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LMOP's New LFG Models for Mexico and Ukraine – Tools for LFG Project Screening and Assessment

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Presentation Topics

- Why international landfill gas models are needed
- Actual CDM project performance based on monitoring reports
- Limitations of LFG models used for CER/VER projections
  - LandGEM and IPCC model
  - Lack of guidance on estimating collection efficiency given site conditions in developing countries
- LMOP's country-specific LFG models
  - Mexico LFG Model v. 2.0
  - Ukraine LFG Model

Need for International Landfill Biogas Modeling

- Accurate estimates of LFG recovery are critical for:
  - Evaluating project feasibility and economics
  - Estimating system design and facility sizing requirements
  - Evaluating project performance (predicted vs. actual)
- International landfill biogas modeling is still in a developmental stage
  - Can be a large source of error in evaluating project feasibility and system requirements
  - Unrealistic model projections can lead to investment in uneconomical projects (or neglecting opportunities)
  - Frequent overestimation of LFG recovery in Clean Development Mechanism (CDM) projects' PDDs (data next two slides)

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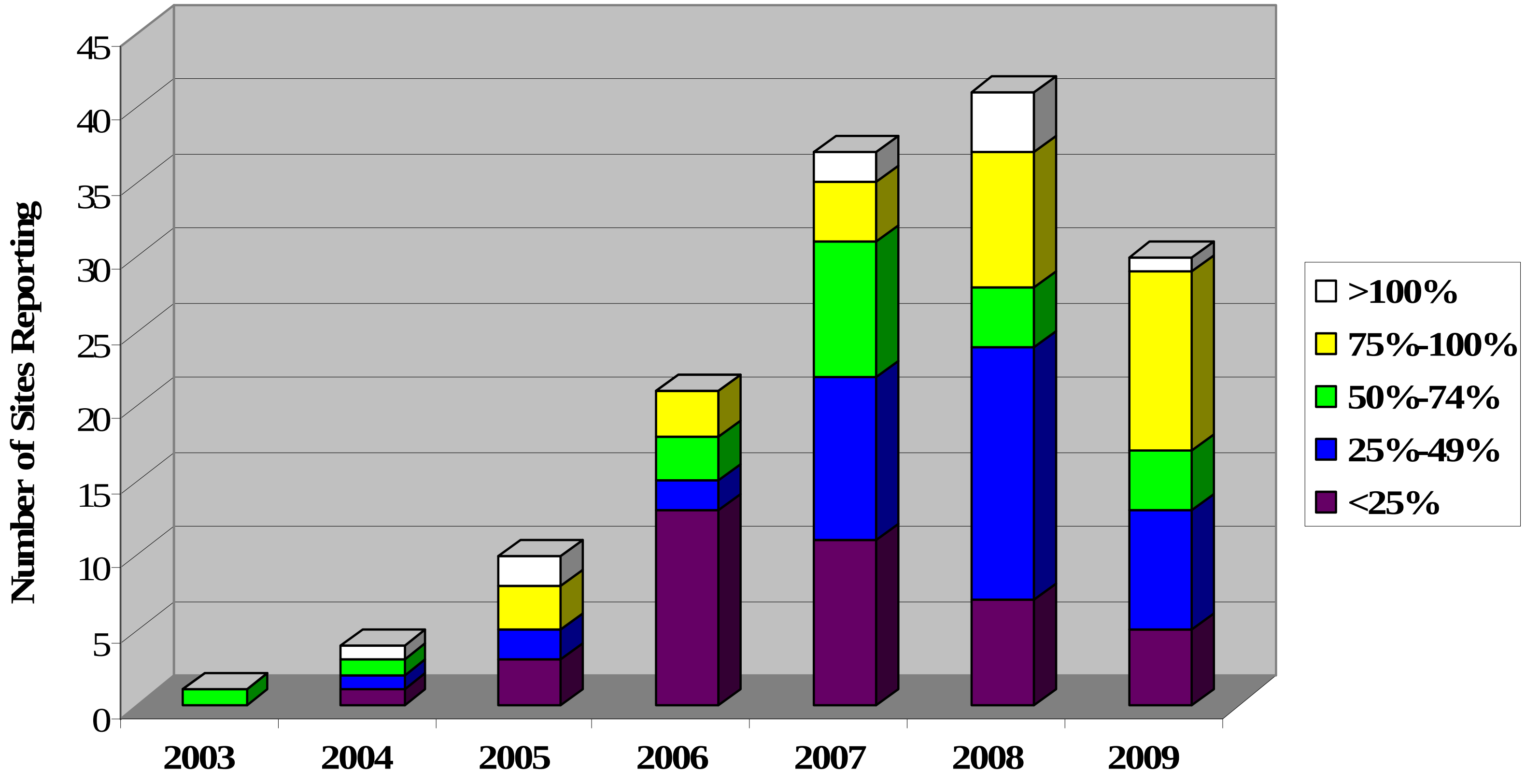
CDM Project Performance as a % of Projected Recovery*

- 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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Landfill Gas Models

- U.S. EPA Landfill Gas Emissions Model (LandGEM)
  - Inappropriate use of this model is one of largest causes of overestimation of landfill methane emission reductions in PDDs
- Intergovernmental Panel on Climate Change (IPCC) Model (2006)
- LMOP's country-specific international LFG models:
  - Mexico LFG Models v. 1 and 2 (2003 and 2009)
  - Central America LFG Model (2007)
  - Ecuador LFG Model (2009)
  - China LFG Model (2009)
  - Ukraine LFG Model (2009)

LandGEM Shortcomings for International Applications

- Model is based on USA waste composition
  - Other countries' waste composition is very different – often much higher food waste % which has high k and low L_0 (includes water weight)
  - NSPS value for L_0 (170 m^3/Mg) and even the AP-42 value (100 m^3/Mg) are too high for many developing countries' landfills
- Model structure doesn't work well with high food waste %
  - Single k value that does not change over time creates significant error for sites or cells that are closed
- Model provides only "wet" and "dry" k values
  - Waste decay rates vary more continuously with precipitation
- Model provides estimates of LFG generation only, not recovery
  - EPA cited collection efficiency at U.S. landfills not an appropriate guideline

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IPCC Model (2006)

- International first-order decay model – improvements over LandGEM
  - Assigns k values based on 4 climate categories
  - Uses different k values for each of 4 organic waste categories (avoids LandGEM single k problem)
  - Includes a methane correction factor (MCF) to account for aerobic decay in unmanaged sites
  - Recognized by UNFCCC for CDM and JI projects
- IPCC Model shortcomings
  - Developed as a global model
    - Limited ability to reflect conditions in individual countries
    - Uses continental scale default waste composition values
  - Two precipitation categories too coarse to capture effects on k which varies continuously with precipitation
  - No guidance on estimating collection efficiency

Effects of Site Conditions on Collection Efficiency

- Site conditions that limit landfill gas recovery rates:
  - Shallow waste depth, poor compaction, lack of soil cover
  - Poor drainage, high rainfall, leachate accumulation
  - Fires, waste pickers, security
  - Problems with collection system design and/or operations
  - Delays in wellfield installation in active cells

El Trebol Dump Site, Guatamala

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LMOP's Landfill Gas Models

- LMOP recognized need for country-specific models
  - Developed first version of the Mexico Biogas Model in 2003
- 2007 – LMOP's Central America Biogas Model
- 2009 – Several country-specific LMOP models:
  - Ecuador LFG Model
  - China LFG Model
  - Mexico LFG Model Version 2
  - Ukraine LFG Model

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Developing the Mexico LFG Model v. 2.0

- Build on the old Mexico Model
  - Expand waste composition database with new data
- Have the model reflect local conditions
  - Model reflects climates in all regions of Mexico and assigns waste composition by state
- 4 k model structure to capture Mexico conditions
- Use data from sites with operating LFG systems
- Allow model to run with simple user inputs
  - Waste disposal rates and collection efficiency calculated based on user inputs

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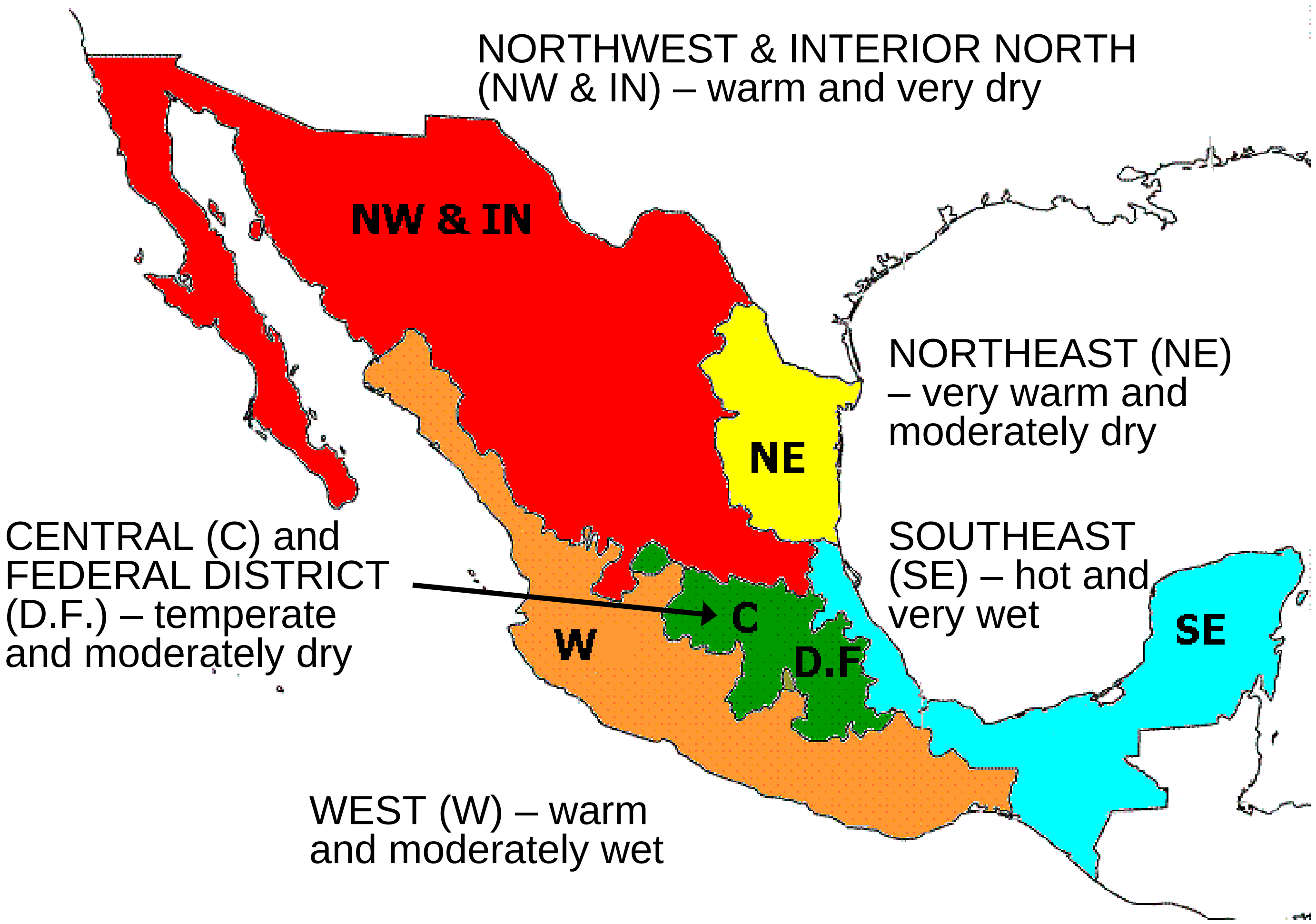
Waste Composition and Climate Data

- Compile waste composition data
  - Waste composition database expanded to cover 40 cities in 18 states plus Federal District
  - Average waste composition assigned to each state
- Divide Mexico into 6 regions (5 climate zones)
  - Average annual precipitation and temperature data collected from major cities in each state
  - Group states into climate zones

Mexico's Climate Regions



Data from Operating LFG Systems

- Identify sites with operating LFG extraction systems that can be used to test the model
  1. Merida Landfill
  2. San Nicolas Landfill in Aguascalientes
  3. Cuidad Juarez Landfill
  4. Simeprodeso Landfill in Monterrey
- Perform site visits to collect data and evaluate collection efficiency
- Evaluate data for model testing

Develop and Test Model

- Start with IPCC Model structure (4 k and Lo values)
- Calculate Lo values for each organic waste group
  - Lo is a function of % organic (dry weight basis)
- Estimate k values for 4 waste groups and 5 climate regions
- Run models for 4 sites with flow data for testing
  - Does collection efficiency implied by model match data?
- Develop model spreadsheet for public use
  - User inputs, automated calculations, table and graph output

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Mexico LFG Model Summary

- Model reflects Mexico's waste composition, climate, site conditions, and actual system performance at 4 project sites
  - Each state has default k and Lo values reflecting climate and average waste composition
  - Multi-phase model with 4 k values for different waste categories (similar to IPCC model)
  - Site visits and LFG flow data from 4 landfills used to develop model
  - User answers questions in input sheet – model automatically calculates collection efficiency
  - Calculated default inputs can be overridden with site-specific data

LMOP's Ukraine LFG Model – Approach to Development

- Model should reflect composition of wastes disposed in Ukraine's landfills
  - Expand waste composition data from prior M2M studies with new data
- Have the model reflect local climate conditions
- Structure model to capture Ukraine conditions
  - Use 4 k model structure
  - Include adjustments to LFG generation and recovery to account for site conditions
- Allow model to run with simple user inputs
  - Waste disposal rates and collection efficiency calculated based on user inputs

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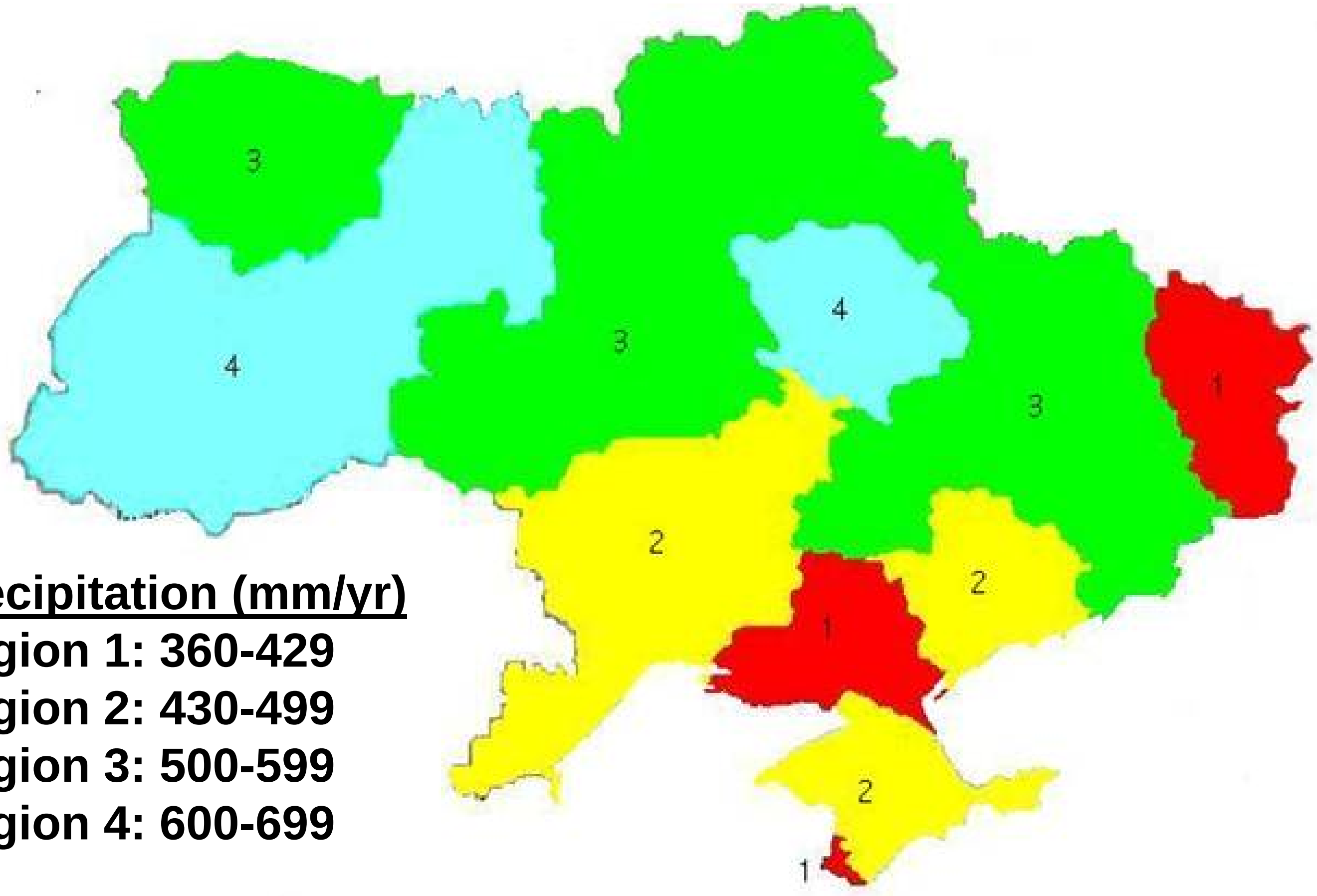
Ukraine's Climate Regions



<u>Precipitation (mm/yr)</u>
Region 1: 360-429
Region 2: 430-499
Region 3: 500-599
Region 4: 600-699

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Waste Composition Data

- **Compile waste composition data**
  - Start with waste composition data from assessment reports and pre-feasibility studies
  - Local subcontractor expanded database to cover 10 cities in 7 provinces
- **Calculate average waste composition for country**

Waste Categories:	Ukraine Average
Food Waste	36.1%
Paper and Cardboard	14.3%
Green Waste (Garden/Park Waste)	9.8%
Wood Waste	1.9%
Rubber, Leather, Bones, Straw	2.2%
Textiles	3.4%
Other Organics	0.4%
Metals	2.3%
Construction and Demolition Waste	3.6%
Glass and Ceramics	6.2%
Plastics	5.8%
Other Inorganic Waste	14.1%
Total:	**100.0%**
Total Organic Waste:	**68.1%**

Assign L_0 and k Inputs

- Calculate L_0 values for each organic waste group
  - L_0 is a function of % organic (dry weight basis)
- Estimate k values for 4 waste groups and 4 climate regions
  - Estimate ratios of waste decay rates for waste groups
  - Variation of k values between climates is a function of differences in precipitation

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Adjustments to LFG Generation

- Methane Correction Factor (MCF)
  - Adjustment to methane generation to account for aerobic waste decay
  - MCF varies with landfill depth and site management practices
  - L_0 values are multiplied by MCF (linear effect on LFG generation)
- Impacts of fires
  - Model accounts for fires by applying a “fire adjustment factor” based on user inputs

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Calculating Collection Efficiency

- Collection efficiency calculated by model based on user's answers to series of questions to account for site conditions and wellfield coverage

Account for site management practices	**Discount is 15% if site not operated as a managed landfill**
Account for waste depth	**Progressive discount if <10 m deep (5% for each meter < 10m)**
Account for wellfield coverage of waste area	**Estimate % of landfill with wells (account for active disposal area, steep slopes)**
Account for soil cover type and extent	**Final cover = 90%; intermediate cover = 80%; daily cover = 75%; no cover = 50%**
Account for bottom liner	**Discount is 5% x % area without liner**
Account for waste compaction	**Discount is 3% if no compaction**
Account for focused tip area	**Discount is 5% if no focused tip area**
Account for leachate	**Discount is up to 30% depending on climate and frequency of leachate ponding/runoff**

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Conclusions

- Large uncertainties in international LFG modeling despite growing demand
  - Models need adjustment to account for varying waste composition and site characteristics
  - Historical overestimation of achievable landfill gas recovery – CDM projects averaging only about 50% of predicted recovery rates
- Uncertainty estimating collection efficiency represents large potential source of error
  - Collection efficiency estimates need to account for site conditions such as leachate in extraction wells
  - Site visits, followed up by field testing can provide site-specific information and lower uncertainties

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Conclusions

- LMOP is providing assistance to better assess international LFG project potential
  - Country-specific LFG models for improved generation/recovery projections
    - LMOP Ukraine and Mexico LFG models developed by SCS for LMOP in 2009
    - Plans for a Colombia LFG model in 2010
  - Other technical assistance (assessment reports, pre-feasibility studies, workshops)

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For More Information

- Mexico, Ukraine, Central America, Ecuador, & China Landfill Biogas Models are available at:
  www.epa.gov/lmop/international.htm
- IPCC Model available at:
  www.ipcc-nggip.iges.or.jp/public/2006gl/vol5.htm
- Alex Stege email:
  astege@scsengineers.com