ENHANCING ENERGY RECOVERY FROM LANDFILLS USING THE BIOREACTOR TECHNOLOGY

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OBJECTIVES OF THE STUDY

- **Compare Conventional "Dry" Landfills to Anaerobic Bioreactor Landfills:**
  - **LFG/Methane Generation and Recovery**
  - **LFG-Related Emissions**
  - **Greenhouse Gas (GHG) Reductions**
  - **Energy Recovery**
- **Compare Project Economics for LFGTE Projects (electricity generation)**

LFG MODELING REFRESHER

- EPA's LFG generation model (LANDGEM)
- Annual waste input ("M_i" value) = Mg
- Age of waste ("T_i" value) = yr
- Methane generation potential ("L_o" value) = m^3/Mg
- Refuse decay constant ("k" value) = yr^{-1}
- Equation: $Q_m = \sum 2\,k\,L_o\,M_i\,(e^{-kti})$

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GENERAL LFG MODELING INPUTS

- LANDGEM developed for “dry” sites
- M_i and T_i are site-specific
- L_o = 100 to 170 m^3/Mg
- k = 0.02 to 0.05 yr^{-1} (conventional); rainfall dependent
- k = 0.1 to 0.25 yr^{-1} (bioreactor); derived from limited lab and pilot scale studies

STUDY MODELING INPUTS

- **Conventional Landfill: 25 million tons, 25 years of life**
- **Bioreactor: 30% density increase**
- **Conventional Landfill: k = 0.05 (wet climate)**
- **Bioreactor: k = 0.12 (average)**

STUDY MODELING INPUTS (cont.)

- No adjustments made to L_o (= 100 m^3/Mg)
- Issue of "ultimate" L_o and "effective" L_o
- Site modeled over 100 years of operational and post-closure life

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STUDY MODELING INPUTS (cont.)

- NMOC Concentration = 595 ppmv (AP-42)
- 75% Collection Efficiency
- NOx = 0.06 lb/ MM BTU
- 98% Destruction Efficiency

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STUDY MODELING INPUTS (cont.)

- **Conventional Landfill: GCCS Installed (Year 8) and Turned Off (Year 75) per the NSPS**
- **Bioreactor: GCCS Installed Early (Year 2)**
- **Bioreactor: GCCS Turned Off 10 Years Sooner (Year 65)**

MODELING RESULTS

LFG Flow	Conventional	Bioreactor
Maximum LFG (scfm)	6362	10,631
LFG Flow in Year 2 (scfm)	650	1265
LFG Flow in Year 8 (scfm)	2633	6358

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MODELING RESULTS (cont.)

LFG Flow	Conventional	Bioreactor
LFG Flow in Year 65 (scfm)	905	99
LFG Flow in Year 75 (scfm)	549	49
LFG Flow – 25 yr. Average (scfm)	~4500	~7500

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MODELING RESULTS (cont.)

Pollutant	Conventional	Bioreactor
Maximum NMOC (tpy)	108	124
Maximum NOx (tpy)	50	84
Maximum CO_2 Reduced (Mg/yr)	496,253	829,202

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MODELING RESULTS (cont.)

Pollutant	Conventional	Bioreactor
Total NMOC (tons/100 yr.)	3121	3283
Total NOx (tons/100 yr.)	1607	2199
Total CO_2 Reduced (Mg/100 yr.)	15.9 MM	21.8 MM

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MODELING RESULTS (cont.)

Energy Value	Conventional	Bioreactor
Maximum Heat (MM BTU/hr)	191	319
Maximum Power (MW)	19	30
25-Year Average Power (MW)	12	20

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DATA SUMMARY

- Bioreactor will collect over 37% more methane and produce 37% more energy
- Bioreactor will reduce over 5.9 million more Mg of GHG
- Bioreactor will increase NMOC emissions by 162 tons (1.6 tpy)
- Bioreactor will increase NOx emissions by 592 tons (5.9 tpy; 34 tpy in peak year)

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ELECTRICITY GENERATION

- Proforma Assumptions
  - 10-Year Analysis Based on Average Gas Recovery Rates
  - Plant Sizes: 12 MW for Conventional and 20 MW for Bioreactor
  - Power Sales Rate = $0.05/kW-hr

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ELECTRICITY GENERATION (cont.)

- Proforma Assumptions (cont.)
  - No Subsidies or Tax Credits Assumed
  - Power Generation Technology = Gas Turbines
  - 95% Capacity Factor
  - Economies of Scale for Capital and O&M Costs

ELECTRICITY GENERATION (cont.)

- Economics Comparison
  - Average Gross Revenue = $4.1 million/yr for conventional; $6.9 million/yr for bioreactor
  - Average Net Cash Flow = $2.0 million/yr for conventional; $4.0 million/yr for bioreactor

ELECTRICITY GENERATION (cont.)

- Economics Comparison (cont.)
  - Internal Rate of Return = 7.3% for conventional and 16% for bioreactor
  - Simple Payback: 6.7 years for conventional and 4.6 years for bioreactor

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CONCLUSIONS

- Obvious Energy Benefit
- More Energy for Less Years of Plant Operation
- Gas/Generation Recovery Rates are More Constant
- Gas Generation/Recovery Rates Remain at Peak for Longer Periods of Time
- Additional GHG Reductions (another source of revenue)
- Increases in NMOC/VOC and Combustion Emissions

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