LFG Generators

Gorai Dumping Ground

- In use since 1973.
- Unlined, uncovered dumping ground.
- Up to 17 m high, total area = 19 ha, main mound is about 10 ha.
- Manori Creek (estuary) to the west, marsh/mangrove to the north and northeast.
- Residential/commercial 400 m to the south.
- Slums between residential and the landfill.

Stakeholders

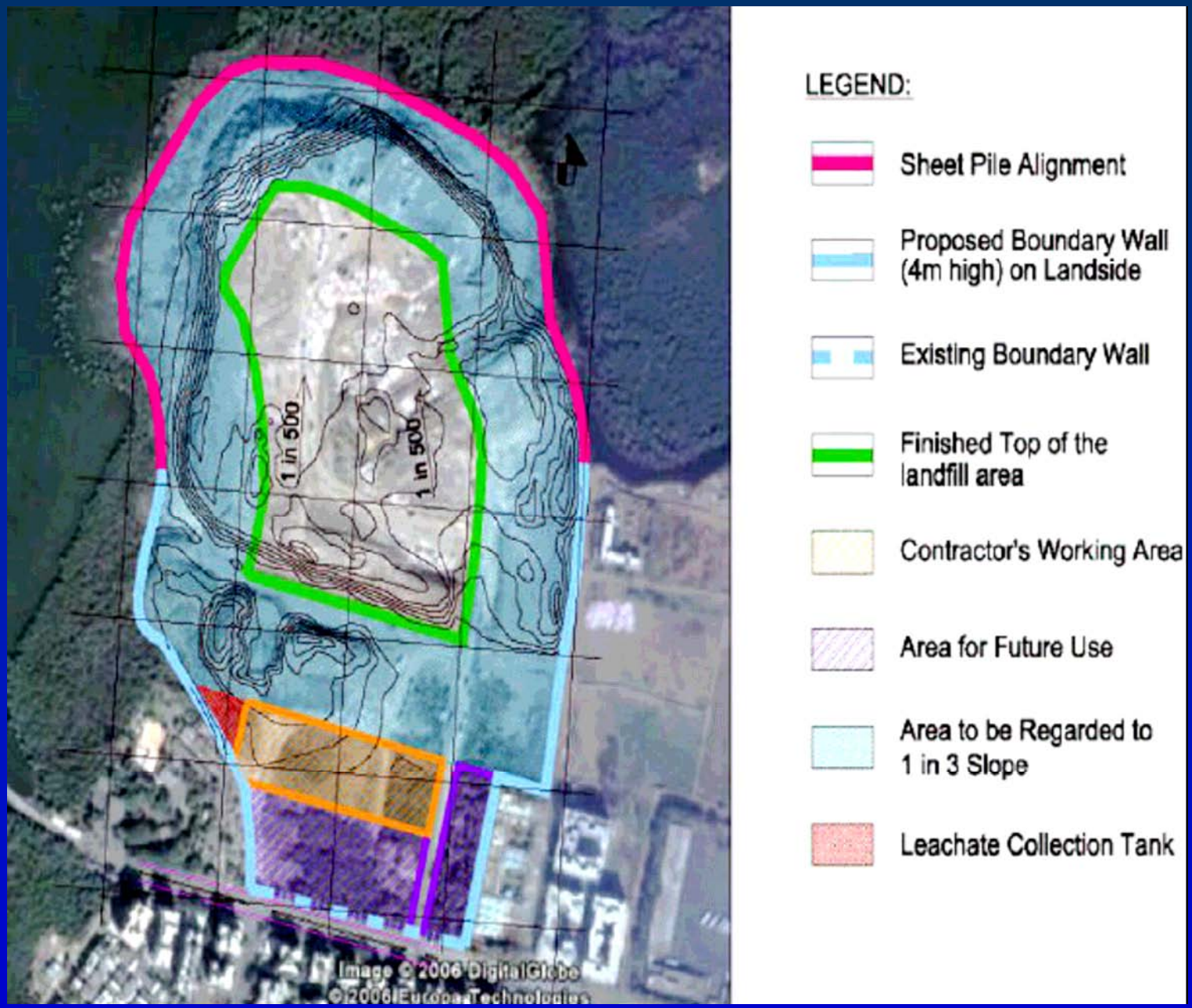
- Municipal Corporation of Greater Mumbai (MCGM): site owner.
- Future landfill operator: being selected by MCGM.
- Tata Power: local utility, interested in developing and operating LFG to energy at the site.
- Neighboring communities: organized in Societies, have longstanding complaints about the dump.
- Scavengers: hundreds of extremely poor informal scavengers eke out a living on the dump.
- Others: US agencies, Government of India, NGOs, investors, carbon credit brokers, etc.

Status

- The Gorai landfill causes widespread odor nuisance, which has led to court action.
- It is under a court order to close at the end of 2007.
- MCGM has contracted out the closure, including construction of a cap and LFG recovery system.
- The fate of the scavengers after the closure is unknown.
- Social intervention could allow access to the Community Development Carbon Fund of the World Bank, worth an additional US$ 0.5-1.5/ ton CO_2e (Rs. 25-65).

Gorai Location Map

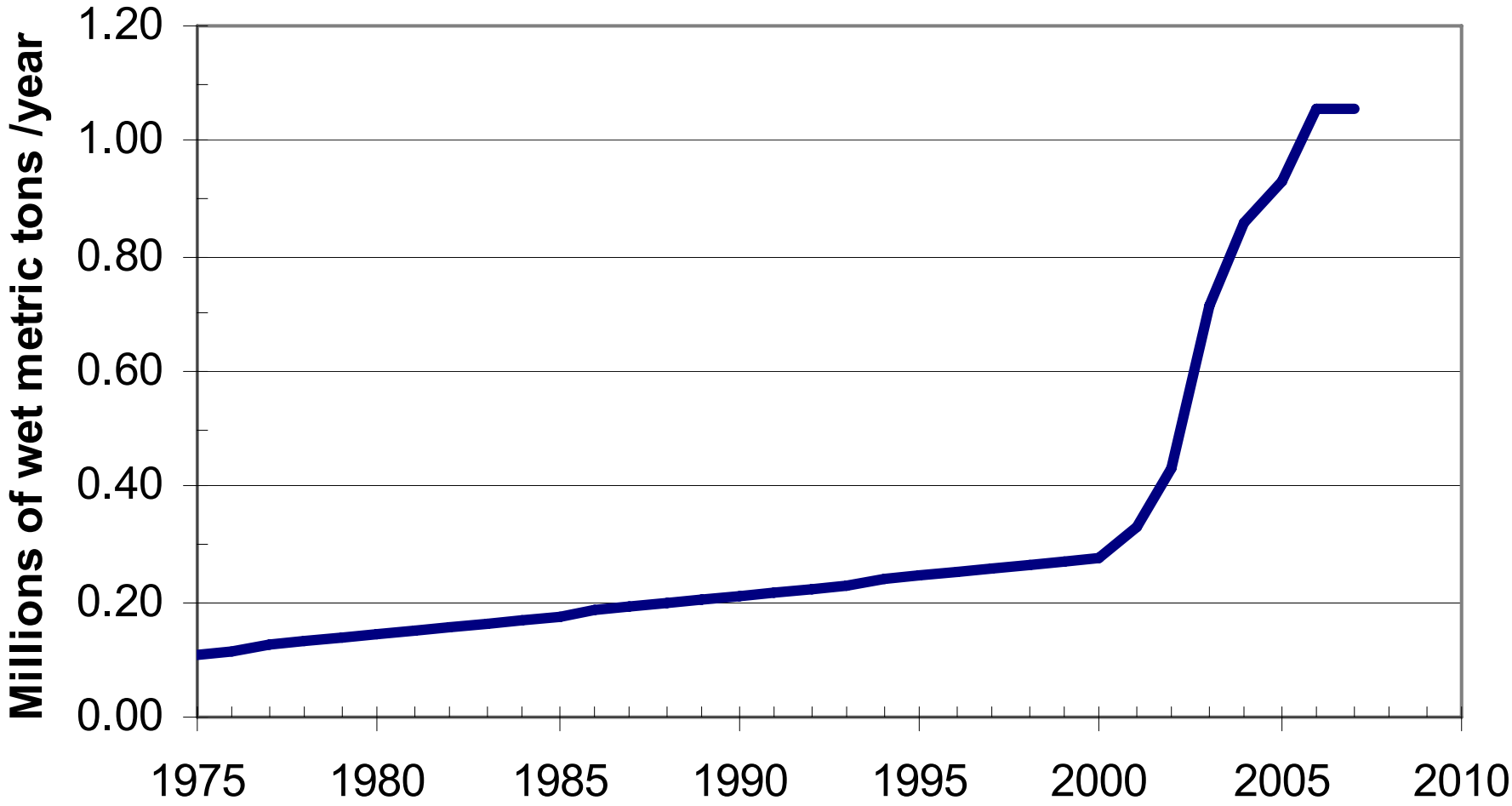
Gorai Aerial Photograph



Gorai Side View

Gorai Side View

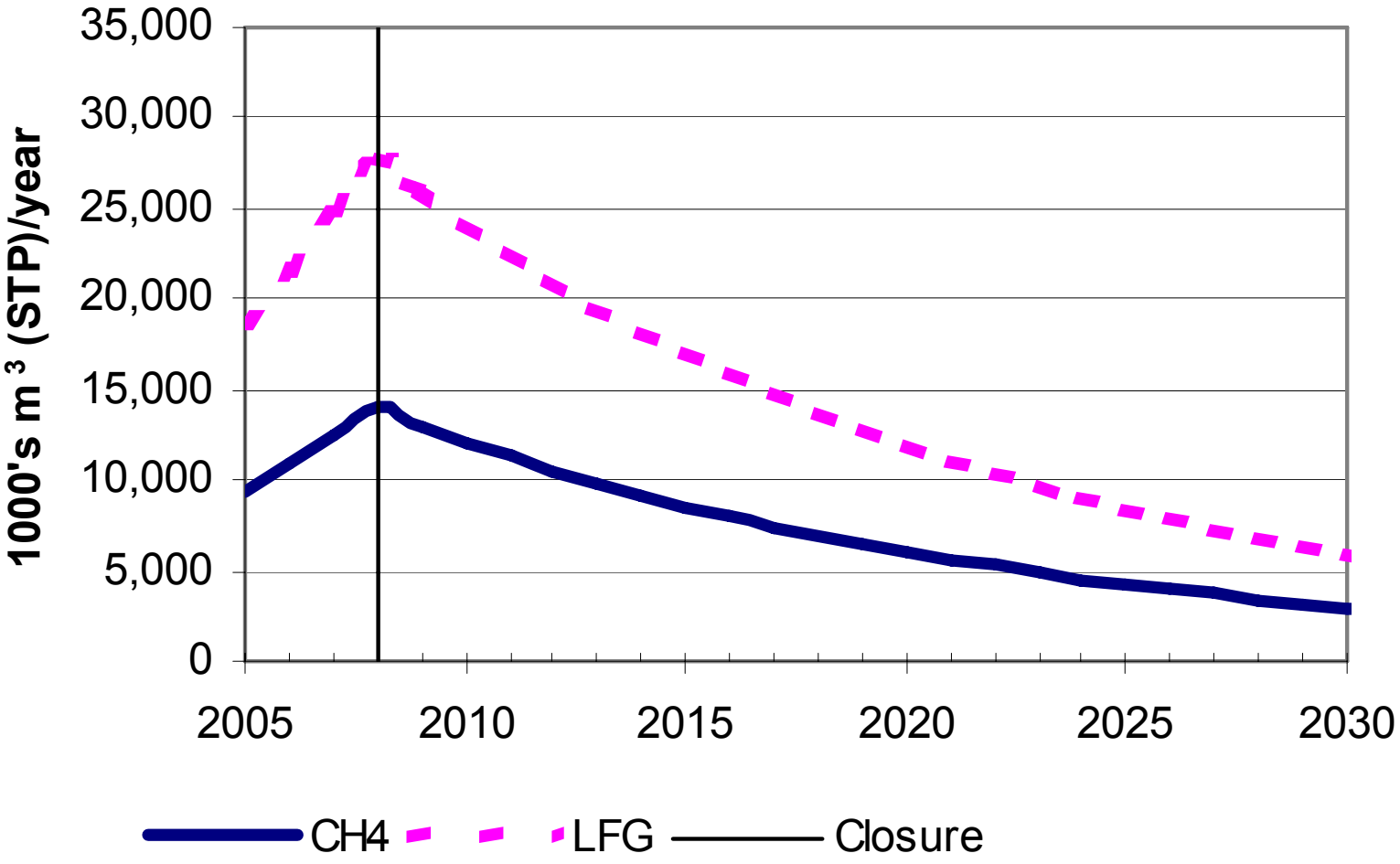
Gorai Landfill Historical Dumping Rate (Estimated)



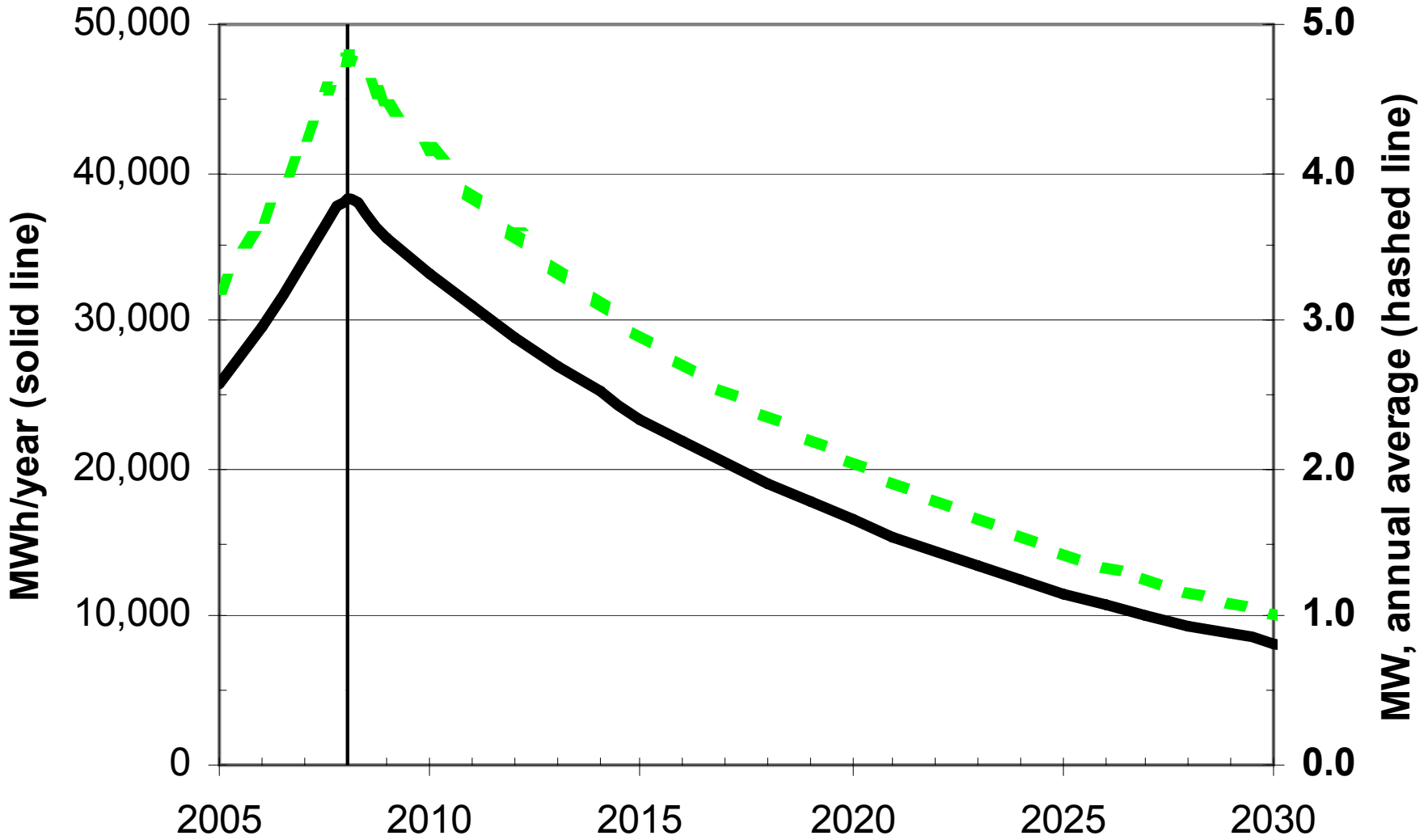
Projected energy potential

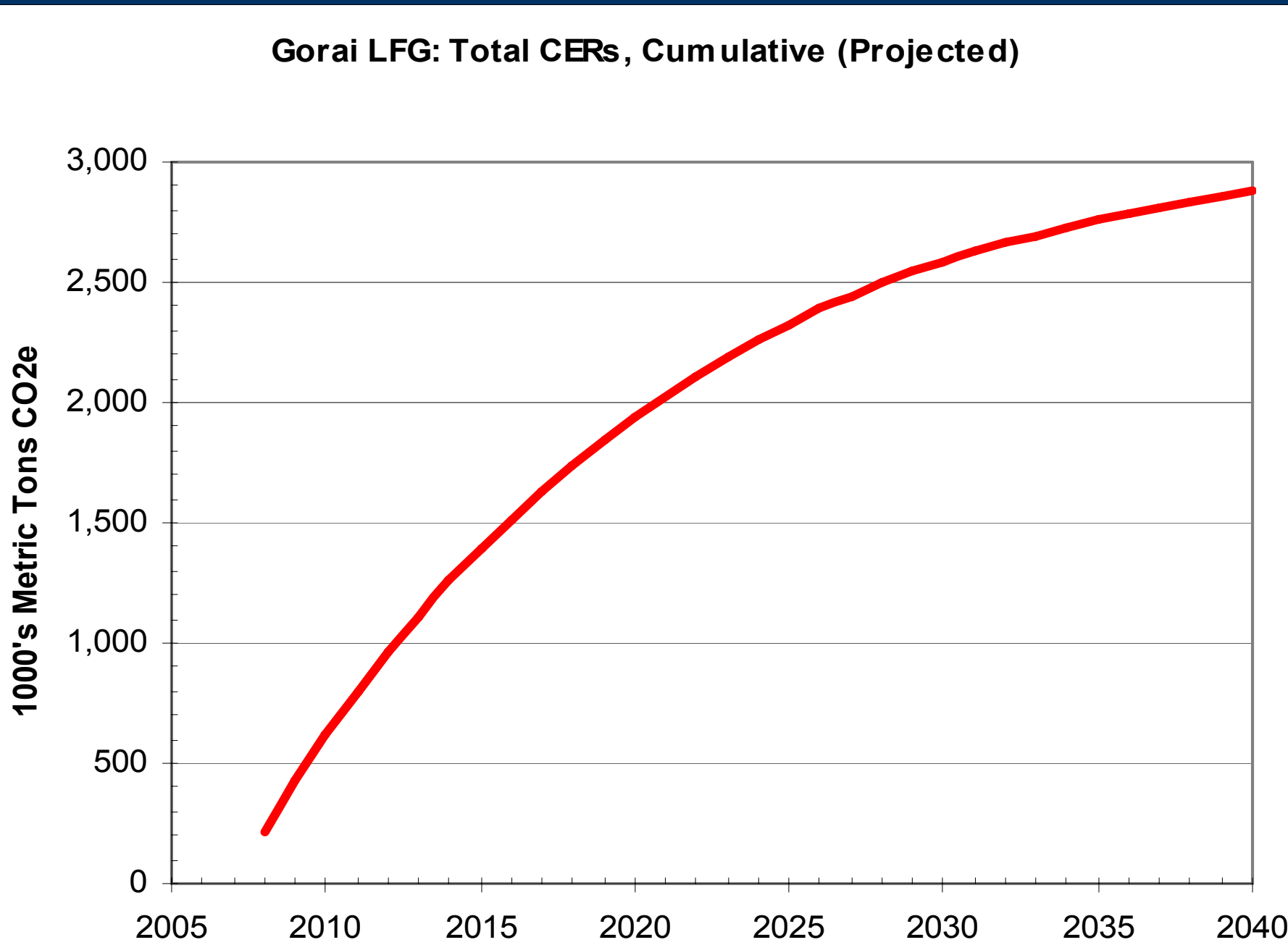
- 1st order model of LFG production, LandGEM (US EPA).
- Key parameters assumed
  - k = 0.07 $year^{-1}$;
  - L_0 = 47 m^3 CH_4/wet metric ton;
  - LFG recovery = 70%, after cap in place.
- Other assumptions: 30% LFG to power efficiency; 3000 ppmV H_2S.

Gorai Landfill: Projected LFG and Methane Recovery



Gorai Landfill: Projected Electricity from LFG




Gorai LFG: Total CERs, Cumulative (Projected)
1000's Metric Tons CO2e
3,000
2,500
2,000
1,500
1,000
500
0
2005
2010
2015
2020
2025
2030
2035
2040

Characteristics of Gorai's LFG

- Sampled and analyzed in May 2005.
- Methane and CO_2 content normal.
- $10{,}000^{+}$ ppmV of carbon monoxide (CO): indicates widespread landfill fires, which may have consumed part of the organic resource in the landfill.
- $10{,}000^{+}$ ppmV H_2S: also unusual, may require extensive LFG treatment to protect the generator engines.
- Gorai's LFG is hazardous to human life, and this warrants special precautions to protect the workers during the capping and LFG recovery installation works.

Profitability analysis

- We examined the profitability of the whole project, without attributing costs and revenues to particular stakeholders.
- We focused on overall project profitability: look at entire cost including capping, and take credit for the carbon credits (CERs) resulting from methane interception and flaring, as well as all other revenue sources.
- One could also examine LFG utilization profitability: look at costs related to power generation and only take credit for power sales and CERs resulting from power plant fuel displacement.

Some base case assumptions

- Project life: 2008-2028 (20 years).
- Estimate includes H_2S treatment process, office buildings etc.
- 70/30 debt/equity; loan 9%, 10 years; return to investors (ROI) 20%/year.
- Electricity rate set at Rs. 3.60/kWh ($0.081) in 2007, with Rs. 0.11 increase per year initially.
- CERs: US$ 10/ton CO_2e (Rs. 446) until 2012, half of that after 2012.
- All unit costs and revenues increase 3.0% per year.

Capital cost
(Rs. millions)

- Reshaping and capping: 92
- LFG recovery system: 19
- LFG utilization system: 252
  - Generator system: 176
  - Chiller and H_2S removal: 11
  - Other (incl. buildings etc.): 65
- Total, with fees: 363

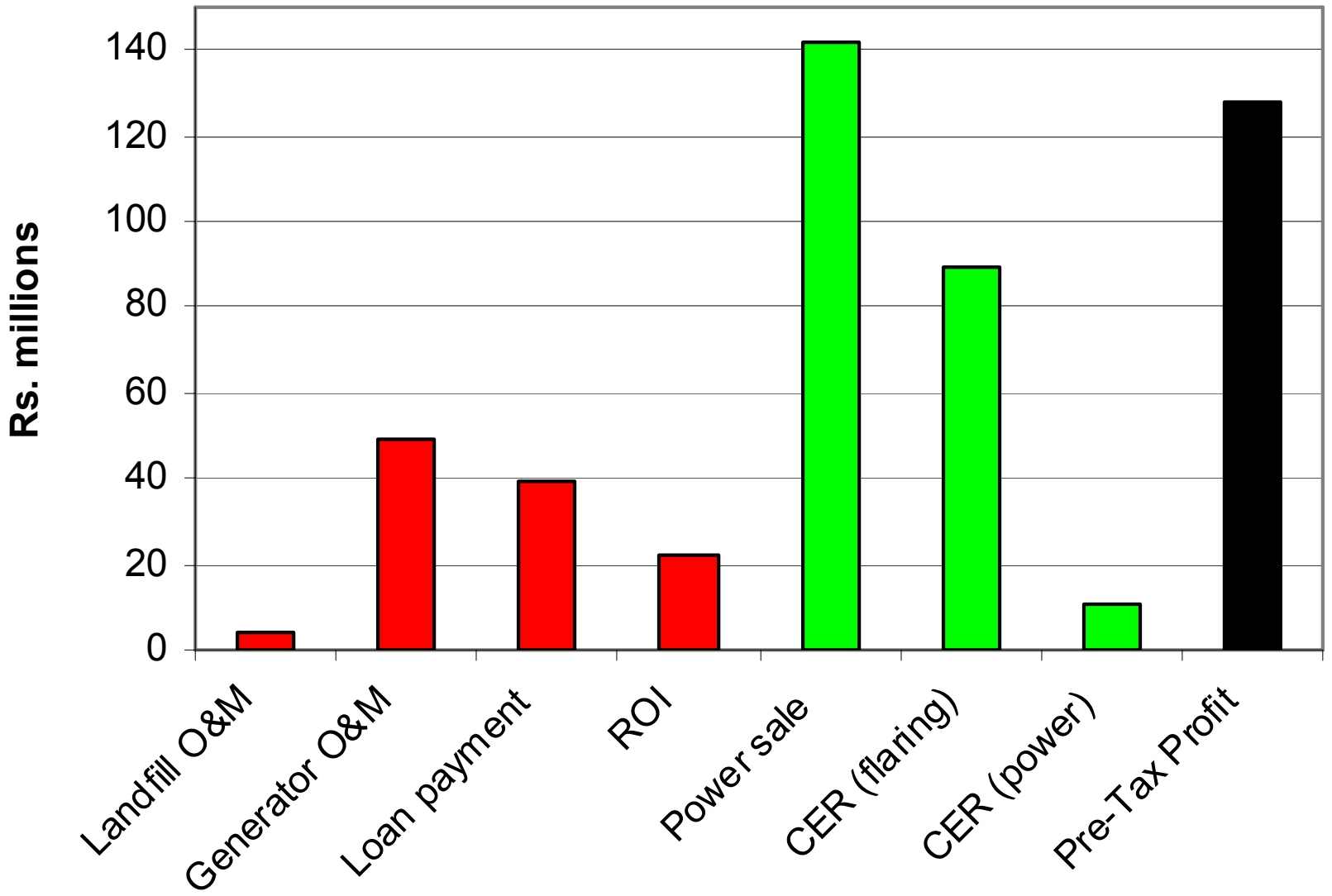
Year 1 recurring costs
(Rs. millions per year)

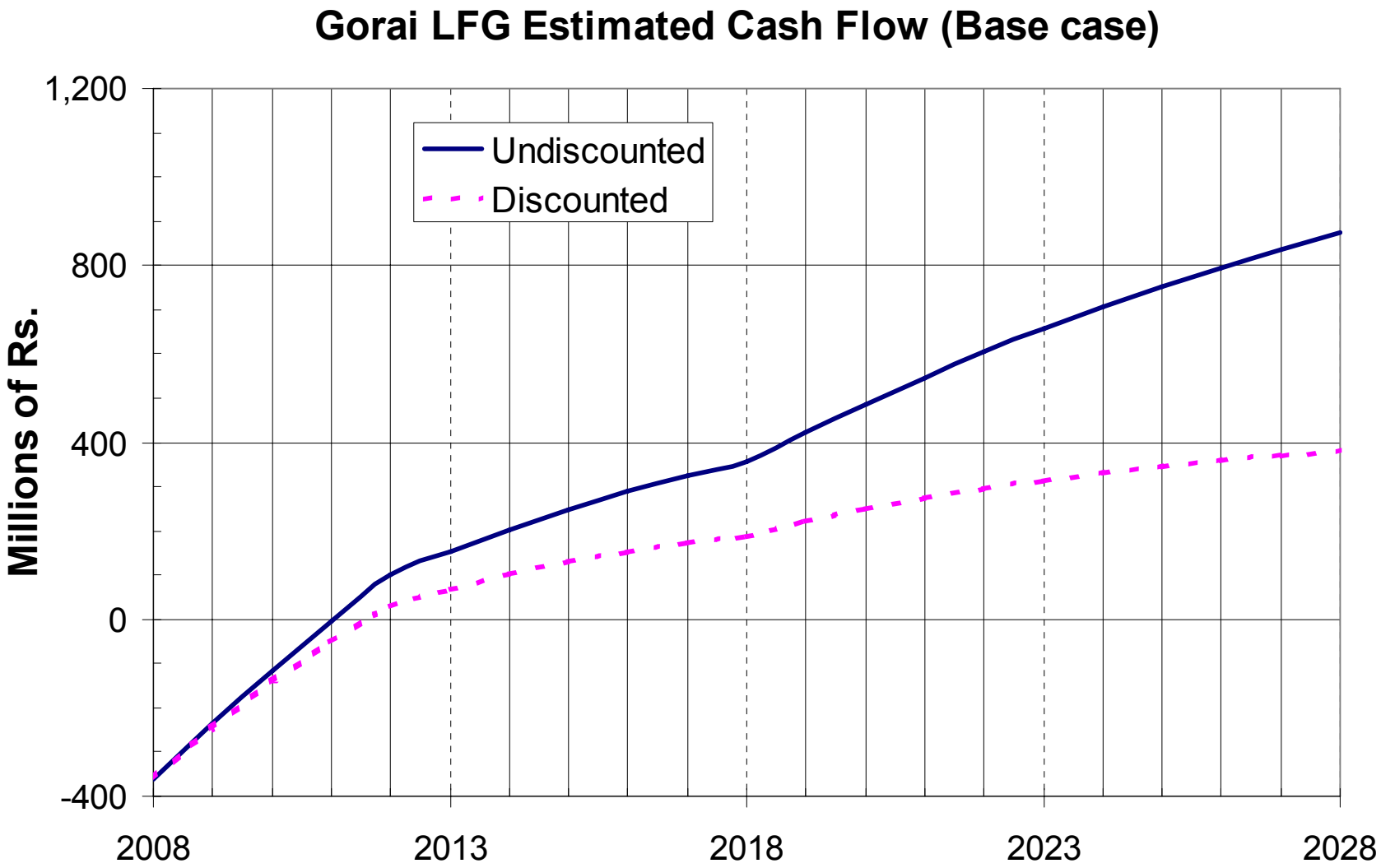
- Operation and Maintenance
  - Landfill cap and LFG recovery system: 4
  - LFG utilization system: 49
    - Generator O&M: 11
    - Sulfur residue disposal: 30
    - Other: 8
- Financing
  - Loan payments: 40
  - Investor return: 22
- Total recurring costs: 115

Year 1 revenues & profit
(Rs. millions/year)

- Electricity sales: 142
- CERs: 101
  - From methane interception: 90
  - From power plant fuel displacement: 11
- No market found for hot water, so far
- Total revenue: 242
- Pretax profit: 128

Year 1 Balance Sheet (Estimate)




Gorai LFG Estimated Cash Flow (Base case)
1,200
800
400
0
-400
Millions of Rs.
Undiscounted
Discounted
2008
2013
2018
2023
2028

Cost sensitivity scenarios

1) CER value 50% higher than base case: assume US$ 15/ton CO_2e (Rs. 668) until 2012, then half of that.
2) Sulfur disposal cost: assume half of US cost used for the base case, or $3/kg sulfur (Rs. 134).
3) Hot water sales: assume a buyer found at an equivalent natural gas price of $6.8/MMBtu (Rs. 286/GJ or Rs./10 m^3).
4) Poor LFG capture: assume LFG capture is 60%, down from 70% assumed in base case.

Cost sensitivities

Scenario	Simple Payback (years)	Net Present Value (Rs. Millions)	Internal rate of return
Base case	**3.0**	**356**	**24.2%**
Higher CER rate	2.1	621	38.5%
Lower sulfur disposal cost	2.6	501	30.4%
Hot water sales	2.0	796	43.1%
Poor LFG capture	4.0	192	16.4%

Recommendations

- Actual LFG production is uncertain due to poorly defined dumping history and modeling parameters, and losses due to aerobic decomposition and fires.
- LFG composition is unusual and could impact costs significantly, so it should be confirmed.
- Need to wait for recovery system to function, then measure both flow and LFG composition, repeat the economic analysis, and make the go/no go decision.
- First, however, a competent recovery system must be installed: it is essential that a landfill gas expert be involved in the 2007 Gorai closure project.

Recommendations (continued)

- Take precautions against toxic LFG (high H_2S and CO).
- The slopes are unstable and hazardous: the design must take this into account.
- Look for a hot water user.
- Check availability of equipment in Mumbai.
- Determine the regional cost of sulfur residue disposal.
- Structure a community benefits program.
- Coordinate multiple stakeholders!

Conclusions

- Efficient LFG to energy requires a landfill cap, i.e. a continued transition from dumps to landfills is necessary.
- Gorai has a substantial LFG potential, and the power market is strong (250 MW power shortage in Mumbai).
- Measure LFG flow and composition when the recovery system is functional, then decide whether to proceed or not.
- The Gorai project has the potential to prevent the emission of 2.5 million tons of CO_2e over the next 20 years.
- LFG to energy can be very profitable in India.
- LFG can displace 9% of India's natural gas demand.

Landfill Gas Potential of the Gorai Landfill; LFG Applicability to India

Funded by IUEP and USAID

Questions?

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