Texas Transportation Institute
CENTER FOR AIR QUALITY STUDIES

Potential for Converting Landfill Gas to Liquefied Natural Gas in India

By
Josias Zietsman and Tara Ramani (TTI)
Rakesh Kumar and Sunil Kumar (NEERI)

Methane to Markets Partnership Expo
March 4, 2010

Texas Transportation Institute
CENTER FOR AIR QUALITY STUDIES

Overview

- **Increasing energy consumption**
- **Fossil fuel depletion**
- **Environmental impacts**
  - Pollutant emissions
  - Greenhouse gases
- **Landfill gas (LFG) as an alternative source of energy**

Texas Transportation Institute
CENTER FOR AIR QUALITY STUDIES

LFG as an Energy Source

- Contains methane (CH_4) - natural gas
- CH_4 is a major greenhouse gas (GHG)
- Beneficial to use LFG as energy source
- LFGTE examples – electricity, piped natural gas, transportation fuel

Texas Transportation Institute
CENTER FOR AIR QUALITY STUDIES

Project Goal

- Perform a “pre-feasibility” analysis
- Converting LFG to CNG to be used as fuel for refuse trucks in India
- Also assess other LFGTE options

Texas Transportation Institute
CENTER FOR AIR QUALITY STUDIES

Research Approach

- Study of MSW management operations in India
- Methodology to evaluate economic feasibility of LFGTE scenarios
- Application of methodology for three Mumbai landfills
- Conclusions and recommendations

Texas Transportation Institute
CENTER FOR AIR QUALITY STUDIES

Landfill Characteristics

- India landfills differ from US landfills
- MSW Management and Handling differ
- Special socio-economic issues

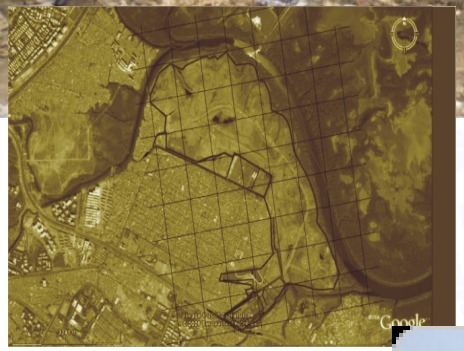
Texas Transportation Institute
CENTER FOR AIR QUALITY STUDIES

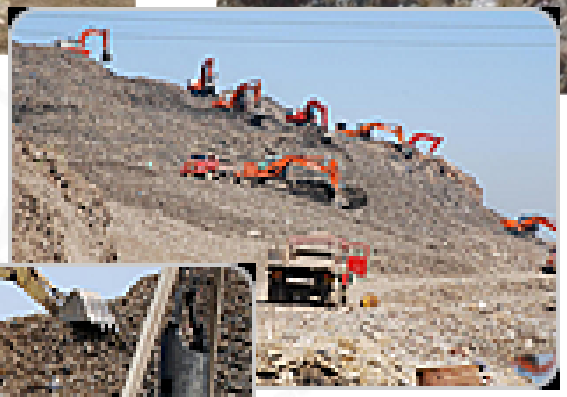
MSW Characteristics

- **Mumbai is a Mega City**
- **Approximately 9000 tons per day**
- **Waste composition**
  - 55% compostable
  - 20% recyclable
  - 25% other (including inerts)

Texas Transportation Institute
CENTER FOR AIR QUALITY STUDIES

Mumbai Case Study Landfills





Gorai

Texas Transportation Institute
CENTER FOR AIR QUALITY STUDIES

Landfill Site Details

Data	Site		
	Deonar	Mulund	Gorai
Landfill size	132.1 Ha	25 Ha	19.6 Ha
Waste in place	7.88 MT	1.50 MT	1.76 MT
Year filling began	1927	1968	1972
Closure year	Partial closure	Not yet planned	2008
Annual waste acceptance	1.5 MT	1.0 MT	0.4 MT

Texas Transportation Institute
CENTER FOR AIR QUALITY STUDIES

Model Development

Landfill Gas Generation → Refuse Truck Operations → Economic Feasibility

Texas Transportation Institute
CENTER FOR AIR QUALITY STUDIES

Analysis Scenarios

- **Landfill Management Options:**
  - Do Nothing;
  - Cap the landfill and flare; or
  - Flare from an active landfill.
- **LFGTE Options:**
  - Convert the LFG to CNG as fuel;
  - Convert the LFG to pipeline grade natural gas; or
  - Convert the LFG to electricity.

Texas Transportation Institute
CENTER FOR AIR QUALITY STUDIES

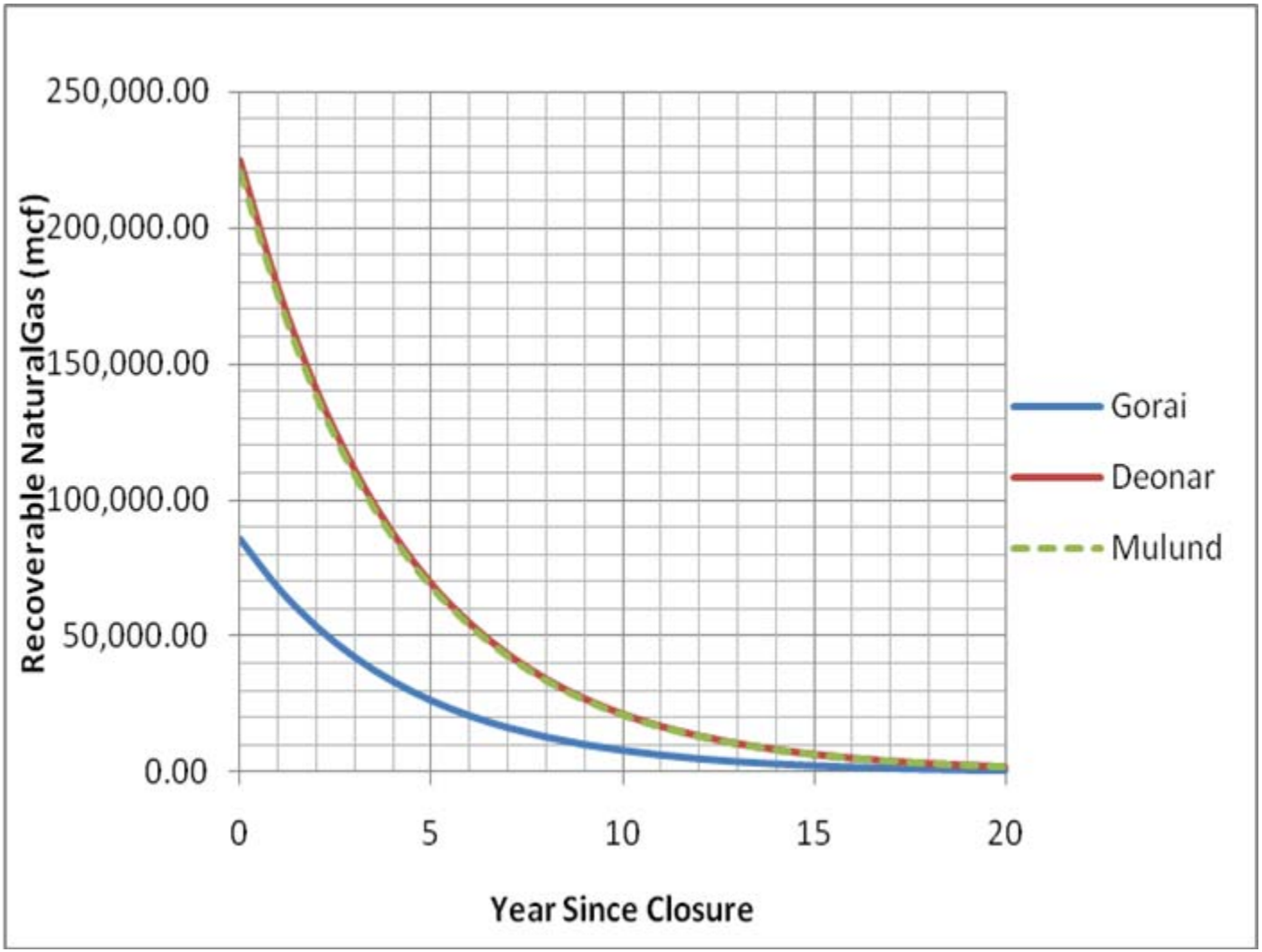
Estimation of LFG Generation

- **EPA model for a closed & active landfill**
- **Estimate LFG quantities**
- **Estimate recoverable biogas**
- **Estimate CNG or LNG quantity**

$$Q_t = 2 * L_0 * m_0 * \left(e^{k*t_a} - 1\right) * e^{-k*t}$$

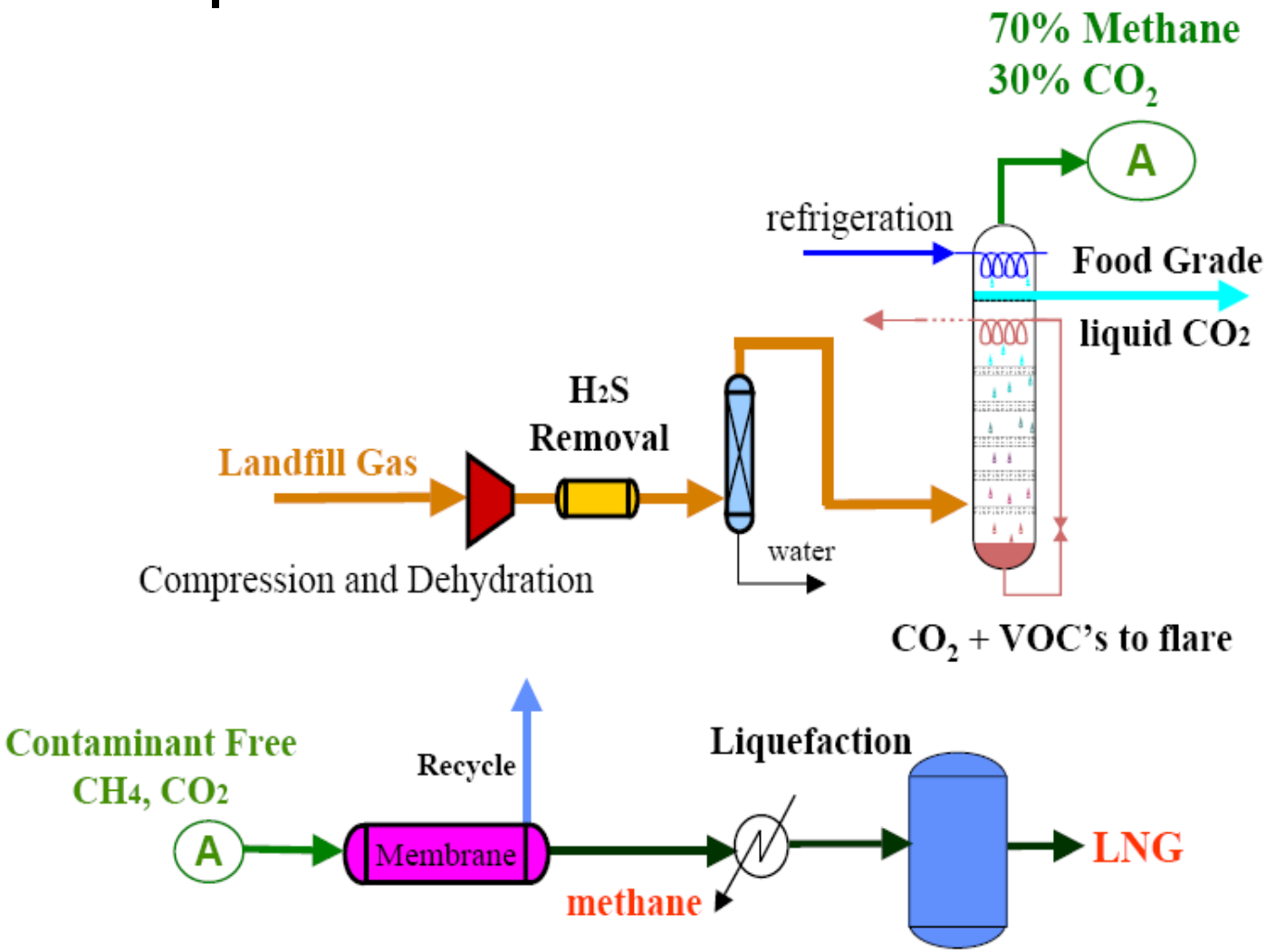
Texas Transportation Institute
CENTER FOR AIR QUALITY STUDIES

Estimated LFG Quantities



Texas Transportation Institute
CENTER FOR AIR QUALITY STUDIES

CO_2 Wash Process



Texas Transportation Institute
CENTER FOR AIR QUALITY STUDIES

CO_2 Wash Processor at EcoComplex

Texas Transportation Institute
CENTER FOR AIR QUALITY STUDIES

LNG Fueling Station

Texas Transportation Institute
CENTER FOR AIR QUALITY STUDIES

MSW Collection Fleet

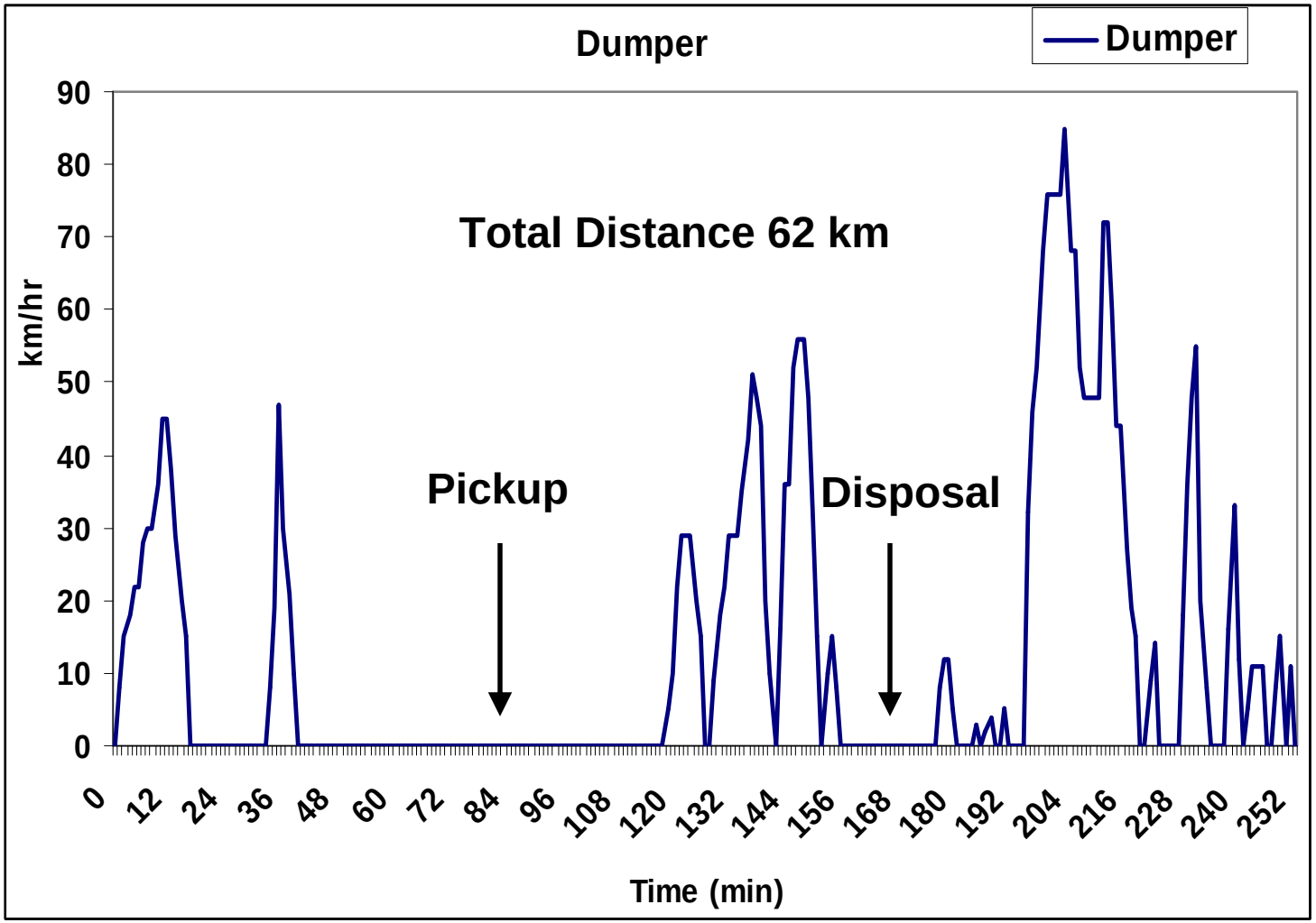
Compactor

Placer

Dumper

Texas Transportation Institute
CENTER FOR AIR QUALITY STUDIES

Speed Profile



Texas Transportation Institute
CENTER FOR AIR QUALITY STUDIES

Emission Differences for Diesel and CNG

- **Emission factors combined with driving profiles and fleet characteristics**

Parameters	ARAI Estimated Emission Factors (g/km)	
	For Diesel Vehicles	For CNG Vehicles
Carbon Monoxide (CO)	6.0	3.7
Hydrocarbons (HC)	0.4	3.7
NOx	9.3	6.2
Particulate Matter (PM)	1.2	Not Applicable

Texas Transportation Institute
CENTER FOR AIR QUALITY STUDIES

Costs Considered

- **As applicable:**
  - Landfill capping costs
  - CNG conversion facility cost
  - Pipeline natural gas facility cost
  - Electricity plant costs
  - Flaring system costs
  - System and landfill operational costs
  - Truck fleet operational and replacement
  - Costs of emissions

Texas Transportation Institute
CENTER FOR AIR QUALITY STUDIES

Benefits Considered

- **As applicable:**
  - Diesel fuel savings
  - Earnings from sale of natural gas
  - Earnings from sale of electricity
  - Carbon credit earnings
  - Emissions reductions

Texas Transportation Institute
CENTER FOR AIR QUALITY STUDIES

Estimation of Net Return

- Costs and benefits brought to NPV
- 20 year analysis period
- Net return – difference between NPV of benefits and costs
- B-C Ratio – [NPV of benefits/NPV of costs]

Texas Transportation Institute
CENTER FOR AIR QUALITY STUDIES

Additional Analysis – without Capping Costs

- Cost of capping and collection system is significant
- Capping has many social and environmental benefits
- Possibility of obtaining funds for this from other sources (i.e. grants)
- Alternative analysis without capping costs was also performed.

Texas Transportation Institute
CENTER FOR AIR QUALITY STUDIES

Analysis Results

Scenario	Gorai		Deonar		Mulund	
	Net Benefit ($)	Return (%)	Net Benefit ($)	Return (%)	Net Benefit ($)	Return (%)
Landfill Management Options						
Scenario 1: Do Nothing	$(17,015,502)	**N/A**	$ (44,693,492)	**N/A**	$(43,859,505)	**N/A**
Scenario 2: Cap the Landfill and Flare the LFG	$ (3,140,569)	**-31%**	$(7,870,880)	**-30%**	$5,252,208	**42%**
Scenario 3: Flare the LFG from an Active Landfill	$ (1,377,397)	**-16%**	$(18,025,538)	**-48%**	$8,389,332	**80%**
LFGTE Options						
Scenario 4: Convert LFG to CNG for Use as a Transportation Fuel	$ (7,375,991)	**-33%**	$ 465,457	**1%**	$ 13,208,186	**54%**
Scenario 5: Convert the LFG to Pipeline Grade Natural Gas	$ (9,374,035)	**-51%**	$ (11,718,243)	**-33%**	$ 1,332,408	**6%**
Scenario 6: Convert the LFG to Electricity	$ (3,719,716)	**-29%**	$ (15,788,418)	**-40%**	$ (1,965,718)	**-9%**

Texas Transportation Institute
CENTER FOR AIR QUALITY STUDIES

Additional Analysis – Without Capping Costs

Scenario	Gorai		Deonar		Mulund	
	Net Benefit ($)	Return (%)	Net Benefit ($)	Return (%)	Net Benefit ($)	Return (%)
Scenario 4: Convert LFG to CNG for Use as a Transportation Fuel	$ (1,665,390)	**-10%**	$ 22,084,157	**135%**	$ 21,366,186	**130%**
Scenario 5: Convert the LFG to Pipeline Grade Natural Gas	$ (3,663,435)	**-29%**	$ 9,900,457	**70%**	$ 9,490,408	**67%**
Scenario 6: Convert the LFG to Electricity	$ 1,990,884	**28%**	$ 5,830,282	**33%**	$ 6,192,282	**46%**

Texas Transportation Institute
CENTER FOR AIR QUALITY STUDIES

Concluding Remarks

- LFGTE is an important consideration
- Pre-feasibility study based on conservative assumptions
- Methodology can be applied to different landfills
- Some India landfills have potential
- LFG to CNG for refuse trucks is a promising option
- Full feasibility analysis is required