Methane to Markets

Mexico Landfill Gas Model – Version 2 (2009)

Landfill Subcommittee Meeting

Monterrey, Mexico

January 28, 2009

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Why an LFG Model for Mexico?

- **Methane generation and recovery estimates for LFG projects**
  - Screening tool for project development
  - Basis for assessing project feasibility

- **Other models currently available**
  - U.S. EPA Landfill Gas Emissions Model (LandGEM)
  - Old (2003) LFG Mexico Model
  - Intergovernmental Panel on Climate Change (IPCC) Model (2006)

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LFG and Methane Generation and Recovery

- **LFG generation from anaerobic waste decay is a function of:**
  - Waste disposal rates
  - Waste composition (% of dry organics)
  - Moisture (precipitation)
  - Limits to landfill depth, waste compaction, extent of soil cover
- **LFG recovery is determined by LFG generation and "collection efficiency" – function of:**
  - Collection system design
  - Collection system operation and maintenance
  - Landfill configuration and operations

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U.S. EPA LANDGEM

- **First-order decay model – LFG generation is calculated using the following variables:**
  - Waste disposal rates - M_i (Mg/year)
  - Methane generation potential – L_0 (m^3/Mg)
  - Methane generation rate – k (1/year)

- **LandGEM shortcomings:**
  - Model assumes USA waste composition
    - Mexico waste composition is different – higher food waste %
    - No guidance for L_0 and k adjustments in LandGEM
  - Model provides only “wet” and “dry” k values
    - Waste decay rates vary more continuously with precipitation
  - Model structure (single L_0 and k values that do not change over time)

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Mexico LFG Model 2003

- **First introduced in December 2003**
  - Model and user manual released in a workshop
  - User's manual provided on how to run model and estimate collection efficiency
- **Model uses LandGEM structure modified for Mexico**
  - Waste composition data from 31 cities
    - Average waste composition calculated for Mexico
    - Model Lo values developed based on ratio of dry organics (average Mexico vs. U.S.)
  - LFG recovery data from SIMEPRODESO LFG project used to develop model k value for Monterrey (~600 mm/yr rain)
  - Variation of model k with rainfall estimated based on U.S. experience

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Mexico LFG Model 2003 Shortcomings

- **Model assumes average waste composition for all of Mexico**
- **Model applies a single-k LandGEM equation:**
  - Effects of high food waste % not accounted for
  - Single-k model structure tends to:
    - Over-estimate LFG generation in wet climates
    - Under-estimate LFG generation in dry climates
- **Model default k values based on limited site data**
- **Model uses outdated version of LandGEM**
- **Model does not include projection of CERs**

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IPCC Model (2006)

- First order decay model
- Uses 4 waste categories,
- Uses 4 climate categories
- PDDs for CDM projects require application of a multi-phase first order decay model with variables found in the IPCC model
- Includes a methane correction factor (MCF)
- Includes a calculation of oxidation

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IPCC Model Shortcomings

- **Model not designed specifically for Mexico**
  - Uses default waste composition for all of Mexico based on limited data
  - No guidance on regional effects of climate
- **4 climate categories, but only 2 precipitation regimes**
  - Wet vs. dry cutoff is 1000 mm/yr
  - 2 precipitation regimes too coarse to capture effects on k values
  - Temperature not likely to have significant effects
- **Ratio of waste decay rates for food vs. wood too low**
  - Ratio only about 3 to 1 in dry climates

Approach to Development of the New Mexico Model

- **Build on the old Mexico Model**
  - Waste composition data covers 40 cities (vs. 31 cities in 2003)
- **Make the model very country-specific**
  - Evaluate climates in all regions
  - Group states into climate regions
  - Develop default waste composition and model values for each state & D.F.
- **Adopt IPCC Model structure with modifications**
  - Use 4 k values to account for decay rates of different waste fractions
  - Modify IPCC k values to better fit Mexico conditions
- **Evaluate data from sites with operating LFG systems**
  - Site visits to 3 landfills with LFG projects
  - Develop models for 4 landfills with projects to guide default k selections

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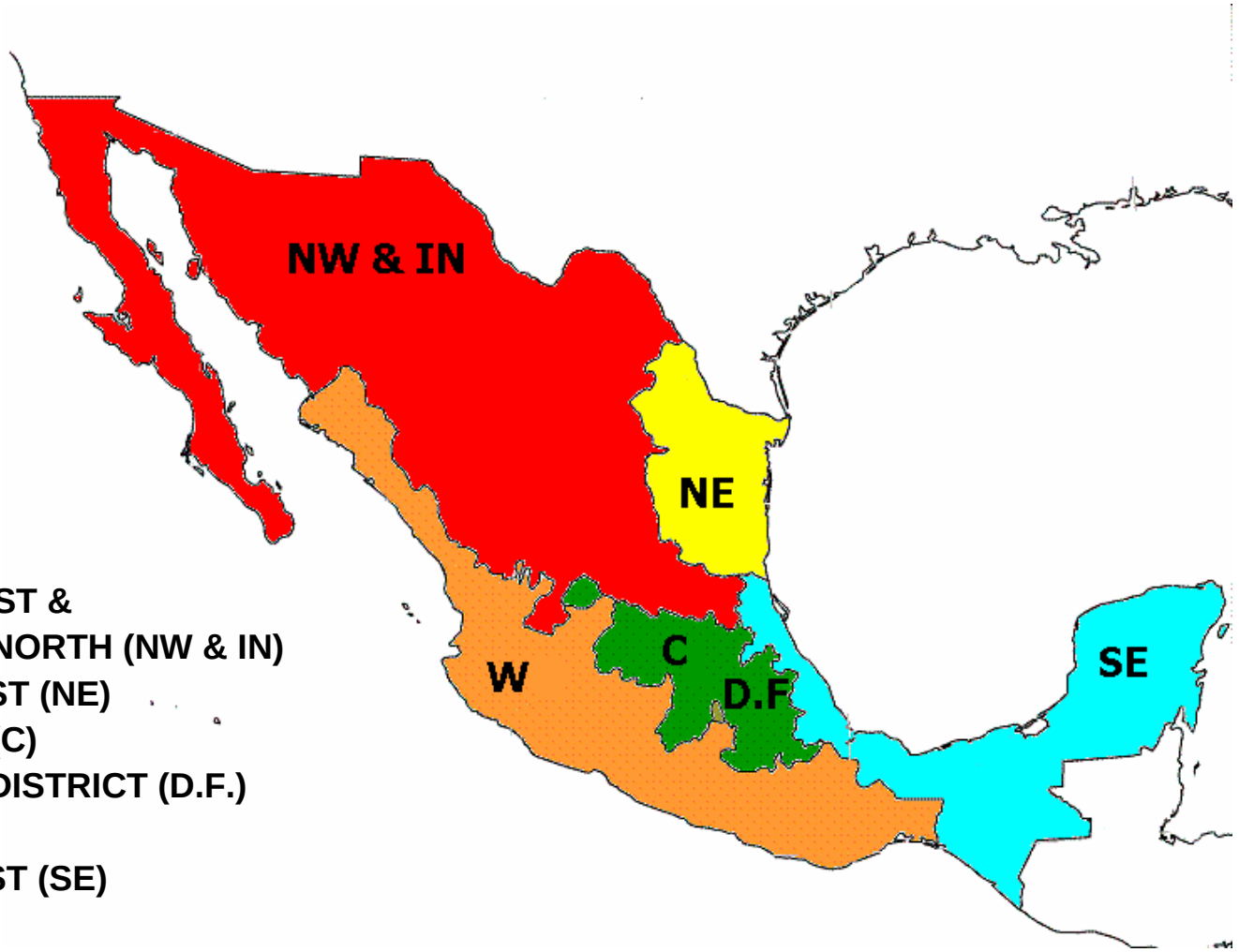
MEXICO'S CLIMATE REGIONS



1. NORTHWEST & INTERIOR NORTH (NW & IN)
1. NORTHEAST (NE)
2. CENTRAL (C)
3. FEDERAL DISTRICT (D.F.)
4. WEST (W)
5. SOUTHEAST (SE)

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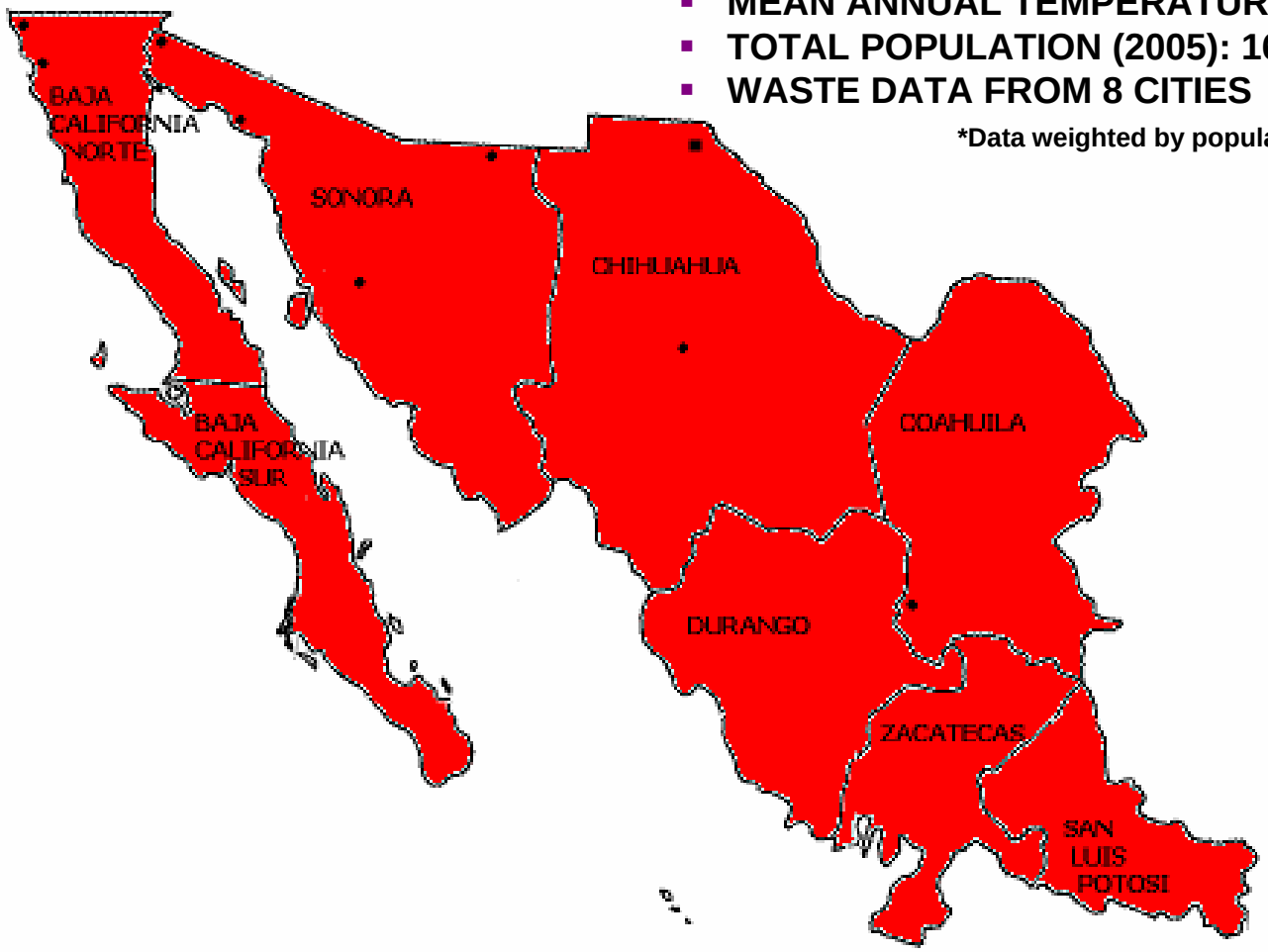
NORTHWEST & INTERIOR NORTH: Very Dry, Moderately Warm Climate

- **AVERAGE ANNUAL PRECIPITATION: 306 mm/yr***
- **MEAN ANNUAL TEMPERATURE: 18.6°C***
- **TOTAL POPULATION (2005): 16,775,360**
- **WASTE DATA FROM 8 CITIES**

***Data weighted by population**



NORTHEAST REGION:
Moderately Dry, Very Warm Climate

- **AVERAGE ANNUAL PRECIPITATION: 613 mm/yr***
- **MEAN ANNUAL TEMPERATURE: 22.3°C***
- **TOTAL POPULATION (2005): 6,482,890**
- **WASTE DATA FROM 8 CITIES AND TOWNS**

*Data weighted by population

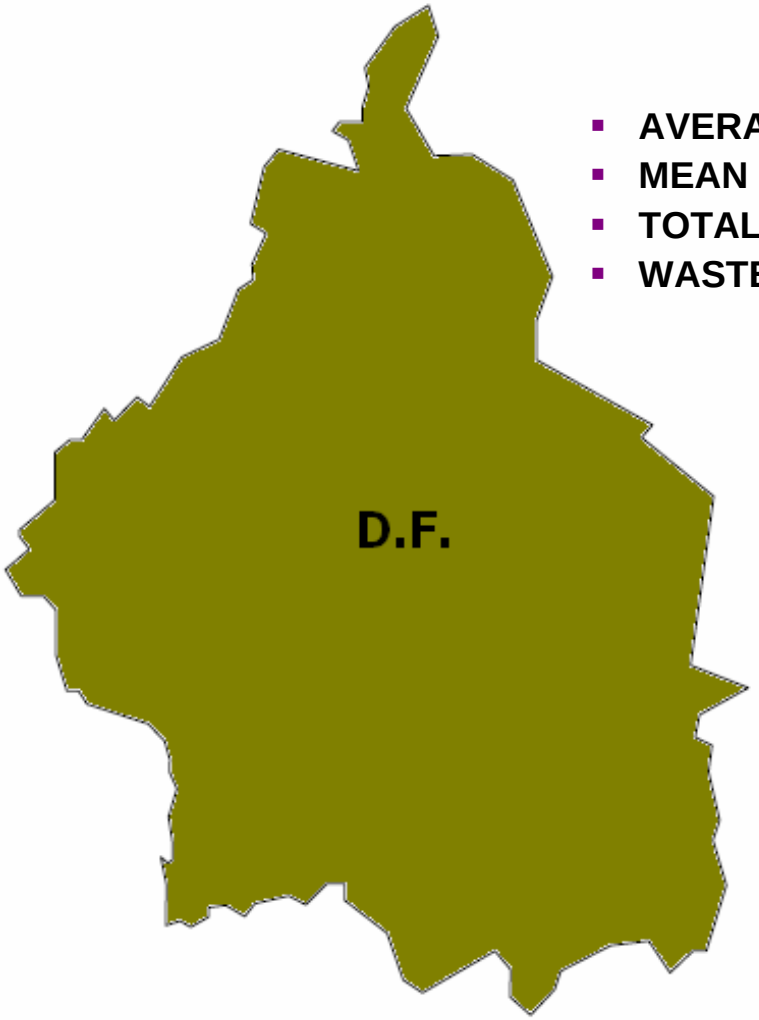
Note: Tampico area in southeastern Tamaulipas is moved into the very wet, hot Southeast Region

CENTRAL REGION:
Moderately Dry, Temperate Climate

- **AVERAGE ANNUAL PRECIPITATION: 664 mm/yr***
- **MEAN ANNUAL TEMPERATURE: 16.6°C***
- **TOTAL POPULATION (2005): 30,901,720**
- **WASTE DATA FROM 6 CITIES AND TOWNS**

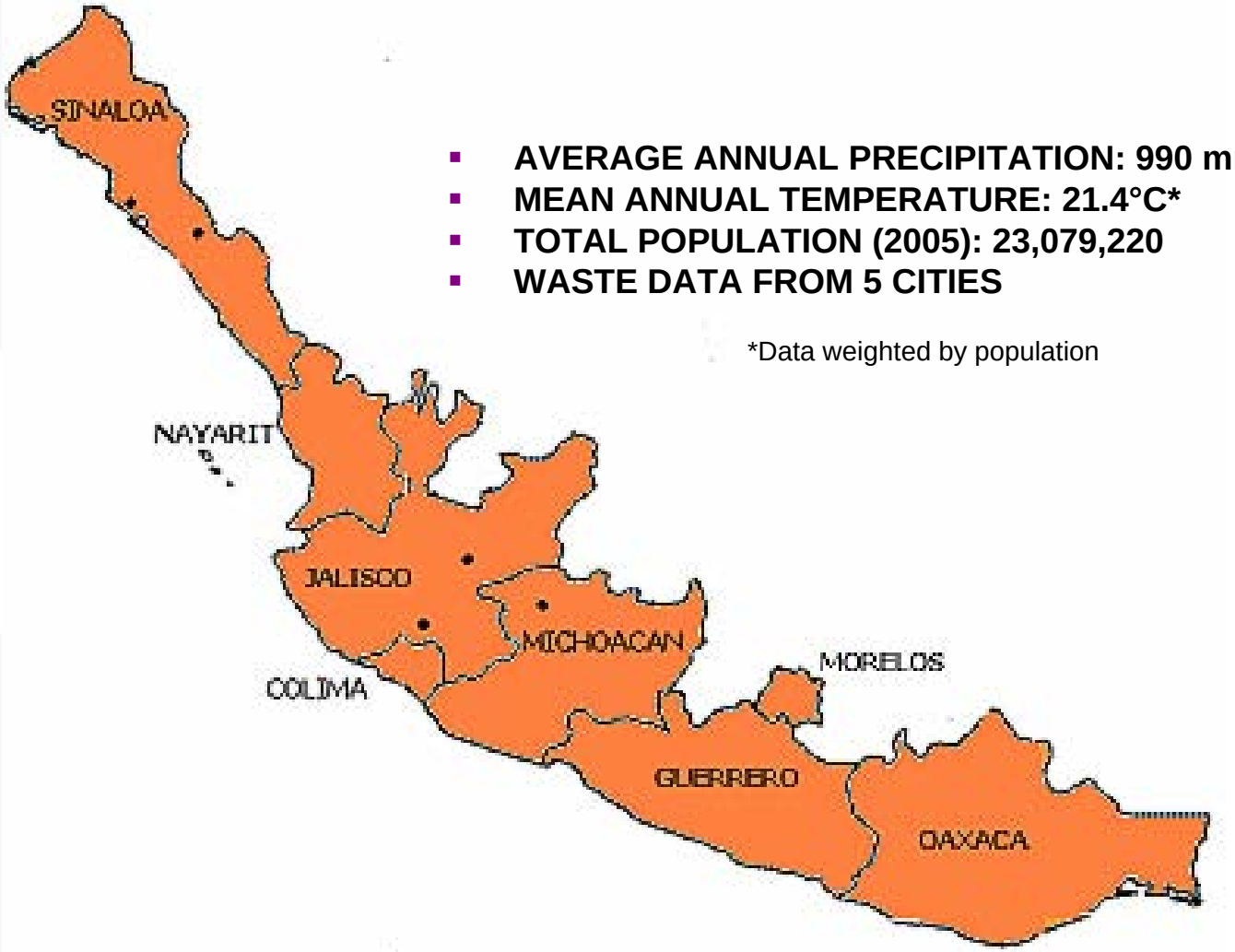
*Data weighted by population

FEDERAL DISTRICT:
Moderately Dry, Temperate Climate



- AVERAGE ANNUAL PRECIPITATION: 635 mm/yr
- MEAN ANNUAL TEMPERATURE: 16.6°C
- TOTAL POPULATION (2005): 8,720,916
- WASTE DATA FROM 3 LANDFILLS

WEST REGION:
Moderately Wet, Warm Climate



- **AVERAGE ANNUAL PRECIPITATION: 990 mm/yr***
- **MEAN ANNUAL TEMPERATURE: 21.4°C***
- **TOTAL POPULATION (2005): 23,079,220**
- **WASTE DATA FROM 5 CITIES**

*Data weighted by population

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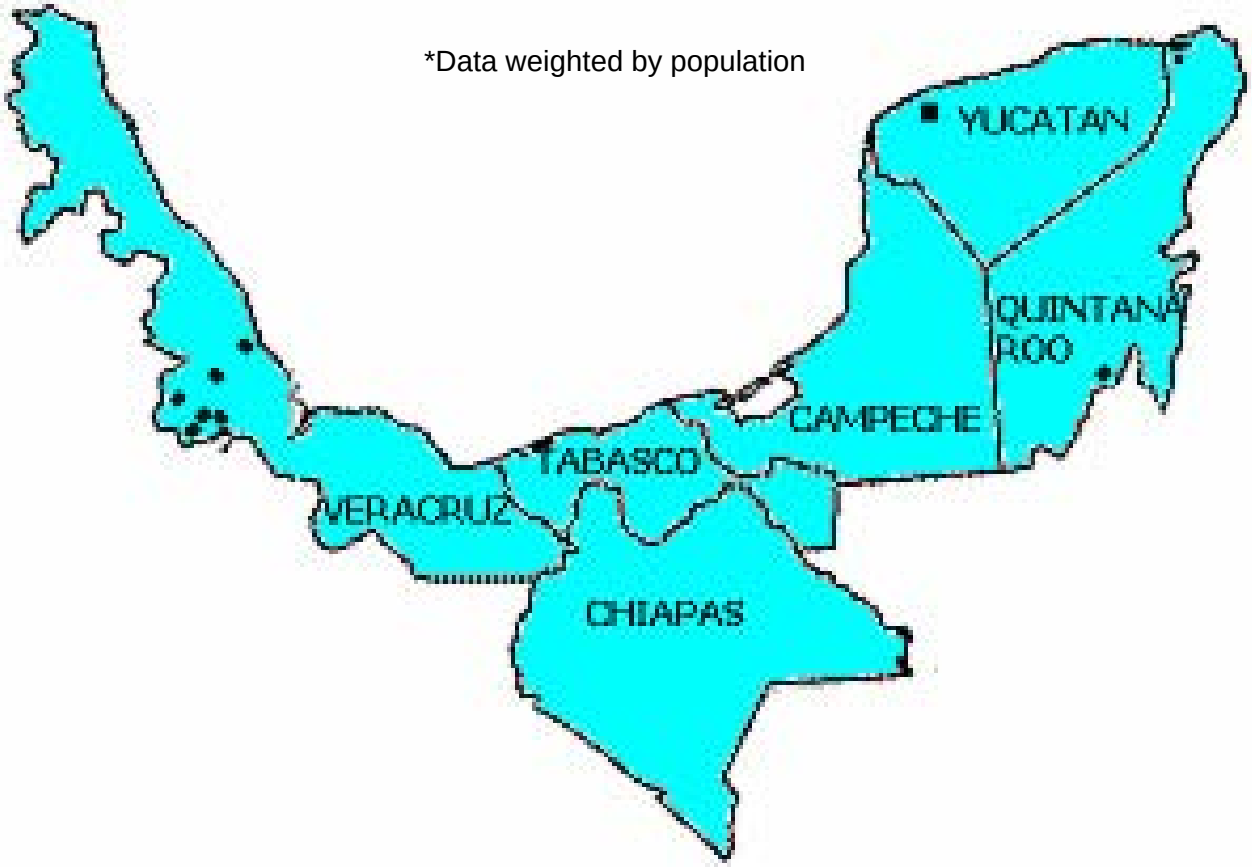
SOUTHEAST REGION:
Very Wet, Hot Climate

- **AVERAGE ANNUAL PRECIPITATION: 1,532 mm/yr***
- **MEAN ANNUAL TEMPERATURE: 24.1°C***
- **TOTAL POPULATION (2005): 17,843,270**
- **WASTE DATA FROM 12 CITIES AND TOWNS**

*Data weighted by population



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Average Waste Composition

Waste Category	Northwest & Interior North	Northeast	Federal District	Central/ Interior	Southeast	West
Food	30.7%	36.1%	12.2%	35.3%	30.6%	25.7%
Paper	16.3%	11.7%	14.8%	15.8%	12.8%	11.2%
Garden waste	9.9%	9.1%	9.1%	13.7%	18.2%	27.4%
Wooden waste	1.1%	1.7%	3.3%	0.5%	2.9%	0.9%
Rubber, leather, straw	1.2%	2.8%	2.1%	2.5%	3.3%	0.7%
Textiles	5.4%	3.6%	5.6%	1.2%	2.0%	0.9%
Toilet paper	No data	1.5%	3.2%	No data	No data	No data
Diapers	6.4%	No data	5.1%	3.1%	1.3%	3.5%
Other organics	1.9%	5.1%	0.2%	3.7%	5.0%	0.9%
Inorganics	26.9%	28.3%	44.4%	24.3%	23.8%	28.7%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

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Merida Site Visit

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Merida Landfill Data

- Landfill owned by the City of Merida; operated by Setasa
- Years of operation: Nov. 1997 – early 2010
- Site capacity: 2,595,000 tonnes
- Waste in place: 2,329,200 tonnes (end of 2008)
- LFG recovery project operated by ProActiva
- Average 2008 LFG recovery (July-Oct): 213 nm^3/hr @ 31% CH_4 (=131 m^3/hr @ 50% CH_4)
- Cells 1-4 with extraction wells installed
  - Cells 1-4 received ~1.04 million Mg (1997-early 2003)
  - Estimated collection efficiency: <30%

Aguascalientes Site Visit

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San Nicolas Landfill Data (Active Aguascalientes Site)

- Landfill owned and operated by the City of Aguascalientes
- Years of operation: 1999 – 2010
- Site capacity: 3,780,600 tonnes
- Waste in place: 3,253,700 tonnes (end of 2008)
- LFG recovery project operated by EcoMethane
- Average 2008 LFG recovery (Jan-Aug): 896 nm^3/hr adjusted to 50% CH_4 (based on 5,222,572 tCO_2e CERs - Monitoring Report)
- Cells 1-3 with extraction wells installed
  - Cells 1-3 received waste 1999 - 2006
  - Estimated collection efficiency: ~50%

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Cuidad Juarez Site Visit

Cuidad Juarez Landfill Data

- Landfill owned by the City of Juarez; operated by PASA
- Years of operation: 1998 – 2010
- Site capacity: 5,587,600 tonnes
- Waste in place: 4,666,400 tonnes (end of 2008)
- LFG recovery project operated by Biogas de Juarez, S.A. de C.V.
- Average 2008 LFG recovery (Jan-Sept.): 1,117 nm^3/hr @ 40% CH_4 (=899 m^3/hr @ 50% CH_4)
- Cell 1 with extraction wells installed
  - Cell 1 received ~2.25 million Mg
  - Estimated collection efficiency: ~65%

Simeprodeso Landfill (Monterrey) Data

- No site visit performed
- Landfill owned and operated by SIMEPRODESO a State of Nuevo Leon entity;
- LFG recovery project operated by Bioenergia de Nuevo Leon, S.A. de C.V.
- Average 2008 LFG recovery: 6,179 nm^3/hr adjusted to 50% CH_4
- Cells 1 and 2 with extraction wells installed
  - Cells 1&2 received ~13.6 million Mg (1991 - ~2003)

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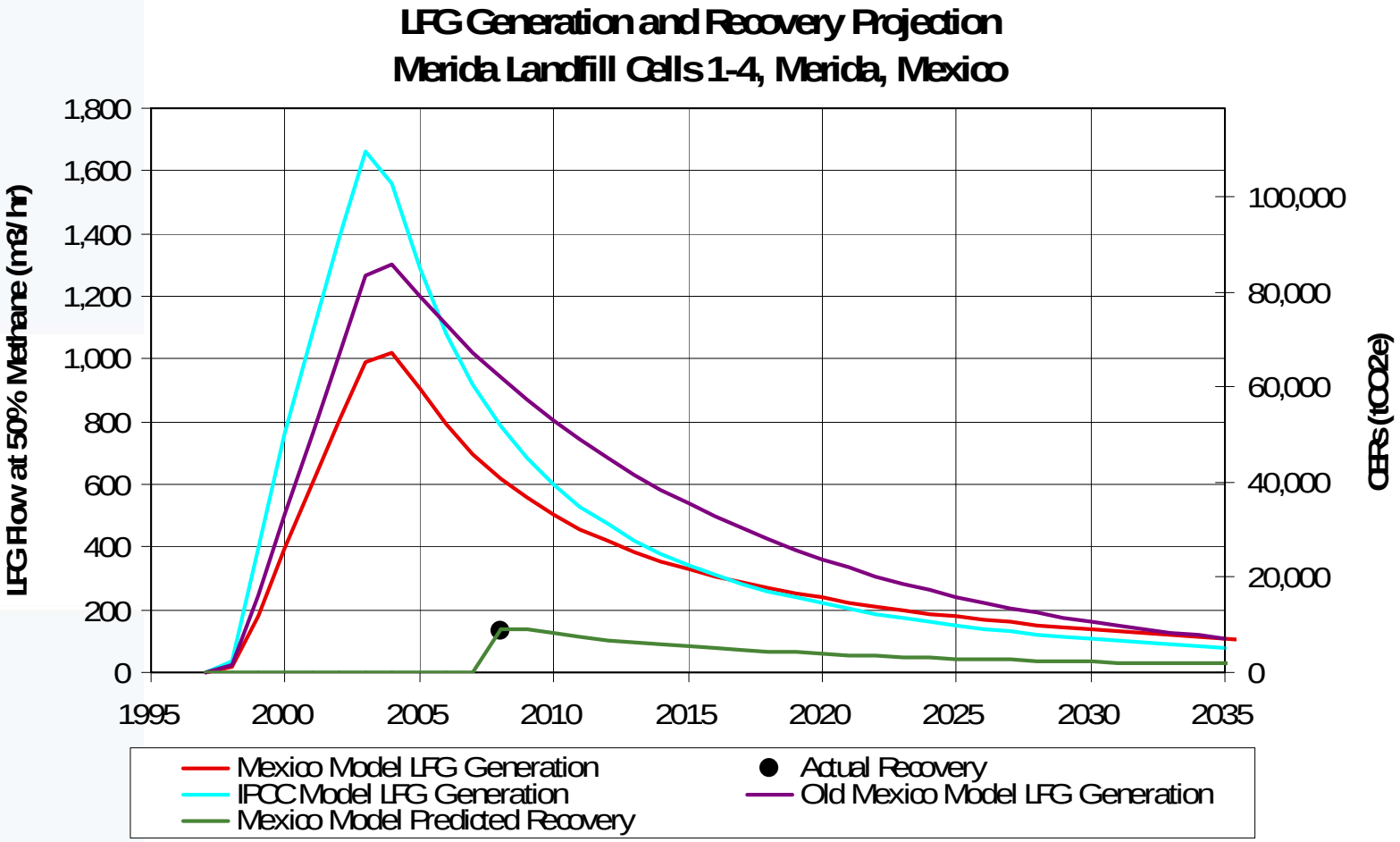
Merida Landfill LFG Model



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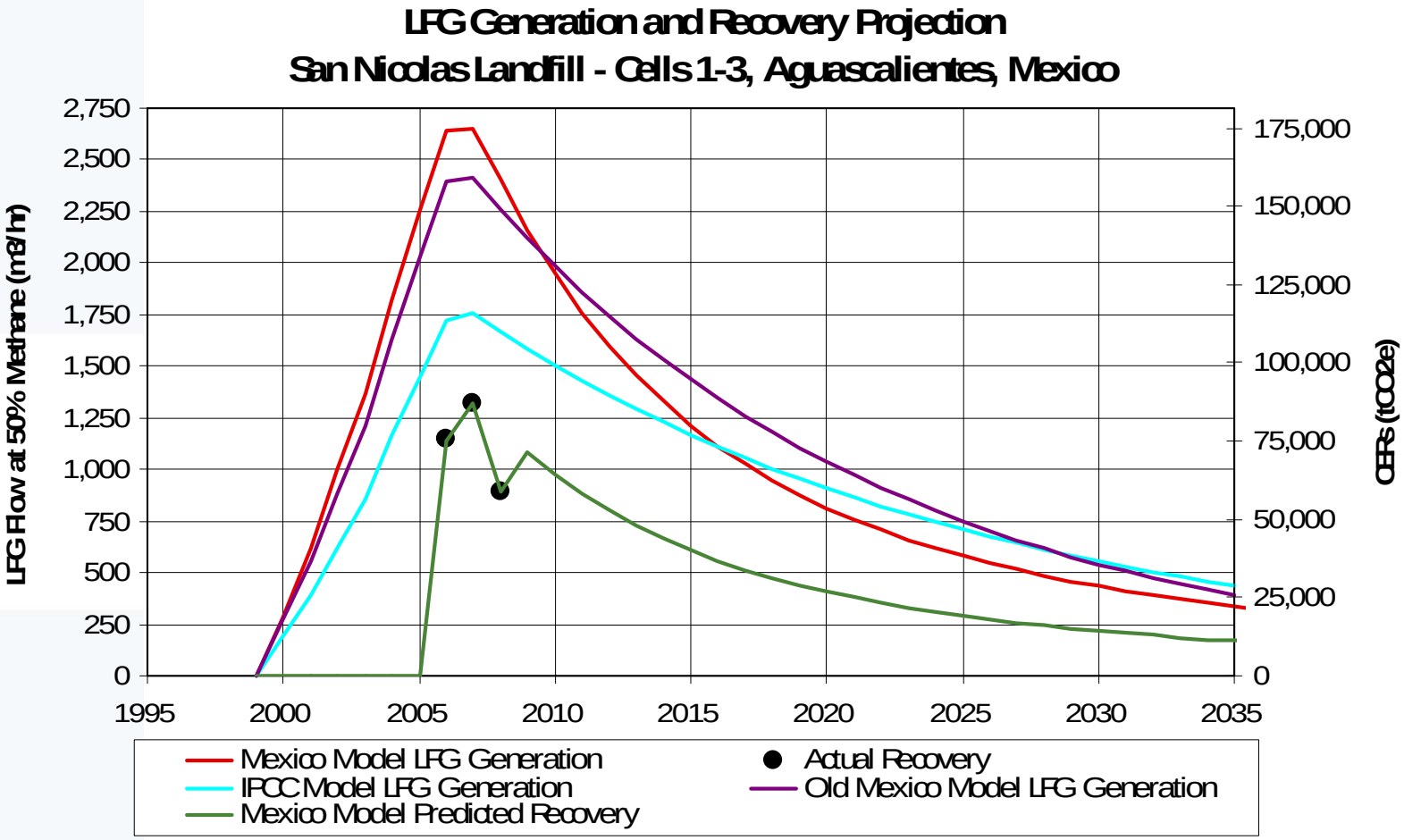
Aguascalientes (San Nicolas Landfill) LFG Model



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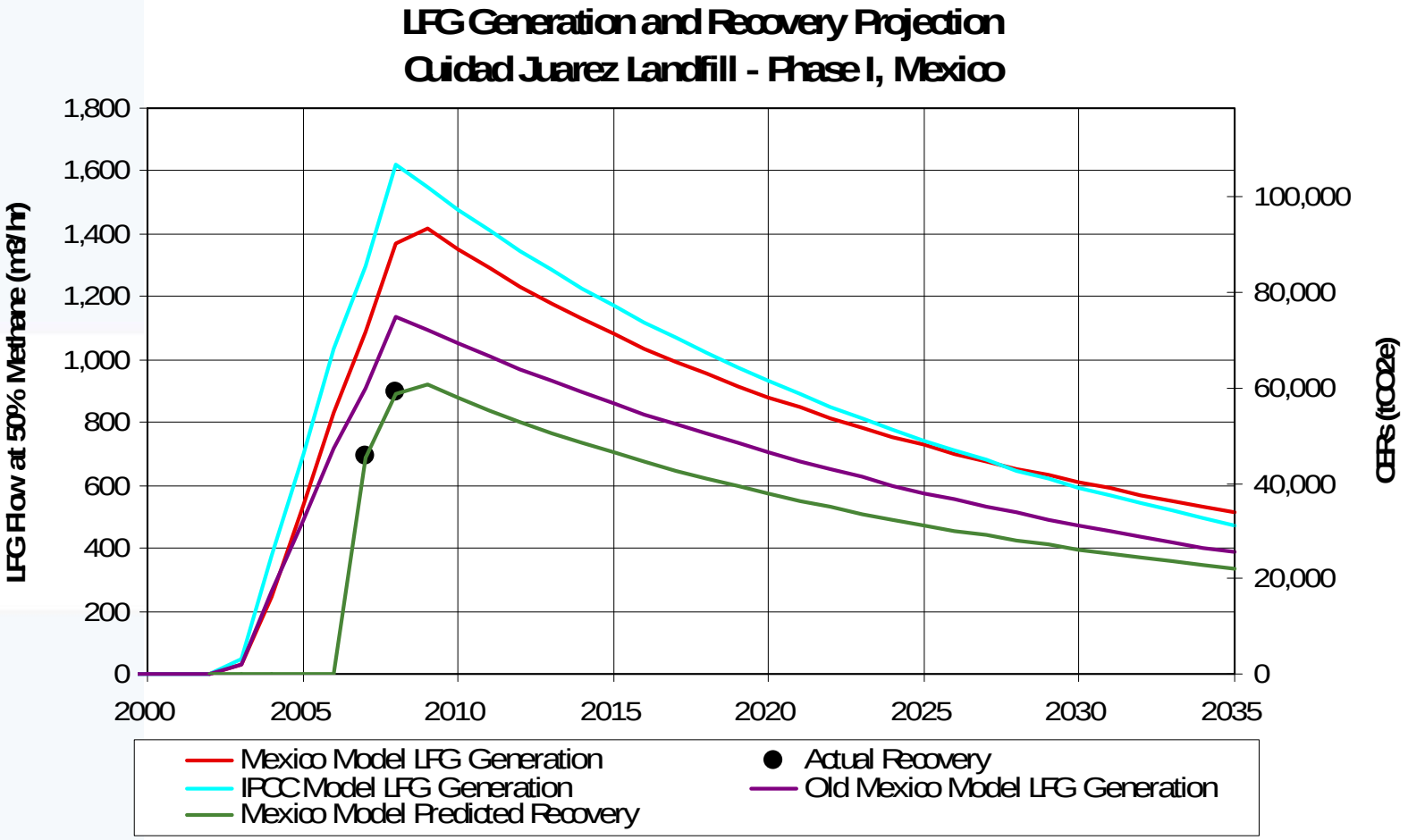
Cuidad Juarez LFG Model



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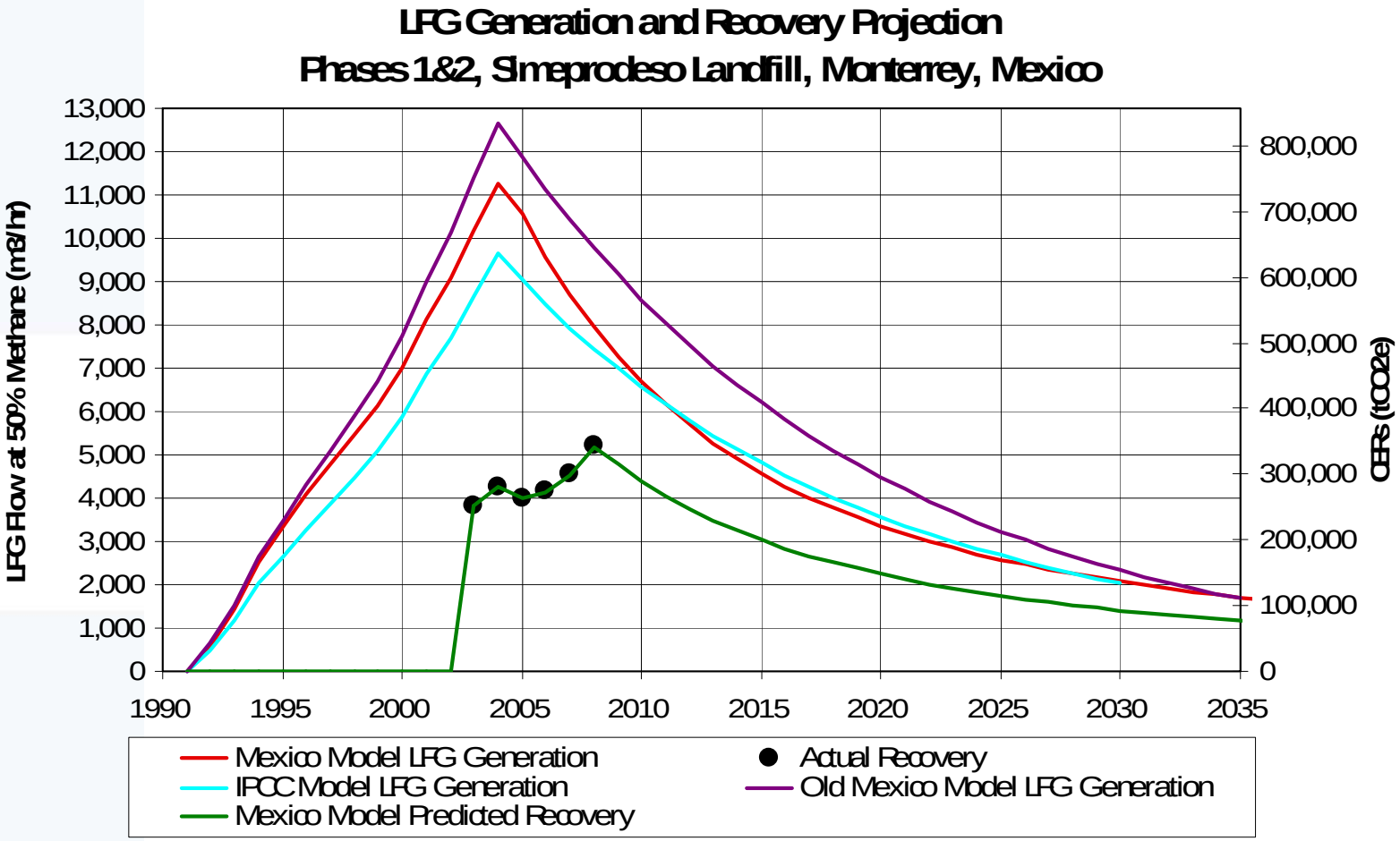
Simeprodeso Landfill LFG Model



LMOP MEXICO MODEL WORKSHOP

- Workshop planned for March
- Location of workshop to be determined
- Model, training on model use, and users manual to be provided at workshop
  - Review of model development
  - Procedure for preparing inputs, producing estimates
  - Practice model runs
- Model to be available on LMOP and M2M websites

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