2 acres in size is called Vasanpuram, which has been used for the past 1.5 years. There is less organic matter disposed at this site than the first site. The input tonnage to the site is about 60 TPD. The dead animals from the slaughterhouse nearby are usually dumped at this site.

Photo 3- Etkur road disposal site adjacent to cotton factory and residential area

Photo 4- Looking toward the cotton factor and the drainage area is being filled with trash

Photo 5- Etkur road disposal site where trash is set on fire by rag pickers to salvage metals

Photo 6-At the Vasantpuram disposal site near the residential area in town, municipal solid waste is deposited in the low areas where surface water runoff drains to and waste is not covered

Photo 7-Vasantpuram disposal site filled near the residential area in town

Other Methods of Waste Disposal

Recently a private company called Shriram Energy Systems, Ltd. Based in Hyderabad, has proposed a waste pelletization and energy generation project. The company proposes to take up to 280 TPD waste from Guntur and 225 TPD waste from Vijayawada for pelletization and produce 6 MW of power. The proposal is to separate the organic matter and produce pellets for burning and electricity generation.

Climatic Conditions

The average annual rainfall in the area is 850 mm. The maximum average daily ambient temperature is 45 C and minimum temperature is 11C.

Distance to Power Grid

The distance to the power grid (33 K.V.) is about 2 kilometers.

Requested information by the municipality

During the interview the following issues were identified to be of interest by the municipality: a) technical assistance in solving the wastewater treatment problem. Currently the facility only treats 8 MGPD of the total wastewater generated from the city that now generates 16 MGPD. The additional 8 MGPD untreated wastewater is released in the ditch and nearby farmers use this untreated wastewater for irrigating crops; b) provide us at Guntur with technical assistance in evaluating the proposal for pelletization of MSW to make sure that the proposal is technically possible and feasible; c) assist us in development of a sanitary landfill project.

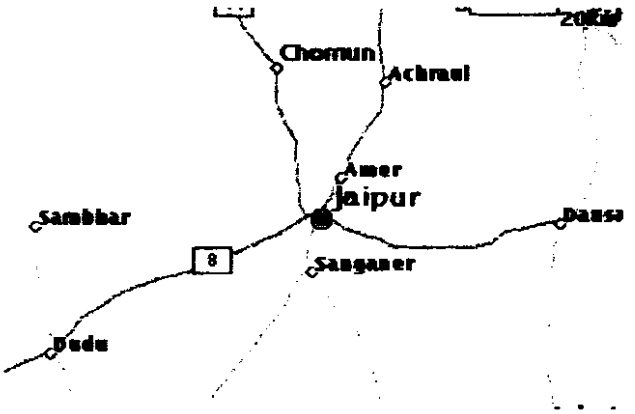
ANNEX E:
TNA SITE ASSESSMENT—JAIPUR

TNA REPORT
METHANE RECOVERY AND RE-USE POTENTIAL IN INDIAN CITIES

CLIN 8—GEP PROJECT
GLOBAL ENERGY PARTNERS

Prepared by: Yazdani Consulting
Ramin Yazdani
for Global Energy Partners

Date: February 19, 2001



I. TNA SITE ASSESSMENT—Jaipur, India

a. **Current Solid Waste Management**
Jaipur is known as the pink city. This city is rich with architectural heritage in terms of traditional structures. The population of the city is over 2.5 million. This city is the third fastest growing city in India. The city is a big attraction for tourism both for the Indian national and international community.

On February 19, 2001 interviews were conducted with Dr. Manjit Singh, Chief Executive Officer and Dr. Dinesh Bhandari, Senior Health Officer of Jaipur Municipal Corporation. Listed below is the summary of this interview.

<u>Waste Handling and Separation, Storage and Processing</u>
There are 70 municipal wards in Jaipur that are responsible for collection, transportation and disposal of waste. They are managed by the zonal commissioners, health officers and sanitary staff officials. Sweeping of waste is done by about 7,000 people in the markets, tourist areas and the city. Dirt and silt in the surface drains are cleaned by 1,000 workers. Presently there is no segregation of collected waste and all collection if done manually. There are 3,300 locations where waste is collected. Only 320 of these locations have containers and with the rest wastes are stored on bare ground. Over 30,000 homes are in the city and only 25,000 homes have waste collection in designated containers. There are 10,000 apartments in the city. Organic and inorganic waste is stored separately and then it's mixed and transported. Two percent of the waste is made of 250 hospitals' and laboratory waste. Twenty-two percent of the waste is inert. About 60 percent of

waste collection is through 12 private contractors and 40 percent by the Jaipur city corporation. Tractors, trolleys, and trucks are used to transport waste and the . Corporation also uses a few hydraulic transportation vehicles for lifting of waste. The city's disposal of waste is accomplished by dumping it along the road sites (see photos below).

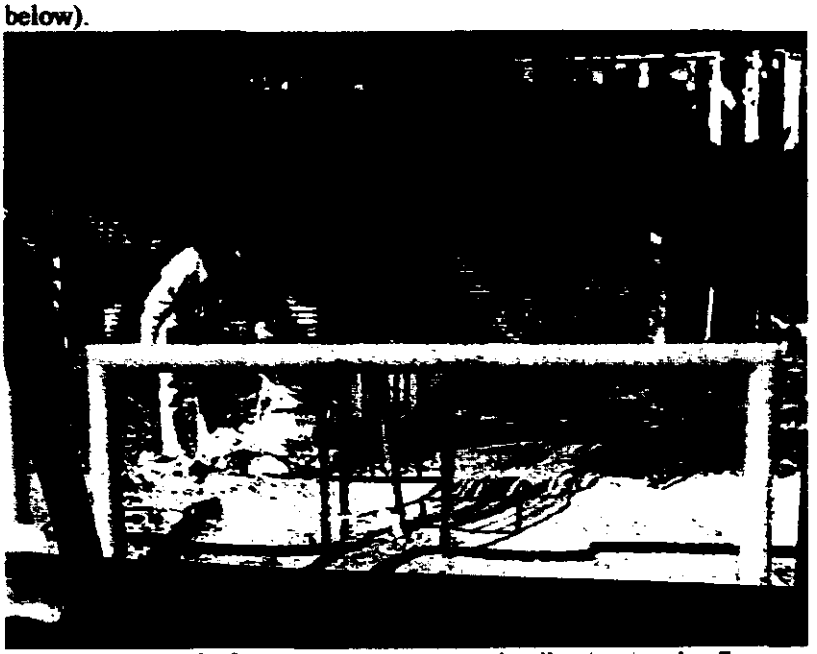


Photo 1- Disposal of waste along streets and collection in wheelbarrows

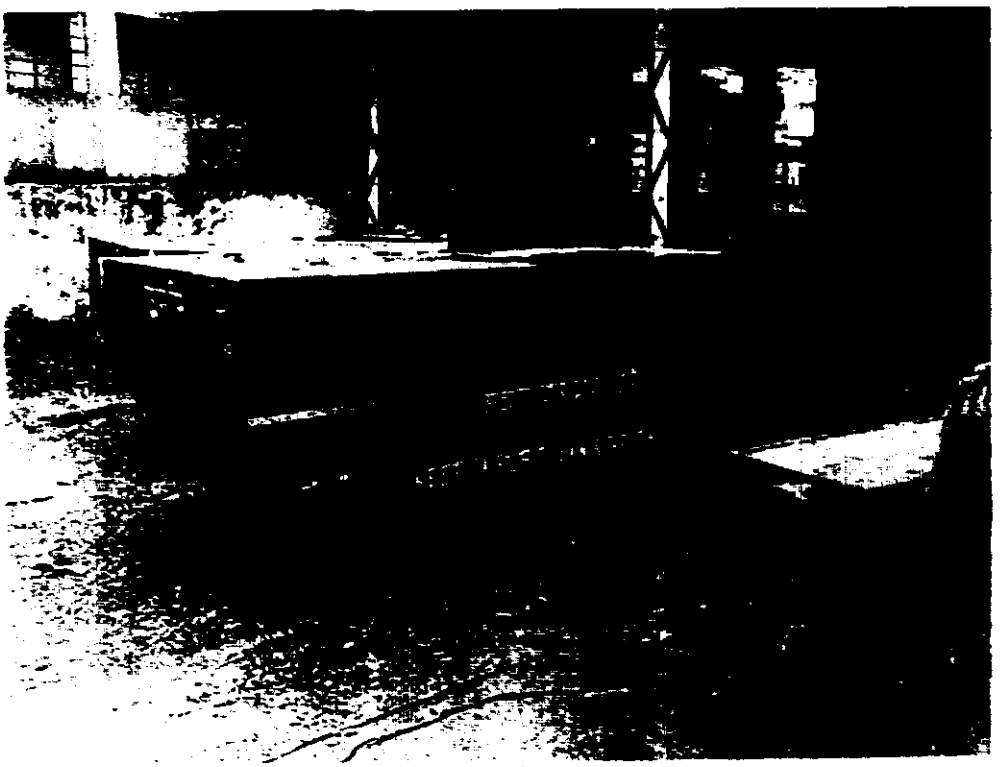


Photo 2- Bins used for collection of waste in Jaipur

Photo 3- Waste collection is done by front end loader

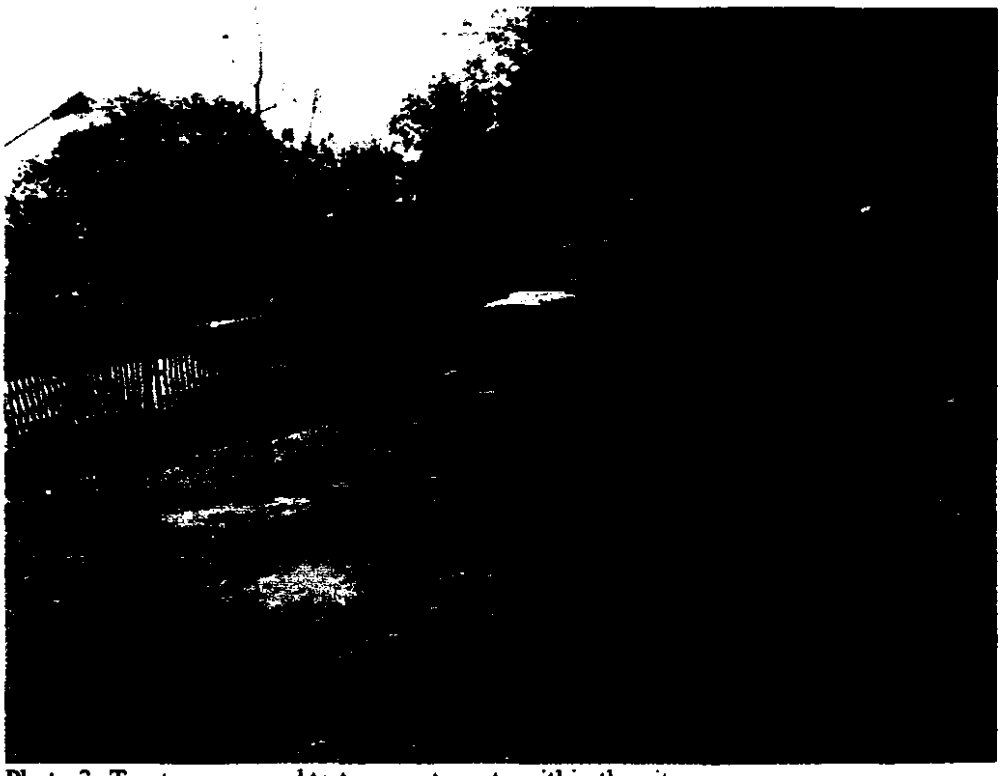


Photo 3- Tractors are used to transport waste within the city

Photo 4- Corporation's waste truck used to transport waste to the disposal sites

Waste Generation and Composition

The total waste generation for the city of Jaipur is 1,000 TPD. This is a mixture of municipal solid waste, hospital waste, and industrial waste. In addition, they received 220 TPD of inert material. The waste composition data provided by the city is as follows: a) metal 0.2-2.5%; b) glass 0.5-3.5%; c) garden waste 40-60%; d) paper 1-10%; e) textile 1-5%; f) plastic/rubber 1-5%; g) inert 20-50%. Moisture content of the waste is 40-80% and the density of the waste is 250-500 kg per cubic meter.

Land Method of Solid Waste Disposal

There are four sites for disposal of waste. One of the sites is called Lakhera village. This site is 55 acres in size and is located about 12 kilometers outside of the city towards Agra. Waste is dumped in a natural depression of depth about 9 to 12 meters (see photos below). The groundwater table is about 30 meters below the ground. Areas of the disposal site have been set on fire by rag pickers. The first site started accepting waste about 6 years ago. About 300-400 TPD of waste was taken to this site. The site soil is silty/sand soil.

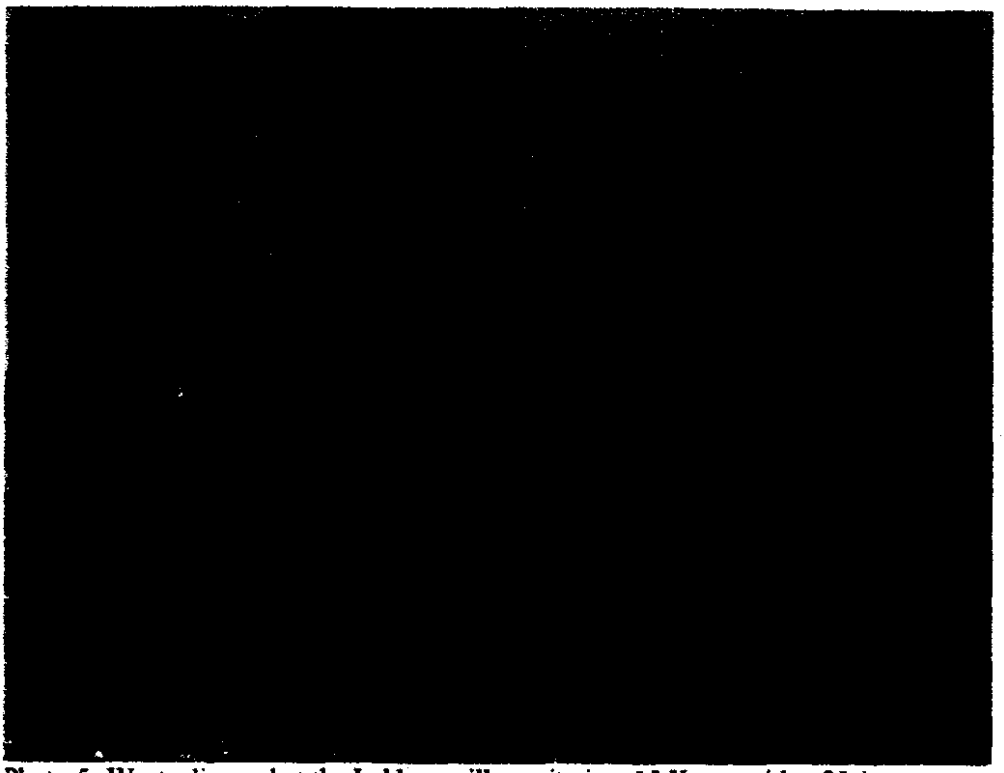


Photo 5- Waste disposal at the Lakhera village site just 15 Km outside of Jaipur

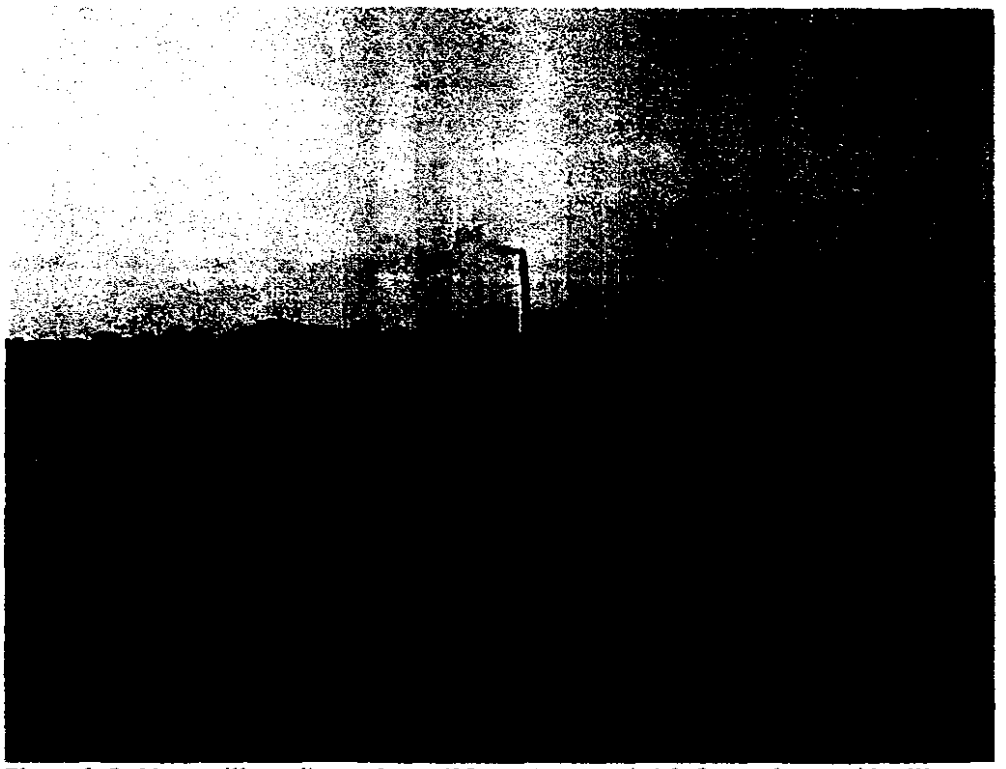


Photo 6- Lakhera village disposal site (55acres) near a brick factor that could utilize landfill gas as direct fuel source

Photo 7- Natural ravines are filled and compacted with waste at the Lakhera village disposal site

Other Methods of Waste Disposal

The city is working on finalizing an agreement with Energy Development Limited India Pvt. Ltd company to setup a waste to energy gasification project that is based on an Australian technology. According to EDL proposal the facility would use 600 TPD of waste for energy production of about 11 MW. The facility will be located about 15 Km outside of the city and will be constructed in 24 months and will be operated under a BOO basis. The corporation will provide the contractor with land for the construction of this facility.

A NGO company called Center for Development and Composting (CDC) is vermi-composting the waste from 25,000 homes, 50 tons of waste. The city has provided one hectare of land and about 50 TPD of waste. The city plans to vermi-compost additional 430 TPD of restaurant waste.

Climatic Conditions

The average annual rainfall in the area is not known. The maximum average daily ambient temperature is 45C.

Distance to Power Grid

The distance to the power grid is about one kilometer.

Requested information by the municipality

During the interview the following issues were identified to be of interest by the municipality: a) the corporation is interesting in landfill gas-to-energy proposal and would consider such a project; b) additional training in needed in understanding the operation and siting of sanitary landfills.

ANNEX F:
PRESENTATION SLIDES OF GREG WIKLER

METHANE RECOVERY AND RE-USE

Mr. Gregory A. Wilder
Principal
Global Energy Partners, LLC
Lafayette, California USA

USAID/USAEP/NIUA
Seminar on Climate Change & Cities

Hyderabad, India
December 8, 2000

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Presentation Summary

- Overview of Methane Utilization Technology
- Review of Methane Recovery and Re-Use Practices in the United States
  - Overview
  - Representative Case Studies
- Methane Utilization Relevancy for India

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What is Methane Recovery?

- In a landfill the anaerobic microbiological processes transform organic waste into usable CH_4 that can power engines or turbines to produce electricity
- Two recovery methods:
  - » Dry: Conventional landfill management practice utilizing gas methane extraction techniques
  - » Wet: Advanced development with liquid added to enhance the quality and quantity of extracted methane gas → a "bioreactor" landfill

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US Methane Output and Recovery

Characteristic	By Weight Tg (teragrams)	Carbon Equivalent MMTCE
Annual Landfill Methane Output	11.6	66.7
Reduction Efforts		
Current Annual	1.5	12.0
Future Annual Potential	4.0 to 6.0	24.0 to 36.0
Annual Reductions Resulting from Energy Projects	0.3	2.0

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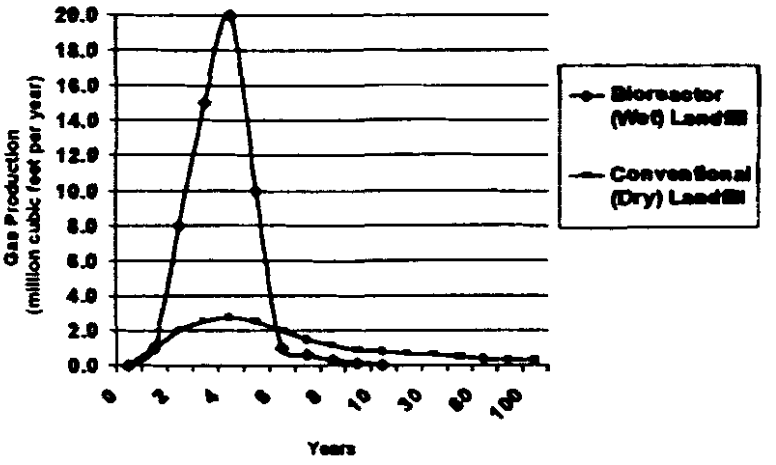
Methane Gas Production for Different Types of Landfills



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Bioreactor Landfill Attributes

- Rapid organic waste conversion and stabilization translates to greater greenhouse gas reductions and improved local environmental conditions
- Liquid waste could beneficially be added to landfill
- Methane gas can be captured and used for cost-effective energy projects
- Landfill space capacity is increased and utilized more efficiently
- Post-closure care, maintenance and risk are all reduced

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Methane Recovery and Re-Use Practices in the US

- According to the US Environmental Protection Agency, in the US there are over 270 landfill gas recovery and utilization projects
- About 500 other landfill sites are potential candidates
- Bioreactor landfills are currently receiving attention as the state-of-the-art practice (less than 10% of total projects)
- Electricity generation of 814 MW with another 159 MW under construction
- Emission reduction benefits of 2 million tons CO_2
  - » Equivalent to planting 2 million acres of forests or removing 1.5 million polluting cars from the road

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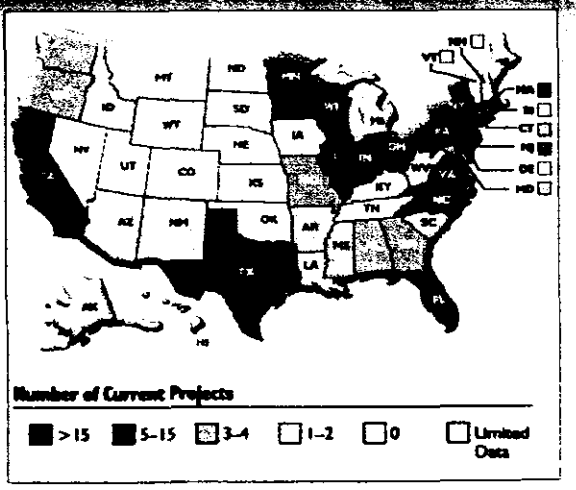
Methane Recovery and Re-Use



Number of Projects for Selected States:

- California: 56
- Illinois: 36
- Pennsylvania: 20
- New York: 18
- New Jersey: 14
- Florida: 9
- Texas: 7

Source: USEPA Landfill Methane Outreach Program

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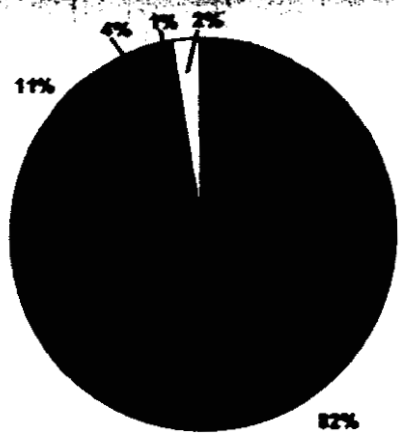
Generation Technologies Employed



- Reciprocating Engine
- Gas Turbine
- Steam Turbine
- Combined Cycle
- Other

Average Per Facility Capacity	
Reciprocating Engine:	3,000 kW
Gas Turbine:	8,037 kW
Steam Turbine:	14,300 kW
Combined Cycle:	15,667 kW

Source: USEPA Landfill Methane Outreach Program

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US Sample Statistics

Characteristic	Typical US
Organic Waste Composition	
Paper	34%
Plastics	7%
Miscellaneous Organics	30%
Total Organic	71%
Inorganic Waste Composition	29%
Methane Production (ft^3 per ton waste)	2,000
Energy Production (Btu per ton waste)	1,000,000
Energy Production (kW-Hr per ton waste)	174
Landfill with Waste Inflow of 1,000 tons/day Electricity Production (Megawatt)	7.25
Electricity Would Serve (number of homes)	7,000

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Case Studies

Conventional Techniques:

- Prince Georges County, Maryland
- San Diego County, California

Advanced Techniques (Bioreactor):

- Yolo County, California
- Other examples

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Brown Station Road Landfill, Maryland

- General Characteristics
  - Opened in 1960 with gas recovery operations commencing in 1987
  - Waste in place: 4 million tons at a depth of 100 feet
  - Capital investment of US$ 6.1 million with annual operating cost of US$ 400,000
- Gas Extraction/Generation System
  - 29 active gas wells
  - Gas collection rate of 1 million cubic feet of landfill gas per day
  - Electric generation capacity 2,300 kW using reciprocating engine
  - Space heating provided for adjacent correctional facility displacing over 700,000 gallons of fuel oil each year
- Lessons Learned
  - Early engine seizures due to high oil deposit/contaminant buildup
  - Problems are resolved through more frequent maintenance

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Source: Report by USEPA Landfill Gas Energy Utilization

Sycamore Canyon Landfill, California

- General Characteristics
  - Opened in 1962 with gas recovery operations commencing in 1989
  - Waste in place: 30 million tons at closure in 1989
  - Capital investment of US$ 4 million with annual operating cost of US$ 400,000
- Gas Extraction/Generation System
  - 50 active gas wells
  - Gas collection rate of 1.2 million cubic feet of landfill gas per day
  - Electric generation capacity of 1,300 kW using recuperated gas turbines with power sold to the local electric utility (SDG&E)
- Lessons Learned
  - Poor gas quality resulting from increased parasitic loads due to gas compression have led to equipment performance problems

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Yolo County Landfill

- Basic Characteristics
  - Site opened in 1975 with planned closure in 2021
  - Four million tons of waste in place
  - 150 gas extraction wells
- Project Cost
  - Capital investment: US$1.8 million; operating cost of US$120,000/yr
- Landfill Bioreactor Demonstration Project Features
  - Two test cells (control & enhanced) covering 0.54 acres with about 9,000 tons of refuse in each cell
  - Double lined leak detection system and compacted clay sidewalls
- Energy Production from 4 million tons of waste
  - 1,700 kW generated from 5 reciprocating engines (Caterpillar)
  - Permitted for an additional 300 kW

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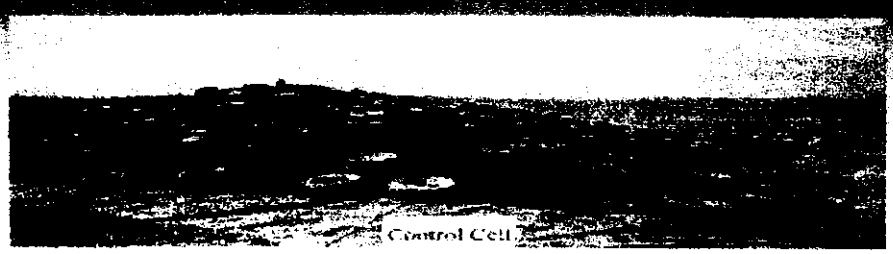
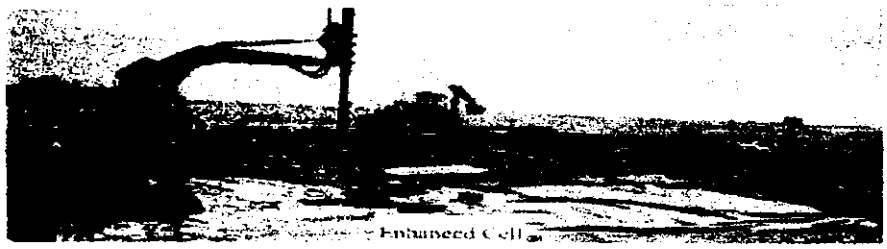
Yolo County Project Photos





Source: Yolo County Planning and Public Works Department

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Typical Gas Collection and Power Generation Engine

Caterpillar 3516 800 kW genset

Gas Collection Well

Source: Yolo County Planning and Public Works Department

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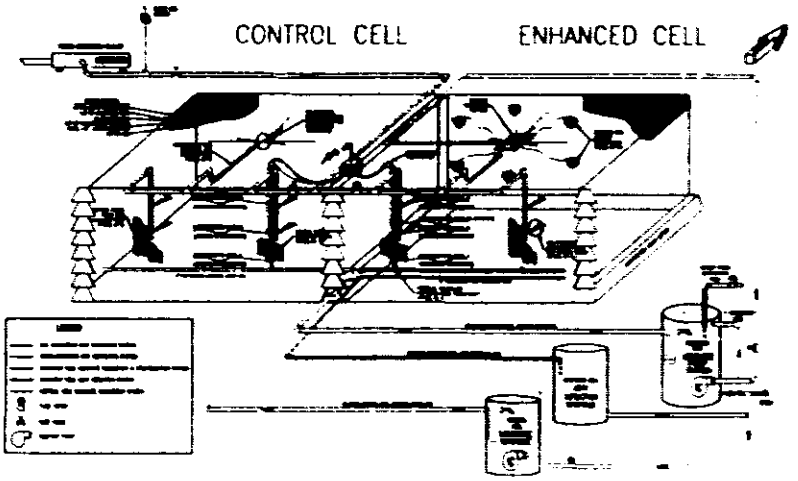
YOLO COUNTY BIOREACTOR DEMONSTRATION PROJECT



Source: Yolo County Planning and Public Works Department

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Other Cutting Edge Examples

- **California:** The state recently allocated $400,000 to establish a full-scale bioreactor landfill demonstration project at Yolo County Landfill
- **Delaware:** The state waste authority has operated a major landfill bioreactor for over 10 years
- **Florida:** The state recently allocated more than $3.2 million to establish a bioreactor landfill demonstration
- **Georgia:** Two aerobic bioreactor landfill projects are operational and producing electricity
- **Iowa:** State grants are provided to support bioreactor projects
- **New York State:** Several bioreactor operations are being carried out at various locations
- **Washington State:** Project support through state law has yielded a number of bioreactor sites

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Relevancy for India

- According to US-EPA, excellent potential exists for methane recovery and re-use in India
  - » Waste volumes are high
  - » Heightened environmental pressures
  - » Estimated annual reductions of 2.4 MMTCE representing up to 50% of India's methane emissions
- Composition of waste would need to be further assessed to determine potential methane gas production
- Technology is not highly complex and can be easily transferred

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Estimations for India

Characteristic	Estimated India
Organic Waste Composition	
Paper	7.5%
Plastics	3.2%
Miscellaneous Organics	43%
Total Organic	54%
Inorganic Waste Composition	46%
Methane Production (ft^3 per ton waste)	500
Energy Production (Btu per ton waste)	497,500
Energy Production (kW-Hr per ton waste)	44
Landfill with Waste Inflow of 1,000 tons/day Electricity Production (Megawatt)	1.83
Electricity Would Serve (number of people)	6,000

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GEP Project–CLIN 8
Methane Recovery and Re-use Potential

- Develop Municipality Screening/Selection Criteria
  - Collection of important data such as population, industrial mix, waste volumes, landfills, electric grid, etc.
- Training Needs Assessment (TNA) Mission
  - Site visits to selected cities
  - Examination of current solid waste management practices
  - Assessment of methane recovery and re-use potential at each site
- Develop Detailed Training Plan
  - Development of comprehensive training plan based on the findings and recommendations from the TNA mission

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References

- US Environmental Protection Agency
  - Primer on Landfills (www.epa.gov/ghginfo/02-Landfills.pdf)
  - Landfill Methane Outreach Program(www.epa.gov/lmop)
  - Options for Reducting Methane Emissions Internationally (www.epa.gov/ghginfo/2opt1.htm)
  - Landfill Gas Energy Utilization Technology Options (EPA-600/R-92-116) dated June 1992
  - Project XL to develop innovative approaches that provide superior environmental protection (www.epa.gov/projectxl)
- Yolo County Accelerated Gas Generation for Energy Production project (www.yolocounty.org/org/ppw/dwm/bioreactor.htm)
- Volunteers in Technical Assistance (http://vdh.vita.org)
- University of Central Florida College of Engineering
- Various papers and research articles

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