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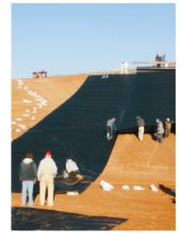


Collection Efficiency and LFG Modeling

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Arizona Solid Waste Management Seminar

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Overview

- Collection efficiency definitions
  - Actual vs. measured vs. modeled
  - Used in GHG emissions calculations
- Collection efficiency – SWICS method
- Long-term collection efficiency estimates using LFG models
- LFG recovery in developing countries
- LMOP program – domestic and international LFGE project promotion

LFG Collection Efficiency Definitions

- LFG generated = recovered + oxidized + emitted + Δ storage
- Collection efficiency = % of generated LFG collected
  - % not collected is "fugitive"
    - Methane: Fugitive CH_4 – Oxidized CH_4 = Emitted CH_4
  - % collected is "non-fugitive" and is combusted - % not destroyed is added to emissions (very low <1% for CH_4)
- Collection % typically does not include oxidation
  - Difficult to separate out oxidation in studies based on measurements of emissions
  - Oxidation a big topic at national SWANA LFG conference in San Diego

LFG Collection Efficiency Issues

- Annual Emission Inventories and Title V
  - Collection efficiency strongly affects LFG emissions
- New GHG Reporting Rule
  - Calculate methane emissions (before accounting for <100% destruction of combusted CH_4) using:
    1. (CH_4 generation-CH_4 recovery) x (1-OX) = CH_4 emissions
       - Use modified version of LandGEM, subtract monitored CH_4 recovery and oxidation (10%)
    2. No LandGEM model – use flows and C.E.

$$\frac{CH_4 \text{ recovery}}{(C.E.) \text{ x } \% \text{ time on-line}} \text{ x } (1 - OX) = CH_4 \text{ emissions}$$

How is Collection Efficiency Calculated?

- 75% (EPA "average for comprehensive systems") is not used in GHG rule
- SWICS Method adopted – collection efficiency is the area-weighted average of calculated C.E. based on soil cover type and wellfield coverage:
  - 0% C.E. for areas without wells
  - 95% C.E. for areas with wells and "final soil and geomembrane cover system"
  - 75% C.E. for areas with wells and intermediate cover
  - 60% C.E. for areas with wells and daily cover only

Example C.E. Calculation

- 80% of areas with waste have active gas collection
  - 20% of LF area has wells and final soil/geomembrane cover system
  - 40% of LF area has wells and intermediate cover
  - 20% of LF area has wells and daily cover only
- To calculate collection efficiency sum the following:
  - 95% C.E. x 20% area = 19%
  - 75% C.E. x 40% area = 30%
  - 60% C.E. x 20% area = 12%
  - Sum = 61%

Other Collection Efficiency Issues

- Recycling advocates claims against landfills:
  - Say that "lifetime" collection efficiencies for landfills =~20%
    - 20% figure is based on IPCC estimate for a lifetime global estimate, which includes all international sites – many challenges (later)
  - Say that period prior to system installation and after de-commissioning creates significant emissions
  - Say that large emissions occur during delays under the NSPS 2 and 5 year rule

Collection Efficiency White Paper

- SWANA LFG Modeling Committee assignment
  - Investigate the extent that LFG emissions occur during the period prior to system installation and after de-commissioning
  - Investigate the extent that LFG emissions occur during delays under the NSPS 2 and 5 year rule
  - Use LFG modeling and SWICS collection efficiency values to develop a 100-year collection efficiency estimate
  - Write a white paper summarizing the results

Collection Efficiency Evaluation

- Data compilation:
  - Use LMOP database to develop average disposal rates for landfills by air district, public vs. private, and other categories
  - Current evaluation: NSPS sites only
  - Split into 6 groups x 2 size categories (< or >= 5 M TIP) = 12 total
  - Develop waste histories
    - Waste disposal histories for each group based on average values for:
      - Opening and closing year
      - Design capacity
      - WIP as of specified year

Collection Efficiency Evaluation (cont.)

- Modeling method:
  - Run models for each of 12 LF categories using average disposal history
  - Assume time lag for LFG generation (1, 1.5 yr?)
  - Estimate lag before well installation (<1 – 5 yrs), depending on owner/operator category
  - Estimate collection efficiency based on cover type using % filled
    - Flow data too incomplete to develop reliable average flow estimates

Collection Efficiency Evaluation (cont.)

- Data needs:
  - Estimates of normal time delay between waste placement and well installation
  - Estimates vary by landfill size, rate of fill, regulatory environment, company policy
- Preliminary results:
  - Large sites much higher average collection efficiency due to longer GCCS operational period
  - Large sites much greater influence on overall collection efficiency

Example Average Collection Efficiency Calculations

- Sites with >= 5 million TIP (sample values):
  - 100-yr average LFG generation: 3,000 scfm
  - 100-yr average LFG recovery: 2,100 scfm
  - 70% average collection efficiency for large sites
- Sites with < 5 million TIP (sample values):
  - 100-yr average LFG generation: 1,000 scfm
  - 100-yr average LFG recovery: 400 scfm
  - 40% average collection efficiency for large sites
- Calculated flow weighted average would be
  - 2,500 scfm recovered / 4,000 scfm generated = **62.5% collection efficiency**

Collection Efficiency In Developing Countries

- Estimated based on an evaluation of :
  - Site conditions impacts (soil cover, leachate, geometry, etc)
  - Collection system coverage and build-out schedule
- Estimated upper limits based on site management:
  - Engineered and sanitary landfills: ~60-95%
  - Open and managed dump sites: ~30-60%

Site Conditions in Developing Countries

- Site conditions that limit LFG recovery rates:
  - Shallow waste depth, poor compaction
  - High food waste %, often rainy climates
  - Lack of soil cover and/or poor drainage lead to high leachate levels
  - Fires, waste pickers, site security

El Trebol Landfill, Guatemala City

LFG Models and Uncertainty

- LFG recovery projections (using LFG models) are basis of entire international project planning process
  - Main determinant of project feasibility & requirements
  - LFG modeling methods (U.S. EPA LandGEM 1st order model) well known but input assumptions uncertain:
    - Waste disposal rates and composition
    - Waste decay rate constant (k) = ln(2)/half-life ($year^{-1}$)
    - Ultimate methane yield (L_0) = m^3 CH_4/Mg waste
    - Collection efficiency = m^3 collected / m^3 generated
  - International modeling poorly understood due to lack of data, uncertain methods of accounting for site conditions

Overestimating International LFG Project Potential

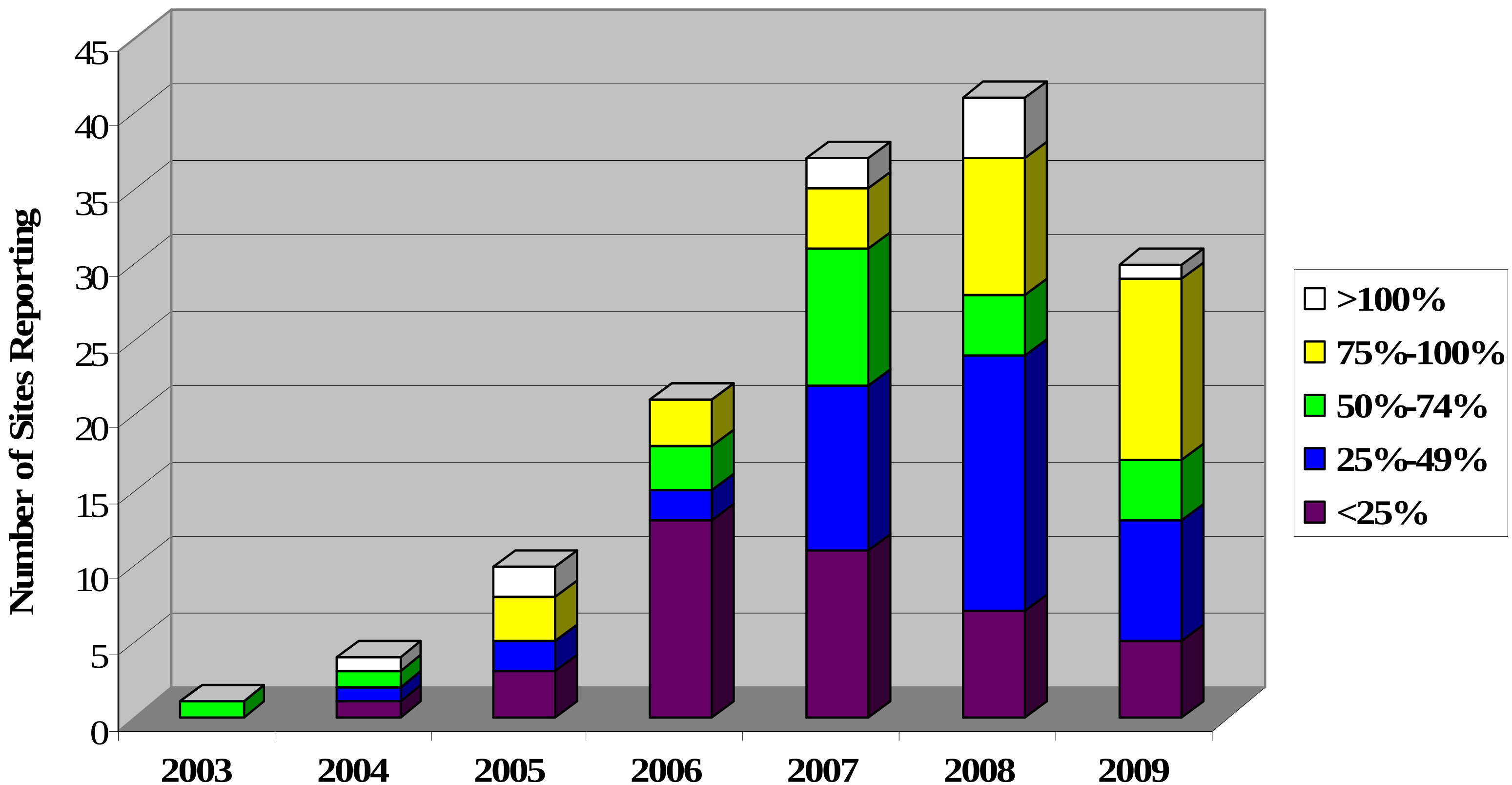
- Project developers estimate high revenues to win bid
- LFG models poorly applied for international sites
- Has caused historic overestimation of LFG recovery and GHG credits for Clean Development Mechanism (CDM) projects
  - Monitoring reports showing actual project results when applying for GHG credits (CERs) indicate low project performance
  - Compare to Project Design Document (PDD) model prediction – average ~50%

CDM Project Performance as a % of Projected Recovery*

- 2003 - 1 project: 60%
- 2004 - 4 projects: 54%
- 2005 - 10 projects: 44%
- 2006 - 21 projects: 30%
- 2007 - 37 projects: 47%
- 2008 - 41 projects: 55%
- 2009 - 30 projects: 59%
- **Overall average: 49%**

***Based on total actual CH_4 recovery from monitoring report data (available on the UNFCCC website for 60 CDM LFG projects as of 12/12/09) divided by total projected CH_4 recovery from PDDs. CER deductions for baseline, methane destruction efficiency, etc. were added to estimate CH_4 flows.**

CDM Project Performance as a % of Projected Recovery



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Under-Performing Projects or Overly Optimistic Models?

- In many cases, overestimates can be traced to common (avoidable) model problems:
  - Model Lo value too high – e.g. U.S. (NSPS) default
  - Use of simple first order decay model with single k value
  - High collection efficiency assumptions
  - Site conditions' impacts not anticipated
- How much of the CER shortfall was predictable or preventable?

EPA’s Landfill Methane Outreach Program

- Established in 1994
- Voluntary program that creates alliances among states, energy users/providers, the landfill gas industry, and communities

Mission: To reduce methane emissions by lowering barriers and promoting the development of cost-effective and environmentally beneficial landfill gas energy (LFGE) projects.

International LFG Project Planning Process

- Steps in the project planning cycle:
  1. Site identification and initial screening
  2. Project assessment
  3. Pre-feasibility study
  4. RFP and select developer
  5. PDD
  6. Project validation and registration

LMOP's Country-Specific LFG Models

- LMOP first recognized need for country-specific models in 2003 (Mexico model v. 1)
- 2007 – LMOP's Central America Biogas Model
- 2009 – LMOP released several country-specific LMOP models:
  - Ecuador LFG Model
  - China LFG Model
  - Thailand and Philippines LFG Models completed
  - Mexico LFG Model Version 2
  - Ukraine LFG Model
- SCS developed Central America, Mexico, and Ukraine LFG models

State of the LFGE Industry

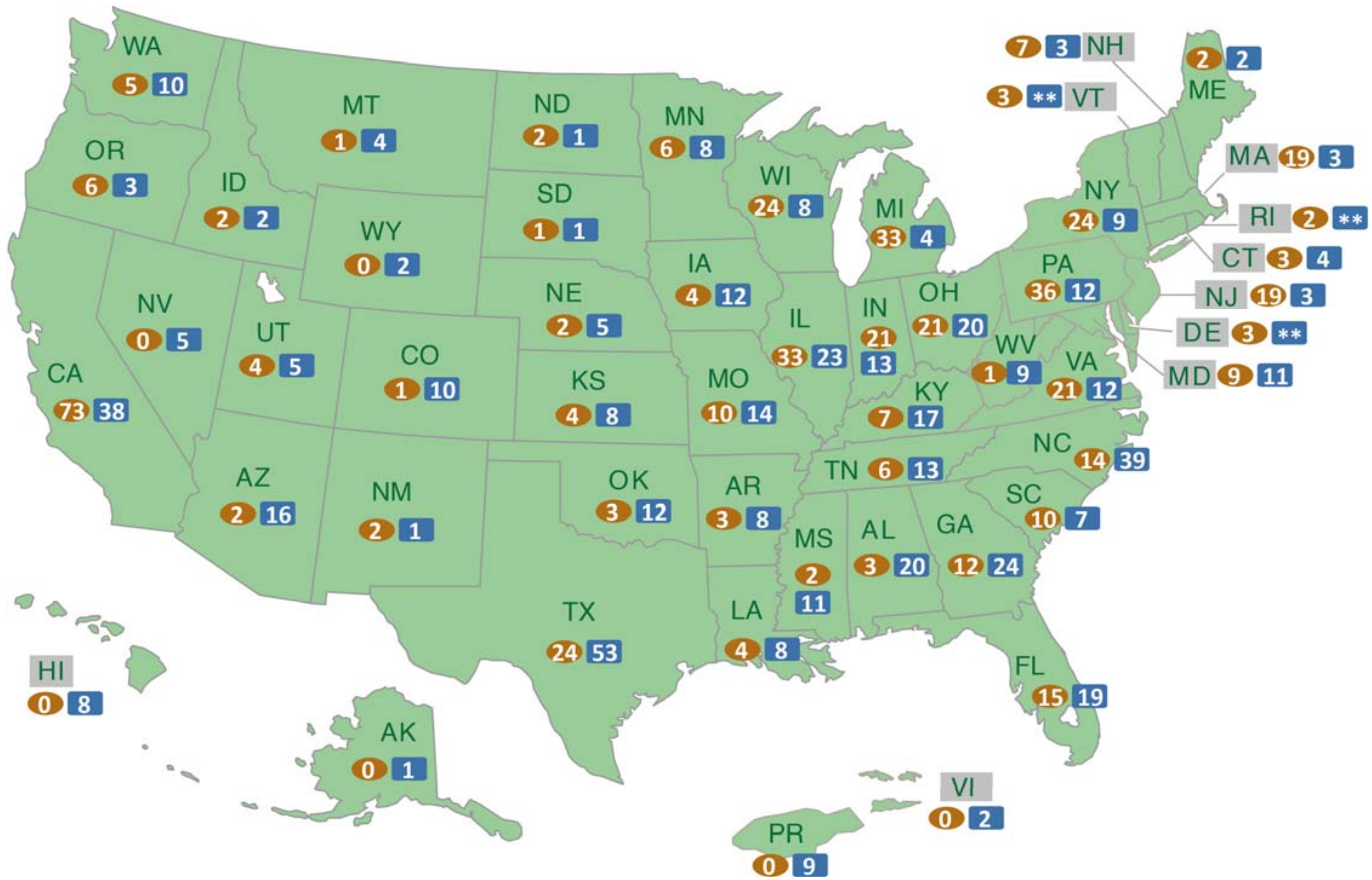
- 509 operational projects in 44 states
  - 72% are electricity generation projects and 28% are direct use projects
  - 12.8 billion kilowatt hours of electricity produced and102 billion cubic feet of gas delivered in 2009
- Estimated Annual Environmental Benefits:
  - Reduce CH_4 emissions by ~4.29 million short tons per year
  - Carbon sequestered annually by ~17.4 million acres of pine or fir forests, or
  - Annual greenhouse gas emissions from ~15.6 million passenger vehicles
- LMOP estimates there are at least 40 LFGE projects under construction in 2010 and more in advanced planning stages

Many Untapped LFG Resources

- ~530 candidate landfills
  - Potential to supply 1,170 megawatts of potential capacity or 220 billion cubic feet of gas/year for direct use
- Annual environmental benefits if projects were developed at these sites:
  - Approximately 13.5 million metric tons of CO_2e in potential emission reductions

LANDFILL METHANE OUTREACH PROGRAM

LFG Energy Projects and Candidate Landfills



Nationwide Summary

509 OPERATIONAL Projects (1,563 MW and 304 mmscfd)

~530 CANDIDATE Landfills (1,170 MW or 600 mmscfd, 13.5 MMTCE Potential)

OPERATIONAL PROJECTS

CANDIDATE LANDFILLS*

* Landfill is accepting waste or has been closed for 5 years or less and has at least 1 mmtons of waste and does not have an operational/under construction LFGE project or is designated based on actual interest/planning.

** LMOP does not have any information on candidate landfills in this state.

These data are from LMOP's database as of December 16, 2009.

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State of LFGE in Arizona

- 4 operational projects
  - All electricity generation
  - Sites include:
    - City of Glendale Municipal Landfill (2.8 MW)
    - Los Reales Landfill (2.4 MW)
    - Salt River Landfill (2 MW)
    - Tri-Cities Landfill (2 MW)
- 15 Candidate Landfills
  - Defined as landfills currently accepting waste or have been closed for 5 years or less and currently do not have an operational/under construction LFGE project

LMOP Tools and Services

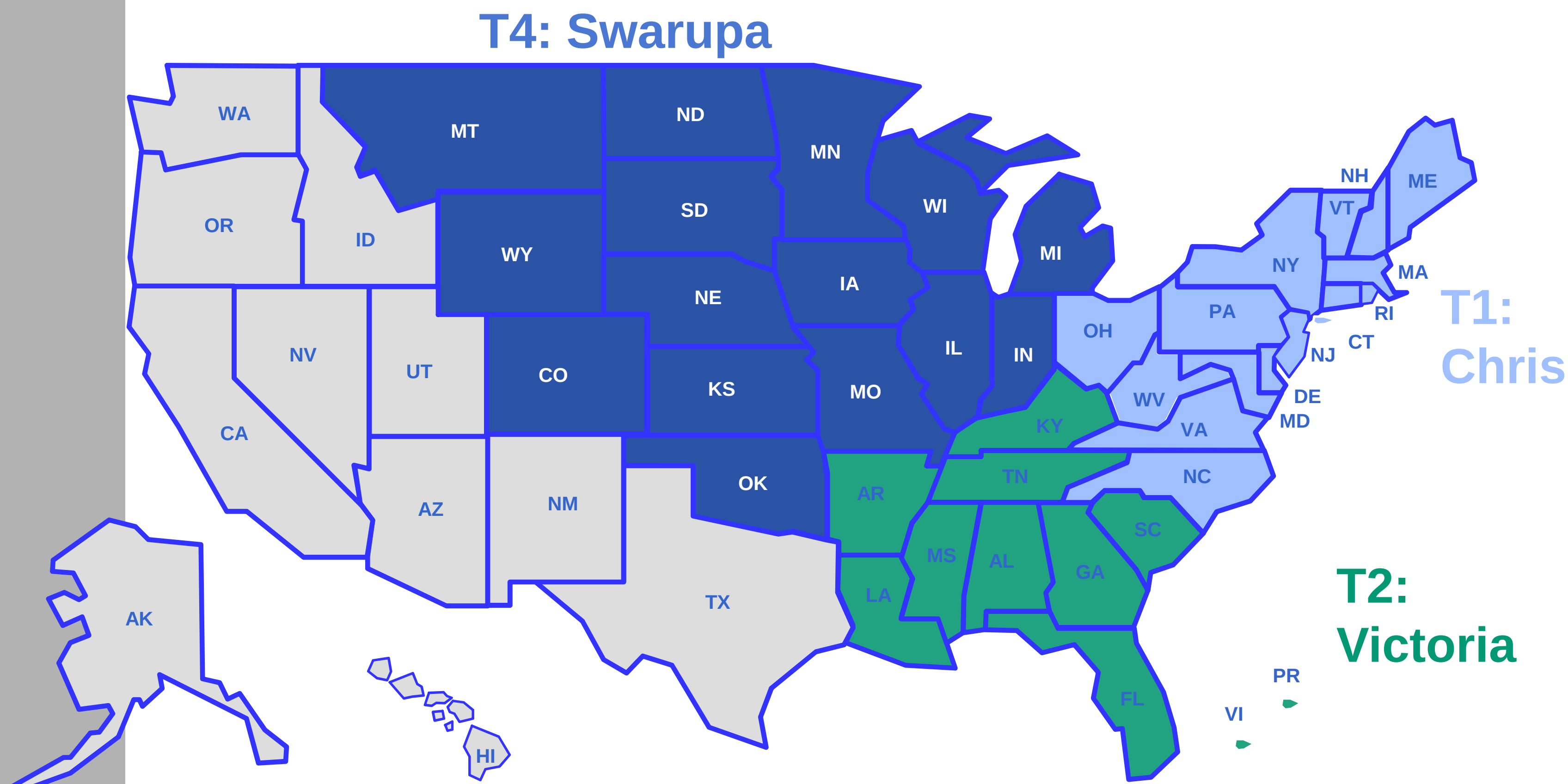
- Network of 800+ Partners
- Direct project assistance
- Newsletter and listserv
- Technical and outreach publications
- Project and candidate landfill database
- Support for ribbon cuttings and other public relations
- Presentations at conferences
- State training workshops

LMOP Provides FREE Direct Project Assistance

- Gas generation projections – *LandGEM*
- Initial project cost estimates – *LFG cost*
- Identify potential matches – *LMOP Locator*
- Look at project possibilities
  - Direct-use (boiler, heating, cooling, direct thermal)
  - Combined Heat & Power (engine, turbine, micro-turbine)
  - Electric (engine, turbine, micro-turbine)
  - Alternative Fuels (medium or high Btu, LNG, CNG)

For More Information

www.epa.gov/lmop



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Summary

- Collection efficiency is important for GHG emissions calculations
  - SWICS method by % cover type
  - Long-term collection efficiency estimates using LFG models
- LFG recovery in developing countries – shortfalls and low collection efficiencies
- LMOP program – tools supporting domestic and international LFGE and GHG reduction LFG projects

For More Information:

- For more information about this presentation, contact Alex Stege at: astege@scsengineers.com
- LMOP can be reached at: http://www.epa.gov/lmop/
- LMOP 's international LFG models are available at: www.epa.gov/lmop/ international/index.htm