Methane to Markets

Modeling Landfill Biogas Generation for Different Countries

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Landfill Methane to Markets Workshop

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Presentation Topics

- Landfill biogas modeling overview
- Challenges of international biogas modeling
- Lessons learned from LMOP biogas modeling projects: Mexico and Thailand
- Using biogas modeling to evaluate suitability of landfills in India for project development

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Need for International Landfill Biogas Modeling

- Ratification of Kyoto Protocol has accelerated pace of landfill biogas project development, particularly in developing countries (CDM)
- U.S. EPA's Methane to Markets Partnership will further promote landfill biogas-to-energy projects internationally
- Good estimates of landfill biogas recovery needed to evaluate project feasibility and economics
  - Methane emission reductions – large source of revenue
  - International landfill biogas modeling in infancy – large source of error in evaluating projects

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Landfill Biogas Generation

- Factors affecting amount of landfill biogas production:
  - amount of waste
  - type of waste
  - age of waste
  - moisture content
  - temperature
  - pH
  - site conditions

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Landfill Biogas Model

- Most widely used model is the U.S. EPA's "Landfill gas generation model" (LandGEM)
- Model equation estimates annual landfill biogas generation
- Model estimates annual landfill biogas recovery

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Model Inputs

- Historic and projected waste disposal rates
- Methane decay rate (“k”)
- Methane generation potential (“Lo”)
- Collection efficiency

Model Equation

- Landfill biogas generation equation:

$$\sum_{i=1}^{n} 2\,k\,L_0\,M\,e^{-kt_i}$$

where:

k = refuse decay rate (1/yr)
L_0 = methane generation potential (m^3/tonne)
M = mass of waste deposited (tonnes) in year "i"
t_i = age of waste (years) in year "i"

Model Inputs – Methane Generation Potential (Lo)

- "L_0" – methane generation potential (units = m^3 methane per metric tonne of waste)
  - Total amount of methane 1 tonne of waste produces
  - Is mainly a function of waste composition – amount of organic waste
- Range of observed values:
  - 0 - 312 m^3 methane/tonne of waste
  - U.S. EPA default for U.S. landfills is 100 m^3/tonne (not 170 m^3/tonne, which is regulatory value)

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Model Inputs – Rate Constant (k)

- "k" – refuse decay rate constant (units = 1/year)
  - Sets rate of waste decay and methane production
  - Influenced by waste moisture – use annual rainfall
- Range of observed values:
  - 0.01/year (desert landfills) to 0.4/year ("bioreactors")

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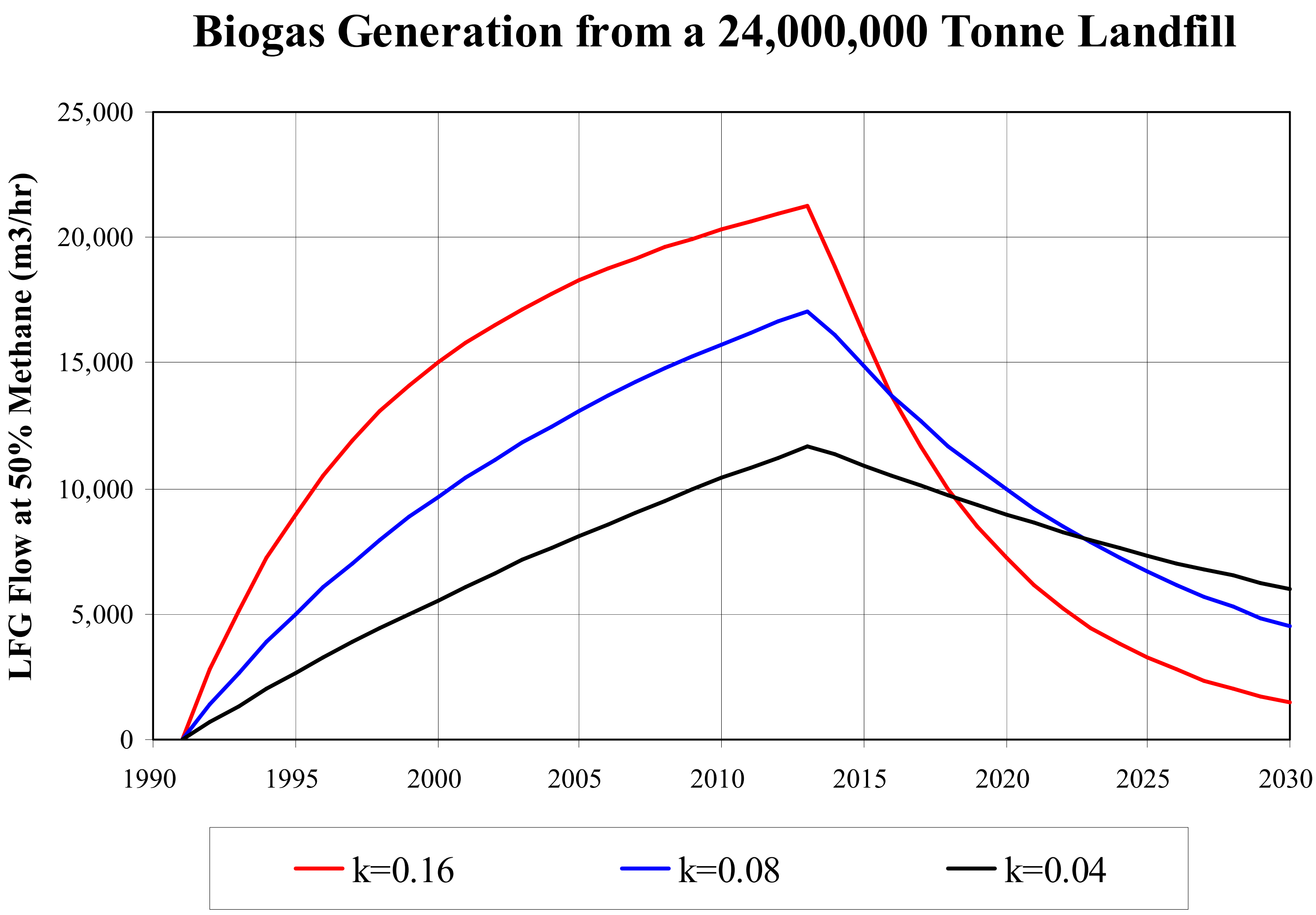
Effect of Varying k



Model Inputs – Collection Efficiency

- Collection efficiency =

$$\frac{\text{Amount of landfill biogas collected}}{\text{Amount of landfill biogas generated}}$$

- Collection efficiency based on:
  - Type of facility (landfill vs. dump)
  - Type/design of collection system
  - Extent collection system covers waste volume
  - Waste characteristics – permeability
  - Collection system operation

Landfill Biogas Recovery Rate

- Landfill biogas recovery = landfill biogas generation x collection efficiency
- Achievable collection efficiencies at disposal sites:
  - Engineered and sanitary landfills: ~60-90%
  - Open and controlled dump sites: ~30-60%

Challenges of International Landfill Biogas Modeling

- Differences in waste composition
  - Developing countries have higher % of food waste and plastics
  - Developed countries have more paper and wood
  - Effects on model parameters (k and L_0)
  - U.S. based first order model (LandGEM) may be less accurate for developing countries

Challenges of International Landfill Biogas Modeling

- Differences in landfill design & operations – developing countries:
  - Excess rainfall infiltration
  - Often shallow sites; limited soil cover
  - Effects on timing of landfill biogas generation
  - Effects on achievable collection efficiency

LMOP Landfill Biogas Model for Mexico

- Partnership between U.S. Government and Mexico.
- Model is based on the LandGEM, with modifications to the k and Lo values to be suitable for Mexico's landfills.
- Model use demonstrated at Monterrey workshop in December 2003
  - Model and user's manual provided

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Thailand Project

- Partnership with World Bank
- Evaluated project feasibility through the preparation of landfill biogas models for 56 disposal sites
- World Bank Landfill Biogas Training Workshop, Bangkok: April 29-30, 2004
  - Presented results of modeling work
  - Conducted workshop on landfill biogas utilization
- Landfill site visits: April and May 2004
- Revisions to models for selected sites based on observed site conditions

Thailand Landfill Site Visits

Thailand Landfill Site Visits

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Lessons Learned: Model Problem #1

- Model less accurate when waste stream is very different from U.S.
- Very high food waste (56%) component in Thai waste causes very rapid decay
  - Food waste includes high water (inert) weight, which requires using a lower Lo
  - Use of a low k may under-estimate peak and over-project long-term potential after site closure
  - Use of high k may over-estimate peak

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Solution to Model Problem #1

- Adjust Lo to account for water (inert) weight as well as organic content of waste
  - U.S. default Lo = 100 m^3/tonne
  - Thai Lo = 78.4 m^3/tonne
  - Delhi Lo = 64.3 m^3/tonne
  - Mumbai Lo = 68.7 m^3/tonne
- Develop composite model with 3 k values:
  - Fast-decay organic waste (food); k = 0.1 to 0.4
  - Medium-decay organic waste (paper); k = 0.02 to 0.08
  - Slow-decay organic waste (textiles); k = 0.005 to 0.02

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Lessons Learned: Model Problem #2

- Model less accurate when landfill design (dump sites) very different from U.S.
- Site visits found broad, shallow fill areas and/or little soil cover
  - Delays in start of anaerobic conditions
  - Problems and/or delays in achieving expected collection efficiency
  - LandGEM assumes generation follows 1 year lag after waste placement, with no waste decay during this period

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Solution to Model Problem #2

- Incorporate delays in landfill biogas generation and recovery into model
  - Assume aerobic waste decay until adequate waste depth or soil cover to create anaerobic conditions
  - Assume additional delays in new sites until waste depth adequate for installing extraction wells

Lessons Learned: Model Problem #3

- Leachate buildup common problem in developing countries
- High rainfall and waste moisture content, and poor runoff control lead to liquid build-up
  - Vertical extraction wells become ineffective when filled with leachate
  - Significant declines in collection efficiency

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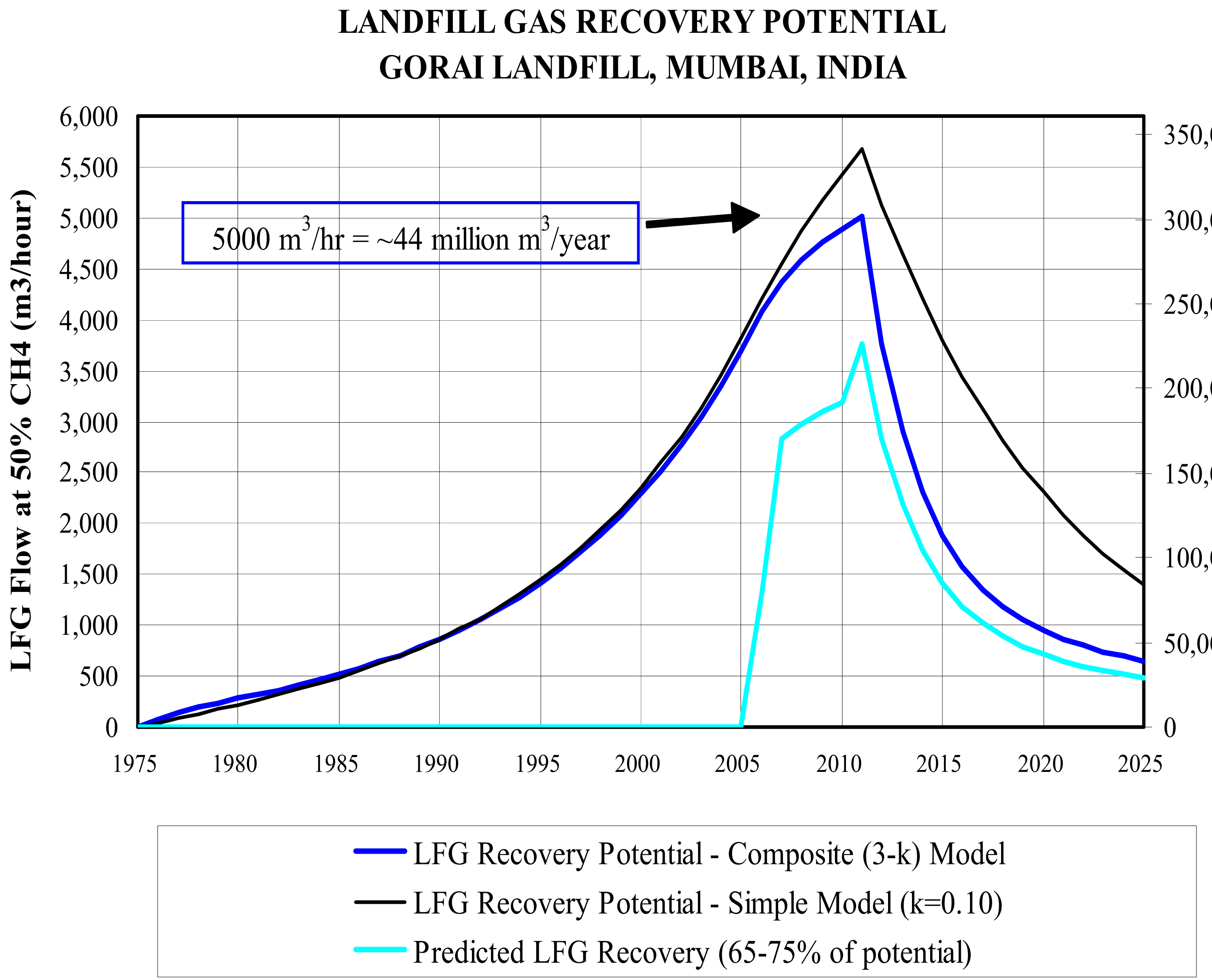
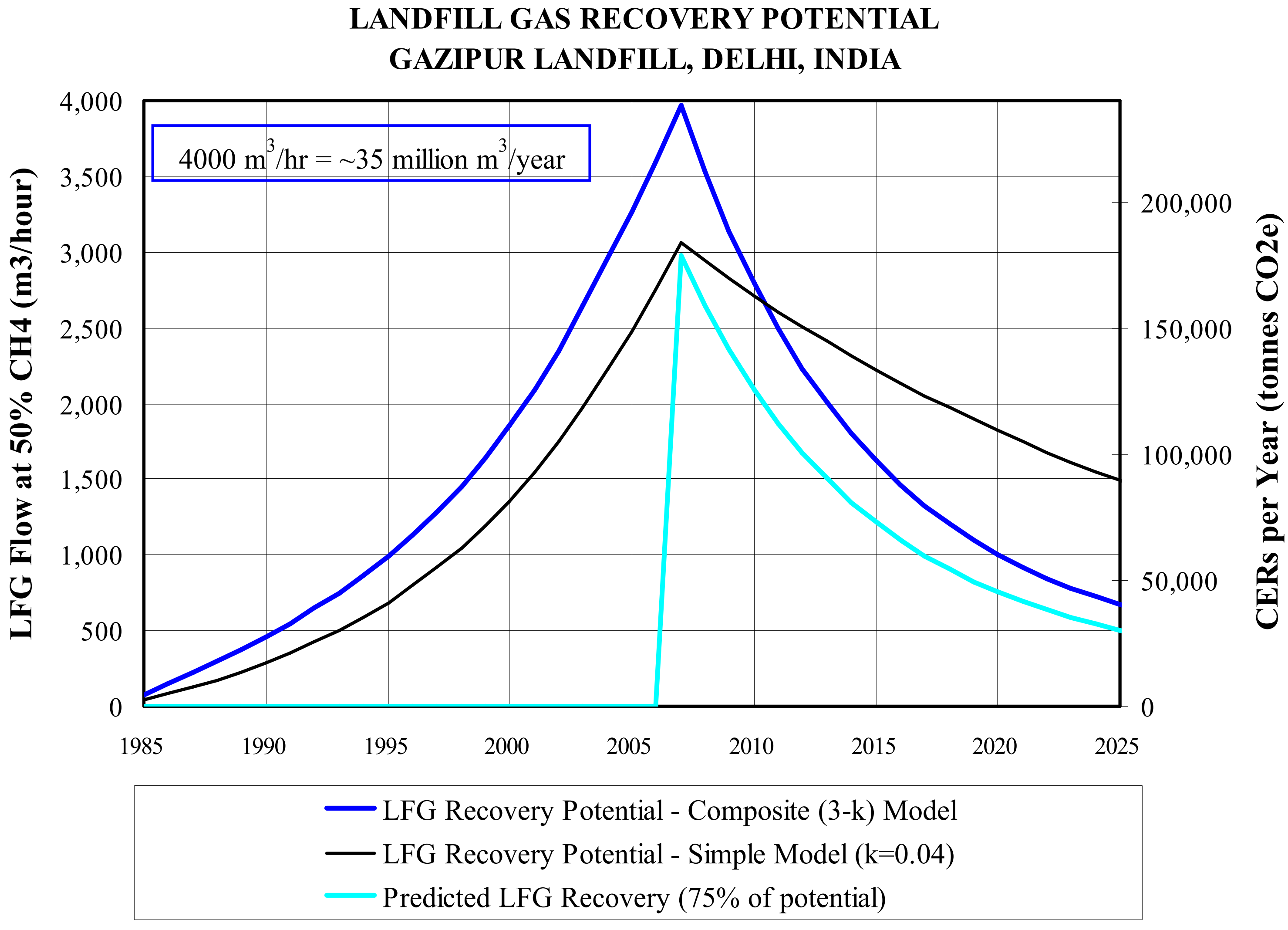
Solution to Model Problem #3

- Need to use conservative model collection efficiency assumptions
- Field investigations (pump test) can indicate extent of leachate problem
- Modifications to collection system design to address leachate problems:
  - Equip vertical wells with leachate pumps
  - Greater reliance on horizontal collectors

Assessing Project Potential – Gorai Landfill, Mumbai



Assessing Project Potential – Gazipur Landfill, Delhi



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Conclusions

- LMOP providing technical assistance workshops promoting international landfill biogas projects
  - Development of an landfill biogas model for Mexico
  - Landfill biogas modeling and project feasibility assessment for Thailand sites
  - Model can be applied to India sites – Gorai and Gazipur examples

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Conclusions

- Large uncertainties in international landfill biogas modeling despite growing demand
  - Need models to account for varying waste composition and site characteristics
  - Collection efficiency estimates need to account for leachate in extraction wells
  - Field testing can provide site-specific information and lower uncertainties

Next Steps and for More Information

- Market/tailor LMOP's international landfill biogas model and training to developing countries (www.methanetomarkets.org)
- Mexico landfill biogas model available at: www.epa.gov/lmop/international.htm
- World Bank information on Thailand available at: www.worldbank.or.th