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State-of-the-Practice for Energy Recovery from Bioreactor Landfills

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Objective

Summarize the additional renewable energy/environmental benefits from expanded development of bioreactor landfills in the US and identify the impediments to widespread implementation of bioreactor landfill technology.

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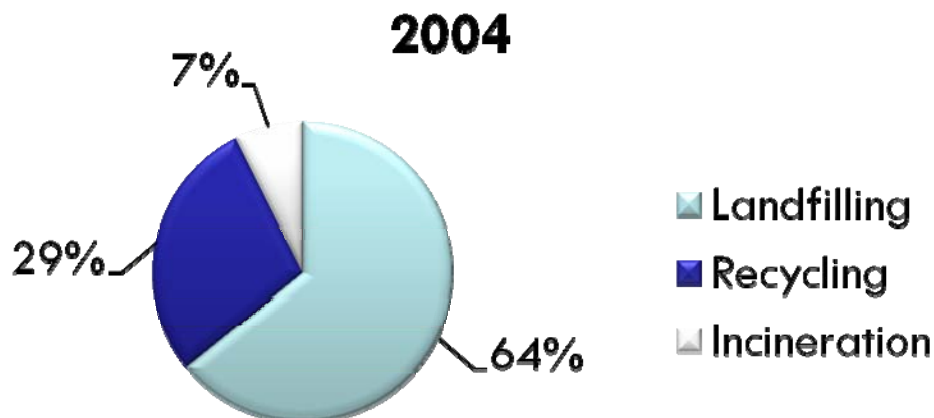
Overview

- State of Solid Waste Management in the U.S.
- State of Energy Recovery from LFG
- Bioreactor Landfills
- Conclusions

State of Solid Waste Management in the U.S.

- MSW Generation
  - 40 percent increase from 1994 to 2004 (Biocycle, 2006)
  - 1.73 tons per person in 2004 (Biocycle, 2006)
  - 59 billion tons estimated over the next 40 years
- Recycling, Incineration, and Disposal



Biocycle, 2006

- Newer Trends (2004)
  - Research, Development and Demonstration (RD&D) Permits

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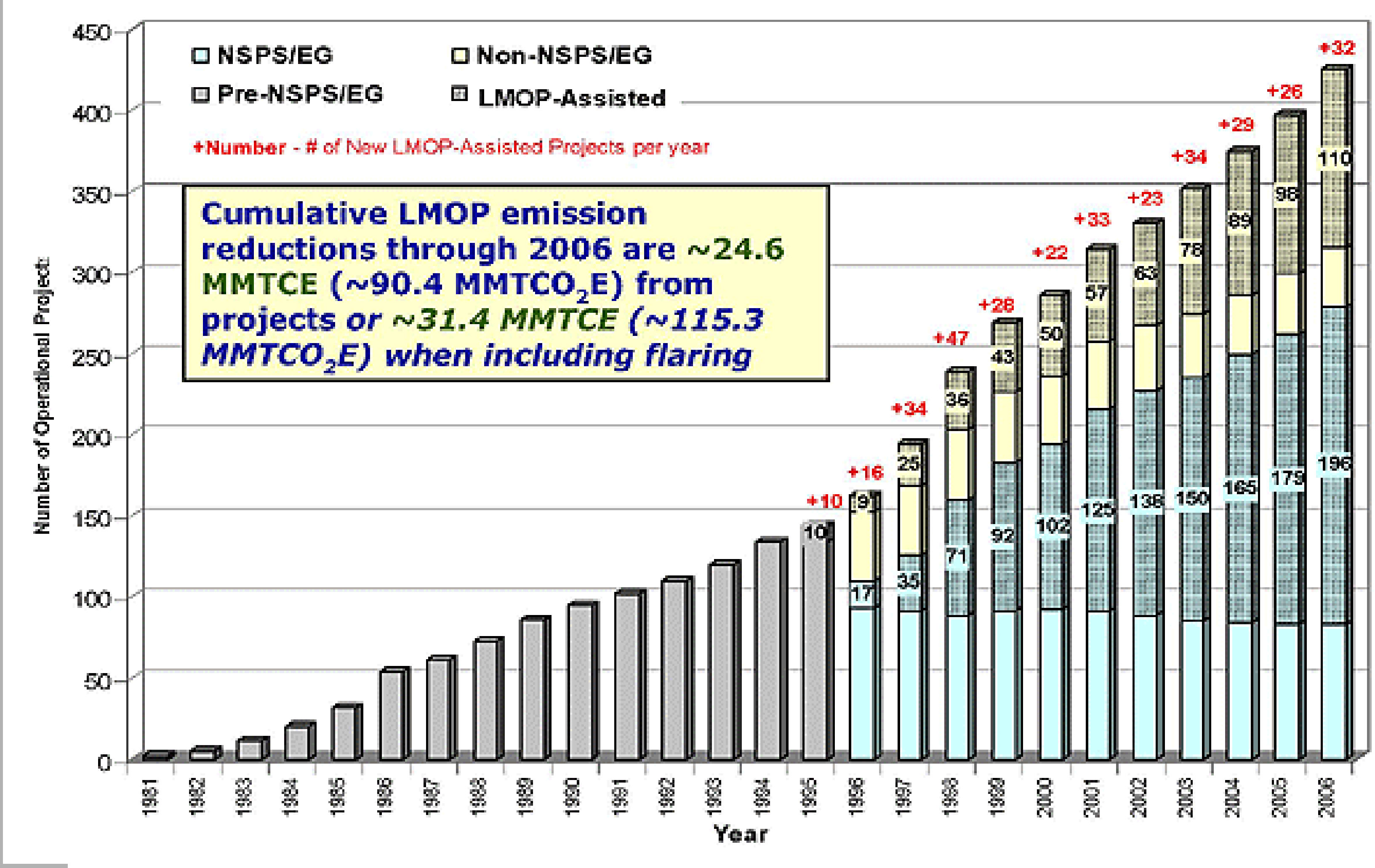
LFG Recovery, Control, and Utilization

- Regulatory Drivers
  - Migration Enforcement Based (RCRA Subtitle D 1991)
  - Compliance Based (NSPS 1996)
- Other Drivers
  - Tax Credits for LFGTE (1998 and 2005)
  - LMOP (1994)
- LFG Control/Utilization Systems
  - Migration Control
  - Energy Recovery
  - Air Quality Compliance

State of Energy Recovery from LFG



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Energy Recovery Benefits and Drivers

- Benefits
  - Since 1994, reduction of over 24 MMTCE
  - Reduces dependence on coal, oil and natural gas
  - Improves air quality by reducing landfill emissions
- Drivers
  - Tax credits (historically)
  - GHG Credits (hopefully)
  - Increasing fossil fuel prices
  - Renewable energy obligations

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Future of LFG Recovery

- Availability
  - 560 Candidate Landfills (LMOP)
    - 870 MW or 553,000 homes
    - Assumes dry-tomb landfill
- Demand (NERC, 2007)
  - 19% increase forecast over next 10 years
    - 141,000 MW need
  - Committed resources increase by only 6%
    - 57,000 MW
  - 84,000 MW deficiency
    - Bioreactor landfills can help meet this

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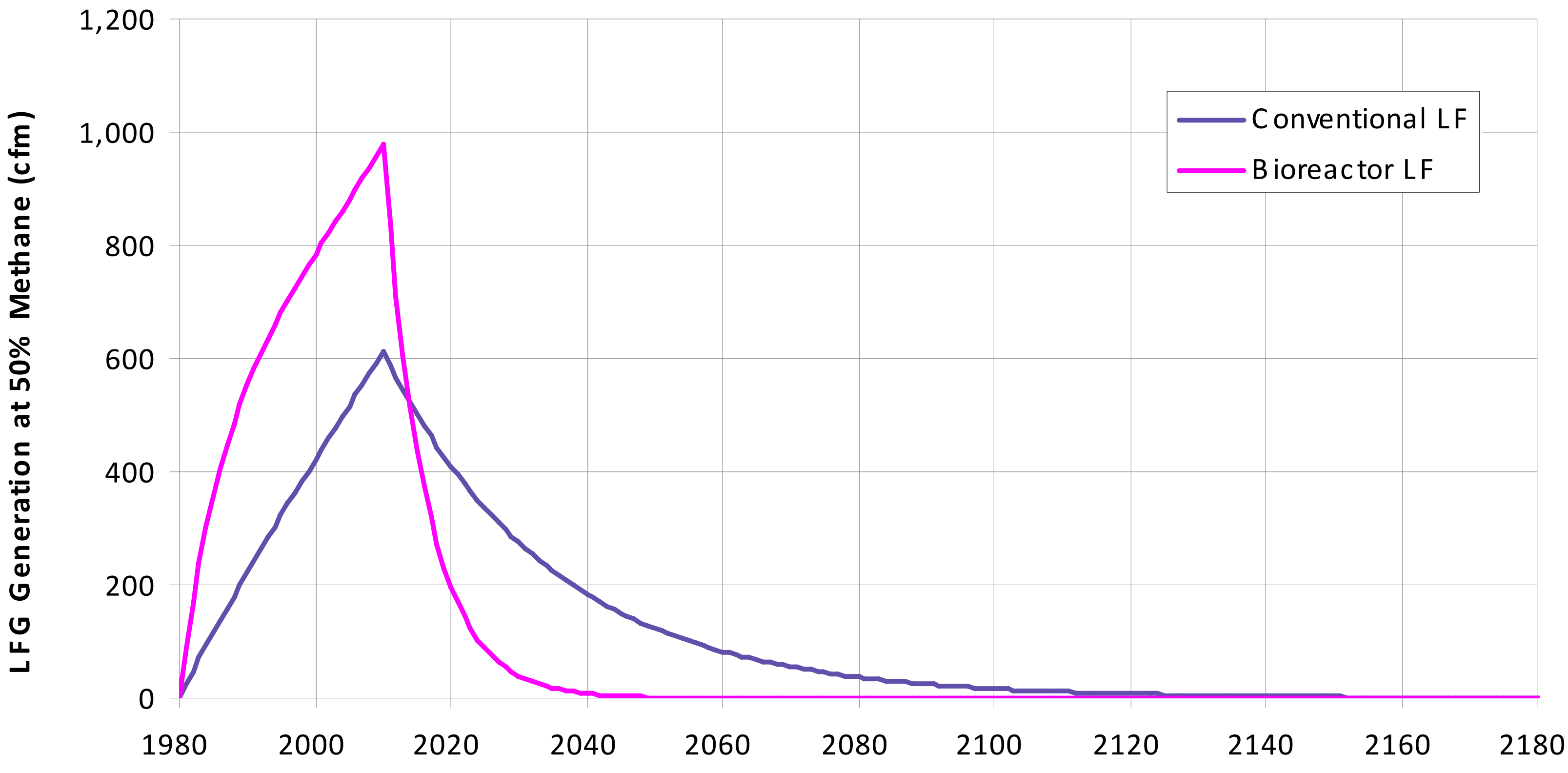
Bioreactor Landfills

- Comparison to Conventional Landfills
- Life Cycle Analysis
- Energy Recovery
- Comparative Energy Recovery
- Advantages
- Disadvantages

Bioreactor Landfills

- Additional water = enhanced microbial activity
  - Accelerates the degradation of refuse
    - Increased LFG generation rates
    - Quicker stabilization
- Expansion of LFG and leachate control systems compared to standard landfills
- RD&D permits allows more flexibility
- Significant demand for liquids may create new options for liquid waste disposal.

LFG Generation Comparison



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Life Cycle Analysis

- Comparative study of MSW management alternatives (Barlaz, et. al., 2003)
  - Recycling, composting, landfilling (conventional and bioreactor)
  - Life cycle inventories assessed for
    - Energy
    - 10 atmospheric pollutants
    - 17 waterborne pollutants
    - Industrial solid wastes
  - Conclusions
    - Composting reduces energy recovery from landfills
    - Bioreactor landfills have highest overall life-cycle environmental benefits with substantial improvement in energy recovery

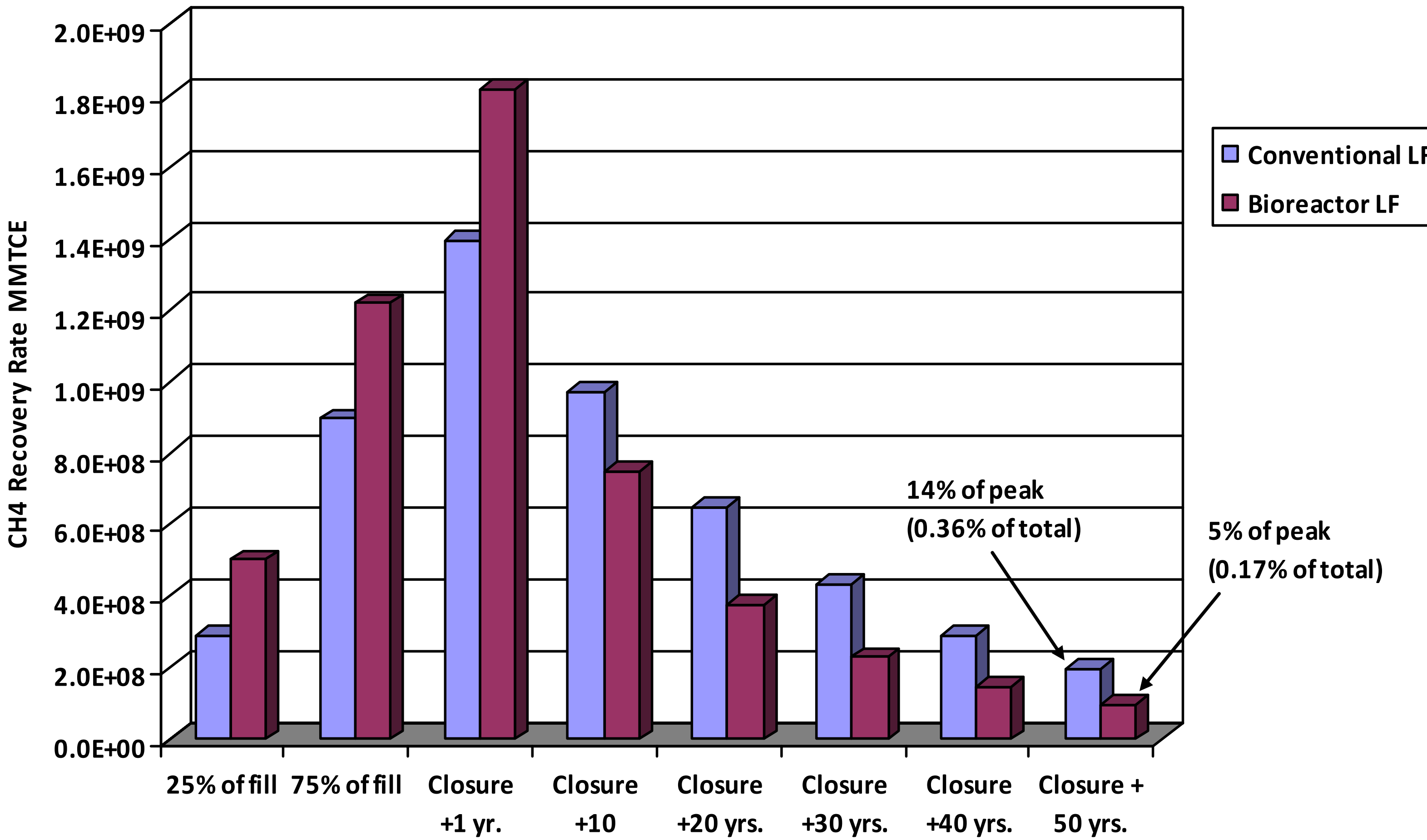
Bioreactor Energy Recovery

- Quality of LFG generated is the same (or slightly higher) than a conventional landfill
- Quantity of LFG is generated at an accelerated rate
- Peak LFG generation and recovery is higher and will remain close peak for a longer period of time
- Peak LFG generation period fits better with energy equipment life spans
- More energy recovery for less years of system operation (lower O&M costs)

Comparative Energy Recovery

- All US waste from 2010 through 2050
  - Scenario #1
    - Conventional landfill of US waste (Baseline)
      - 100% of the waste generated in the US is disposed in conventional landfill
      - 58,966 billion tons of MSW
      - $k = 0.04$, $L_0 = 100$
  - Scenario #2
    - Bioreactor landfills accepts 50% of US waste
      - 29,483 billion tons of MSW to each type of landfill
      - $k = 0.16$, $L_0 = 100$

Methane Recovery Rates



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LFG Modeling Results

	Baseline 100% to Conventional LF k=0.04 Lo = 100	Bioreactor 50% to Bioreactor LF k=0.16 Lo = 100	Net Increase in Recovered Energy	Percent Increase (%)
Peak Methane Recovery (MMTCE)	1,637	2,138	501	31
Total Methane Recovery over 40 years (MMTCE)	30,242	42,913	12,671	42
Peak Heat Recovery (MM BTU/min)	214,202	279,639	65,437	31
Total Heat Recovery (MM BTU/min)	3,956,263	5,613,850	1,657,587	42
Peak Power Production (MW)	20,400	26,632	6,232	31
Average Power Production (MW) (40 years)	8,910	12,701	3,791	43

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Bioreactor Advantages

- Increased methane recovery
- Reduced GHG emissions
- Rapid stabilization of waste provides increased potential for landfill development
- More efficient utilization of disposal airspace
- Reduction in financial uncertainty of long-term post-closure
- Controllable gas yields with economical production profile for energy recovery
- Stabilization of gas and leachate quality

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Bioreactor Disadvantages

- Increased cost for landfill design, construction and operation
- Increased potential for leachate and LFG impacts
- Higher peak criteria pollution rates for LFG combustion devices
- Limited leachate quantities for recirculation in dryer climates

Conclusions

- U.S. energy needs in the near future are more than we can provide
- LFGTE is a substantial provider of renewable energy
- Bioreactor landfills provide significant advantage for energy recovery efforts from LFGTE
  - 31% increase in peak power production
  - 43% increase in average power production (40 years)

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Obstacles to Implementation

- Preconceptions
  - No liquids in landfills
- Challenges
  - NSPS uses conventional landfill model to evaluate emissions
  - Permitting delays
  - Onerous evaluation procedures (OTM-10)
  - Operational Challenges
  - USEPA can lead the way, working with states to overcome these obstacles

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