



Landfill Methane Recovery Projects Lessons Learned – Part 1: Project Design vs. Actual Performance:

***Evaluation of Landfill Gas Models Using
Monitored Recovery from Projects in Latin
America, China, and Eastern Europe***



Methane to Markets

Presentation Topics

- Review of selected international biogas models
- U.S. EPA's LMOP biogas modeling projects:
 - Mexico and Central America models and workshops
 - Other LMOP modeling project work (M2M countries)
- Evaluation of 18 biogas projects at landfills in Latin America, China, and Eastern Europe
 - World Bank evaluation of CER under-delivery: Comparison of projected recovery in PDDs to actual recovery from monitoring reports
 - Focused analysis using biogas recovery projections and recovery data for 8 sites
 - Evaluate reasons for shortfalls: project under-performance or optimistic model estimates?

Selected International Landfill Biogas Models

- U.S. EPA's LandGEM
 - v. 3.02 (2005) calculations in 0.1 year increments
 - older versions most often used in PDD's
- Intergovernmental Panel on Climate Change (IPCC) Model (2006)
- LMOP's International LFG models:
 - Mexico Biogas Model (2003)
 - Central America Biogas Model (2007)
- Proprietary models:
 - World Bank Model
 - SCS Engineers' International Model

LMOP Landfill Biogas Modeling Projects by SCS

- Mexico Landfill Gas Model (12/2003)
- Thailand World Bank - LMOP Workshop (4/2004)
- Central America Biogas Model (3/2007)
- Numerous Assessment Reports and Pre-feasibility Studies involving LFG model development (Latin America, India, Ukraine, Russia).
- Future country or region-specific models planned



El Trebol Landfill, Guatemala City

Thailand LMOP Project

- World Bank – LMOP Landfill Biogas Training Workshop, Bangkok, Thailand (April 29-30, 2004)
- Visits to 5 landfills to observe site conditions
- SCS: 56 sites modeled, 15 using multi-phase FOD (3k)



LMOP's Central America Biogas Model (EPA, 2007)

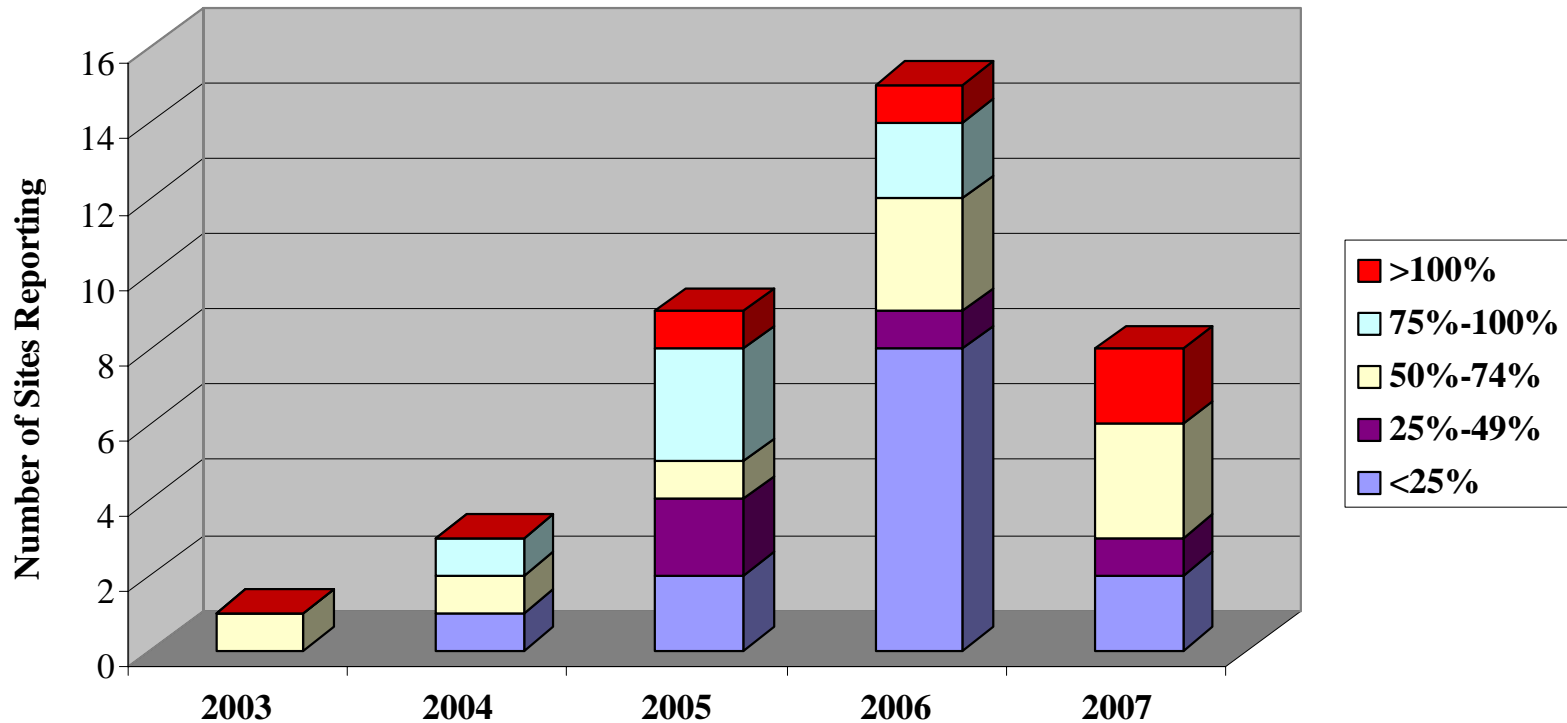
- SCS evaluated waste composition and site conditions, developed model with separate modules for each country
- LMOP workshop in El Salvador, March 29, 2007
 - Included one day workshop and training on model use
 - Site visit to Nejapa Landfill outside of San Salvador



World Bank Evaluation of LFG Project Under-Performance

- SCS Engineers evaluated projected vs. actual project performance (in Monitoring Reports)
- Results used in World Bank presentations:
 - Workshop on project shortfalls at World Bank headquarters in Washington, D.C. on April 19, 2007
 - Carbon Expo Conference in Cologne, Germany on May 3, 2007

Actual Project Performance % of Projected Recovery



- Model needs to account for waste composition and site conditions very different from developed countries

Waste Composition in Developing Countries

- Models must account for:
 - High moisture content: Model L_0 needs to be adjusted to account for moisture content (inert %)
 - High food waste content: fast decay rates (k) cause a steep decline in generation after closure
 - Potential for high inert % in some regions
 - Model error introduced unless different k values are used to account for different waste decay rates
 - High waste moisture content also contributes to leachate buildup

World Bank Evaluation – Modeling Study of 8 Projects

1. Grobina Landfill in Liepaja, Latvia.
2. Tianjingwa Landfill in Nanjing, China.
3. Bandeirantes Landfill in Sao Paulo, Brazil.
4. Villa Dominico Landfill in Buenos Aires, Argentina.
5. Salvador de Bahia Landfill in Salvador, Brazil.
6. Eight landfills in the Province of Guangdong, China.
7. San Nicolas and Cumbres Landfills in Aguas Calientes, Mexico.
8. Nejapa Landfill in San Salvador, El Salvador.

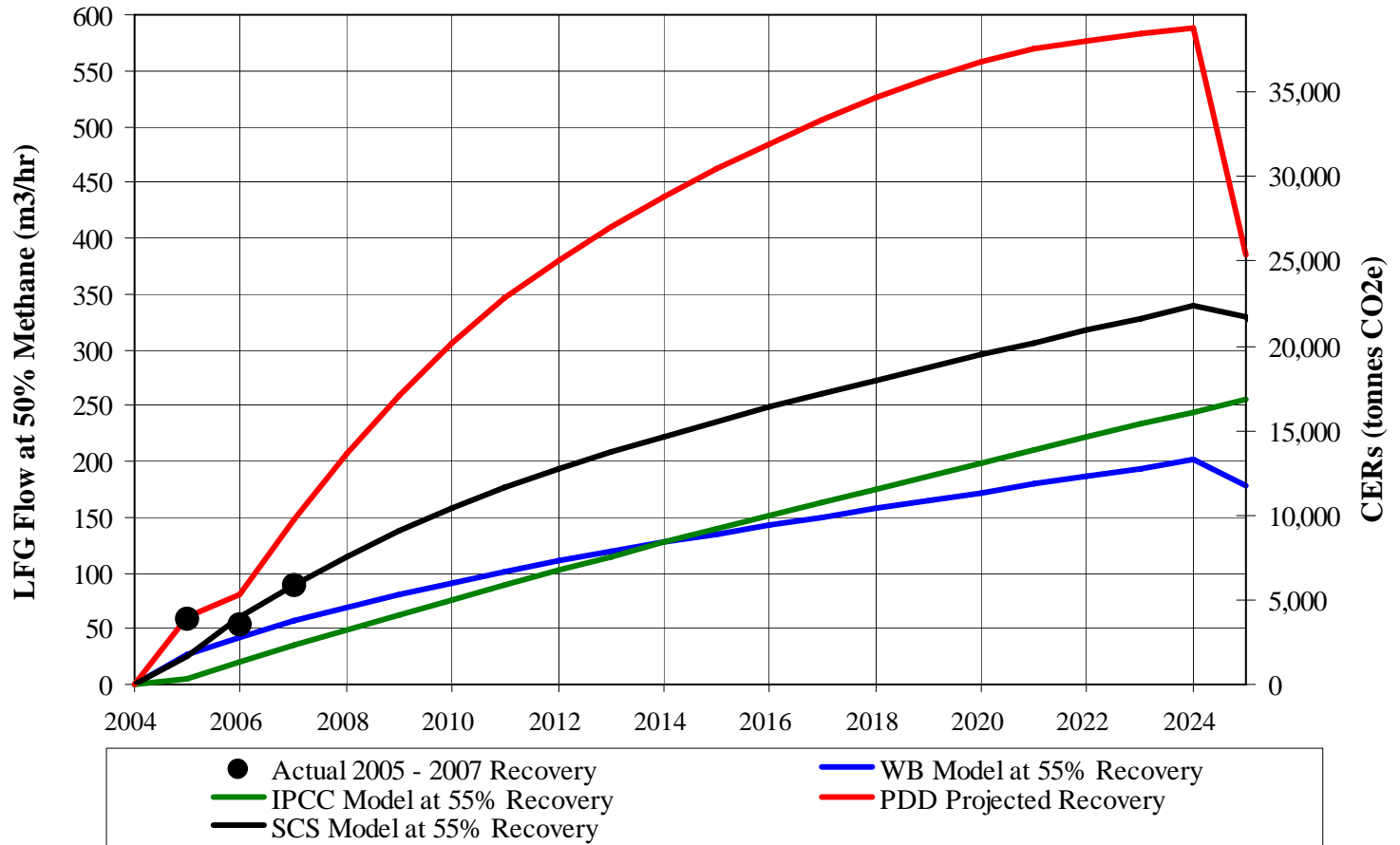
Grobina Landfill, Liepaja, Latvia

Year	Projected LFG Recovery (m³/hr at 50% CH₄)	Actual LFG Recovery (m³/hr at 50% CH₄)	Actual Recovery / Projected Recovery (%)
2005	60	59	98%
2006	80	54	68%
2007	148	89	60%

Grobina Landfill

Gas Curves

Figure 1. LFG Recovery Projections
Grobina Landfill, Liepaja, Latvia

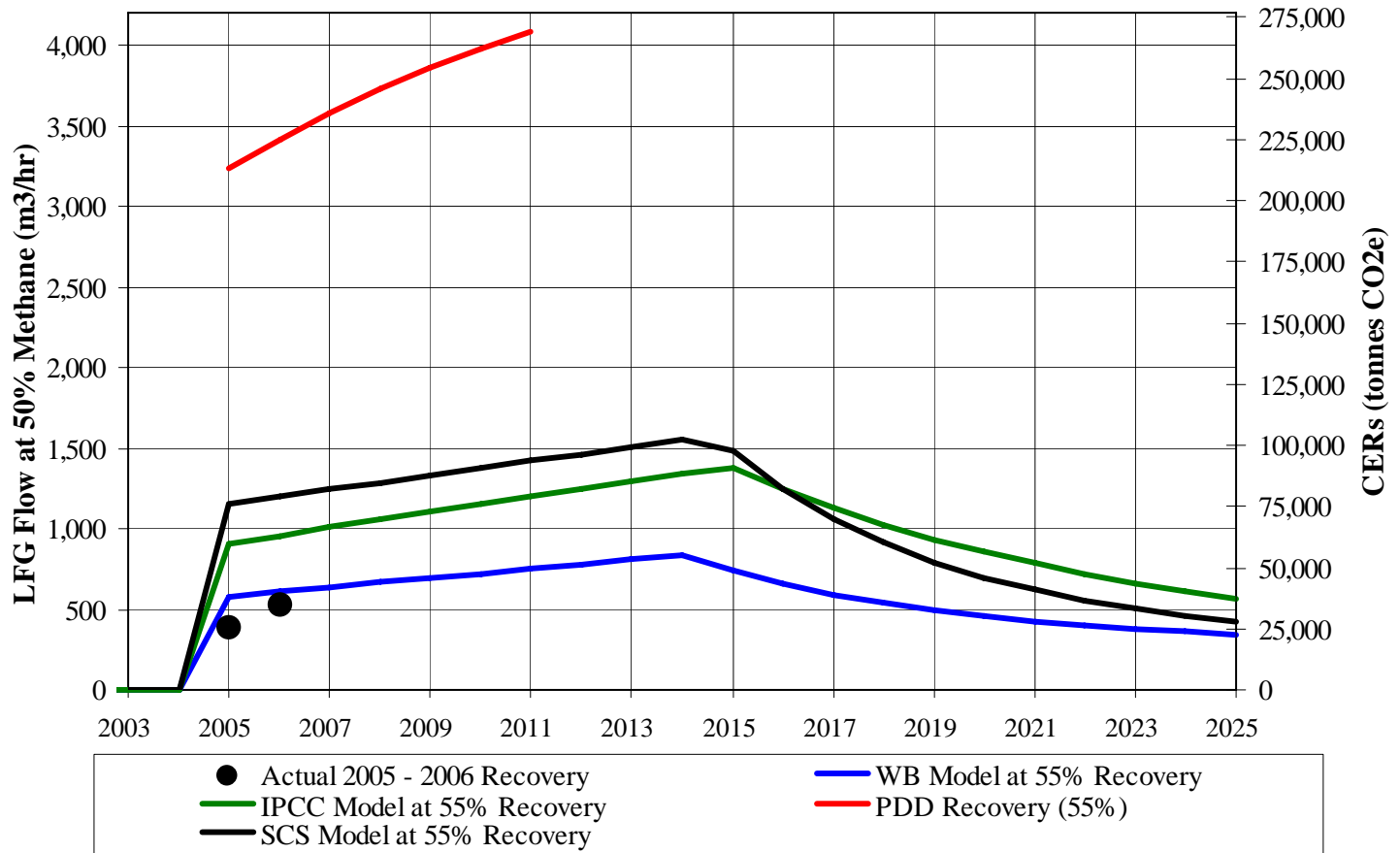


Tianjingwa Landfill, Nanjing, China

Year	Projected LFG Recovery (m³/hr at 50% CH₄)	Actual LFG Recovery (m³/hr at 50% CH₄)	Actual Recovery / Projected Recovery (%)
2005	3,240	389	12%
2006	3,419	531	16%

Tianjingwa Landfill Gas Curves

**Figure 2. LFG Recovery Projections
Tianjingwa Landfill, Nanjing, China**



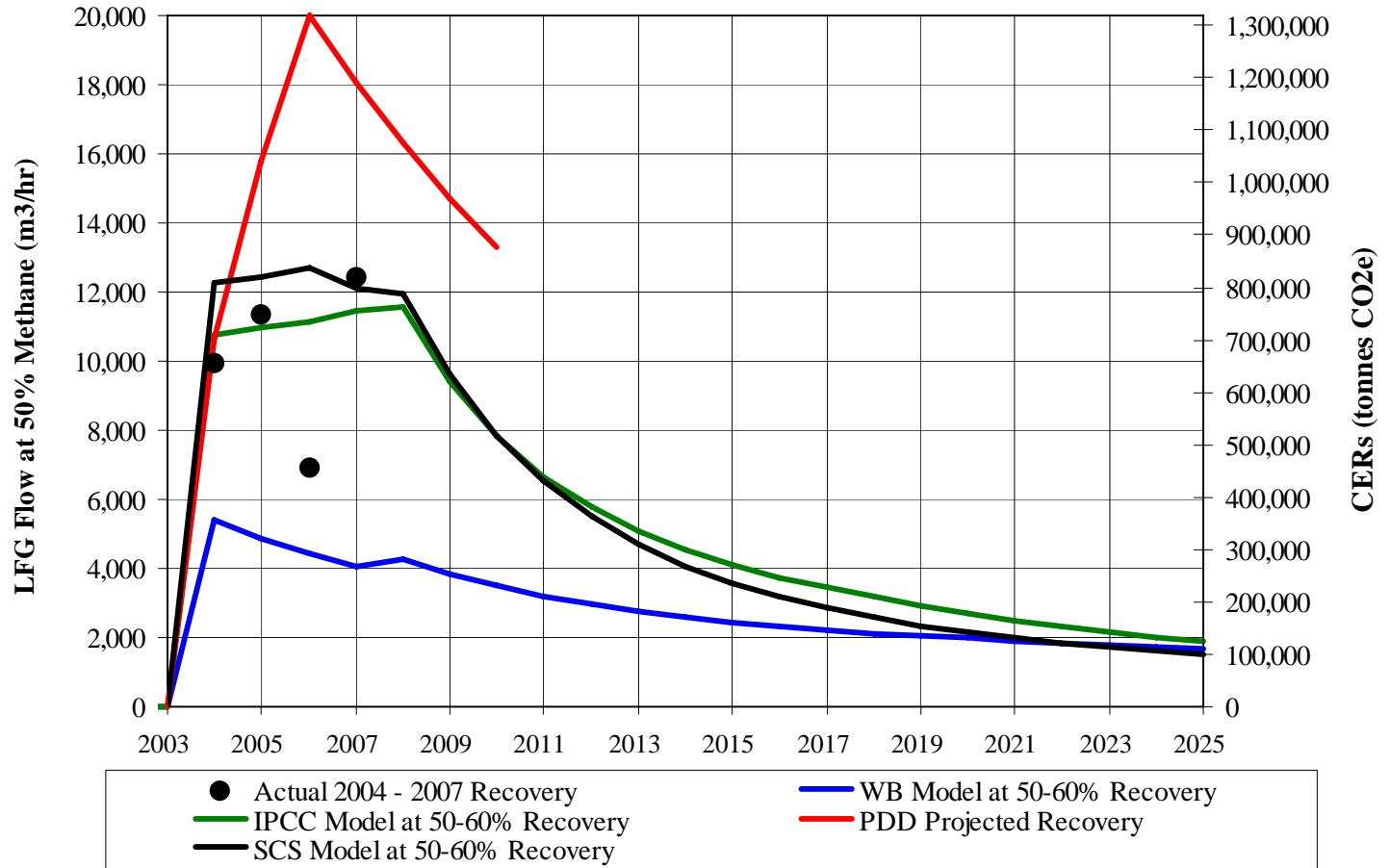
Bandeirantes Landfill, Sao Paulo, Brazil

Year	Projected LFG Recovery (m³/hr at 50% CH₄)	Actual LFG Recovery (m³/hr at 50% CH₄)	Actual Recovery / Projected Recovery (%)
2004	10,666	9,941	93%
2005	15,797	11,350	72%
2006	20,703	6,897	33%
2007	18,061	12,424	69%

Bandeirantes Landfill

Gas Curves

Figure 3. LFG Recovery Projections
Bandeirantes Landfill, Sao Paulo, Brazil



Villa Dominico Landfill, Buenos Aires, Argentina

Year	Projected LFG Recovery (m³/hr at 50% CH₄)	Actual LFG Recovery (m³/hr at 50% CH₄)	Actual Recovery / Projected Recovery (%)
2005	14,416	1,544	11%
2006	13,299	1,584	12%
2007	12,270	1,421	12%

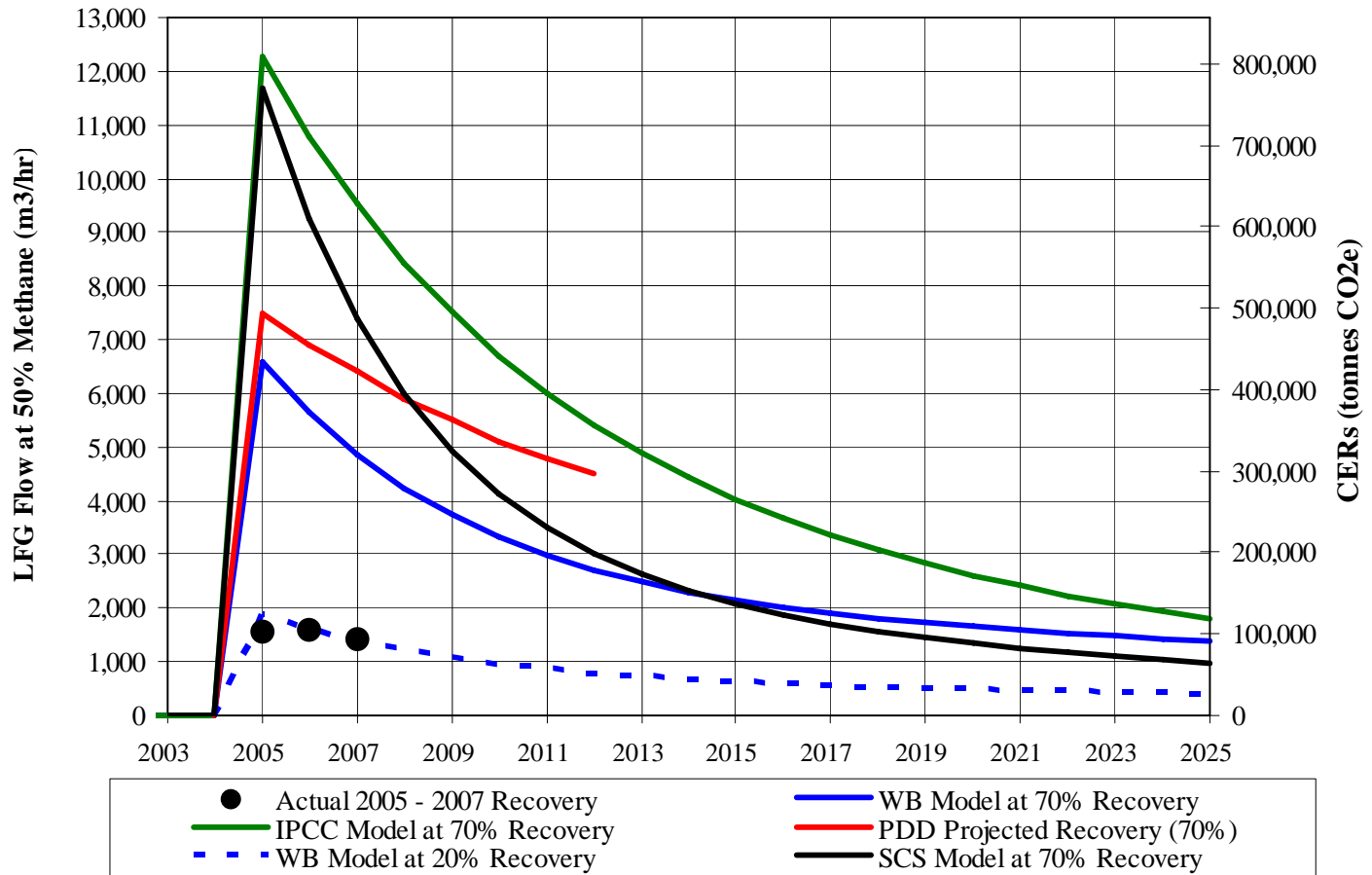


Leachate at Villa Dominico

Villa Dominico Landfill

Gas Curves

Figure 4. LFG Recovery Projections - Implemented Areas
Villa Dominico Landfill, Buenos Aires, Argentina

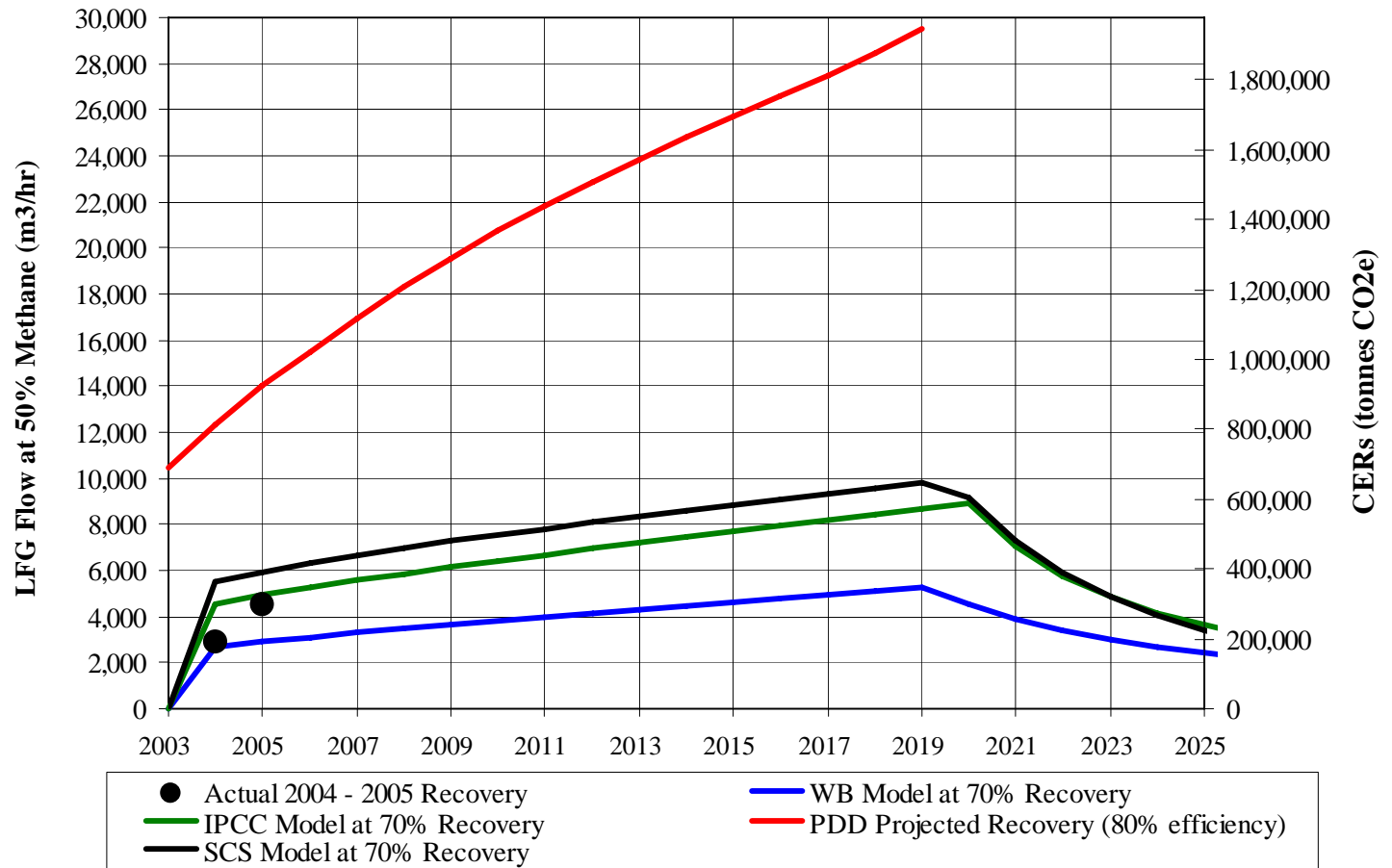


Salvador de Bahia Landfill, Salvador, Brazil

Year	Projected LFG Recovery (m³/hr at 50% CH₄)	Actual LFG Recovery (m³/hr at 50% CH₄)	Actual Recovery / Projected Recovery (%)
2004	12,300	2,900	24%
2005	13,990	4,559	33%

Salvador de Bahia Landfill Gas Curves

Figure 5. LFG Recovery Projections
Salvador de Bahia Landfill, Salvador, Brazil

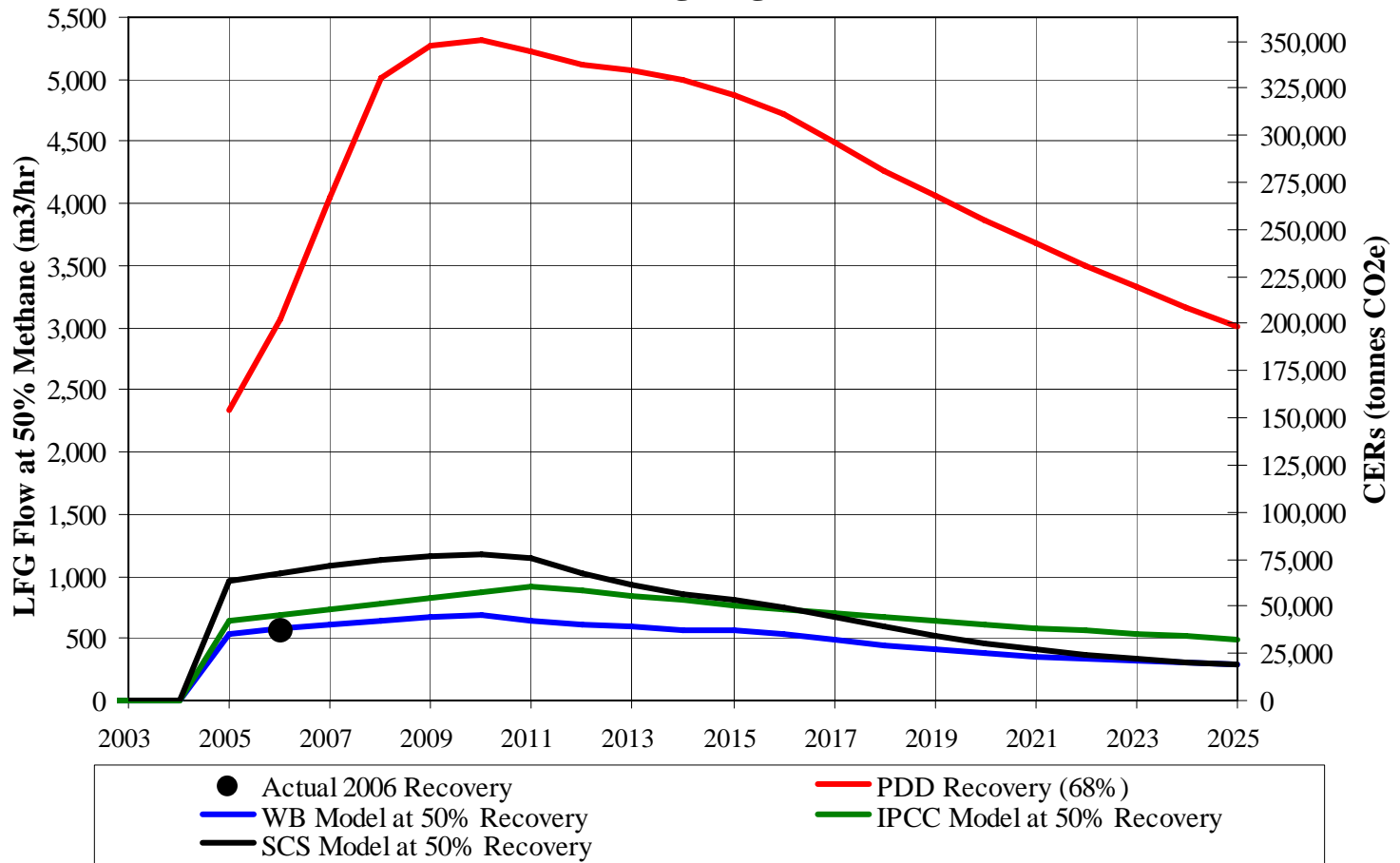


Eight Landfills in the Province of Guangdong, China

Year	Projected LFG Recovery (m³/hr at 50% CH₄)	Actual LFG Recovery (m³/hr at 50% CH₄)	Actual Recovery / Projected Recovery (%)
2006	3,066	559	18%

Eight Landfills in Guangdong Landfill Gas Curves

**Figure 6. LFG Recovery Projections
8 Landfills in Guangdong Province, China**

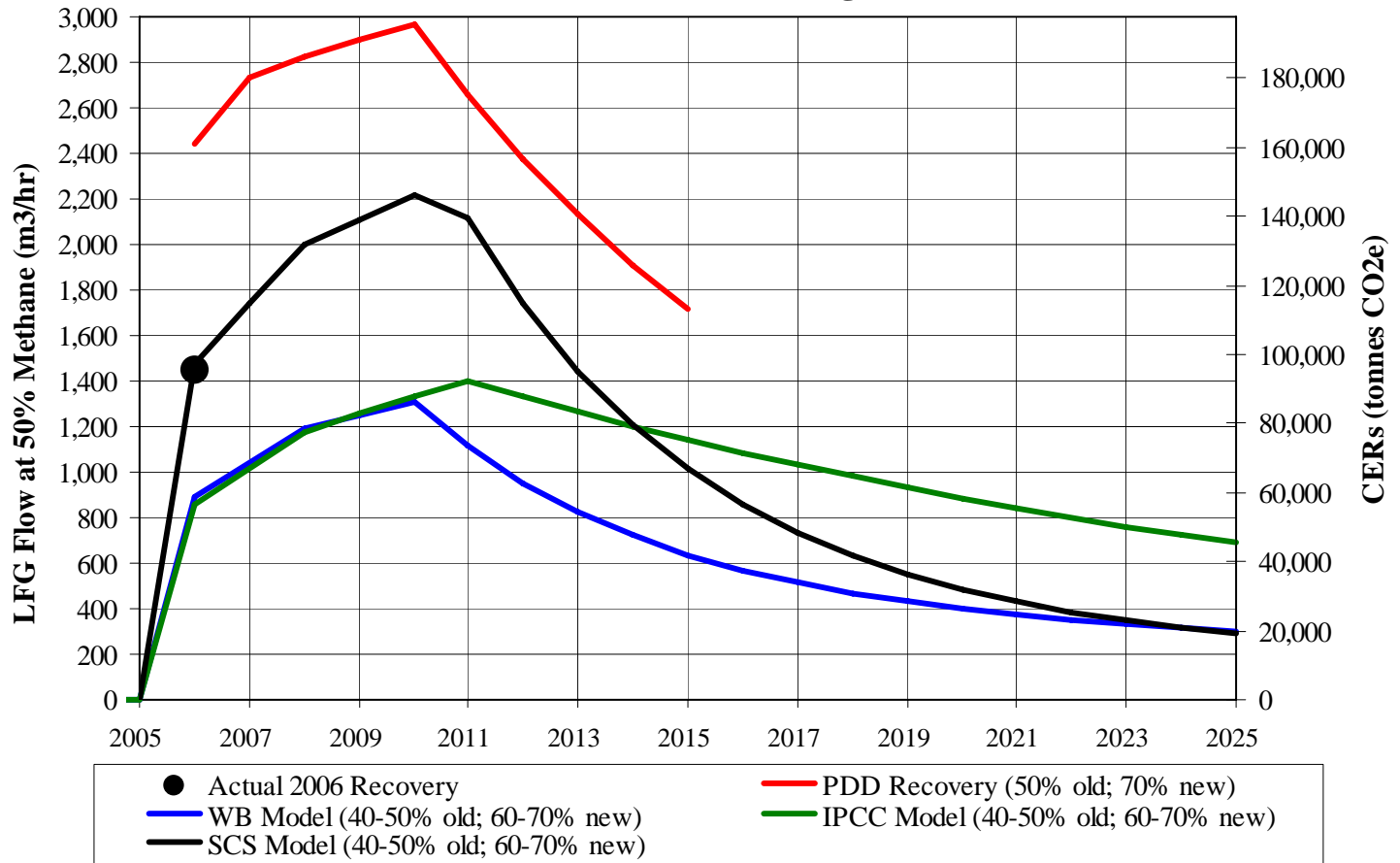


San Nicolas and Cumbres Landfills, Aguascalientes, Mexico

Year	Projected LFG Recovery (m³/hr at 50% CH₄)	Actual LFG Recovery (m³/hr at 50% CH₄)	Actual Recovery / Projected Recovery (%)
2006	2,445	1,454	59%

San Nicolas and Cumbres Landfill Gas Curves

Figure 7. LFG Recovery Projections
Cumbres and San Nicolas Landfills in Aguascalientes, Mexico

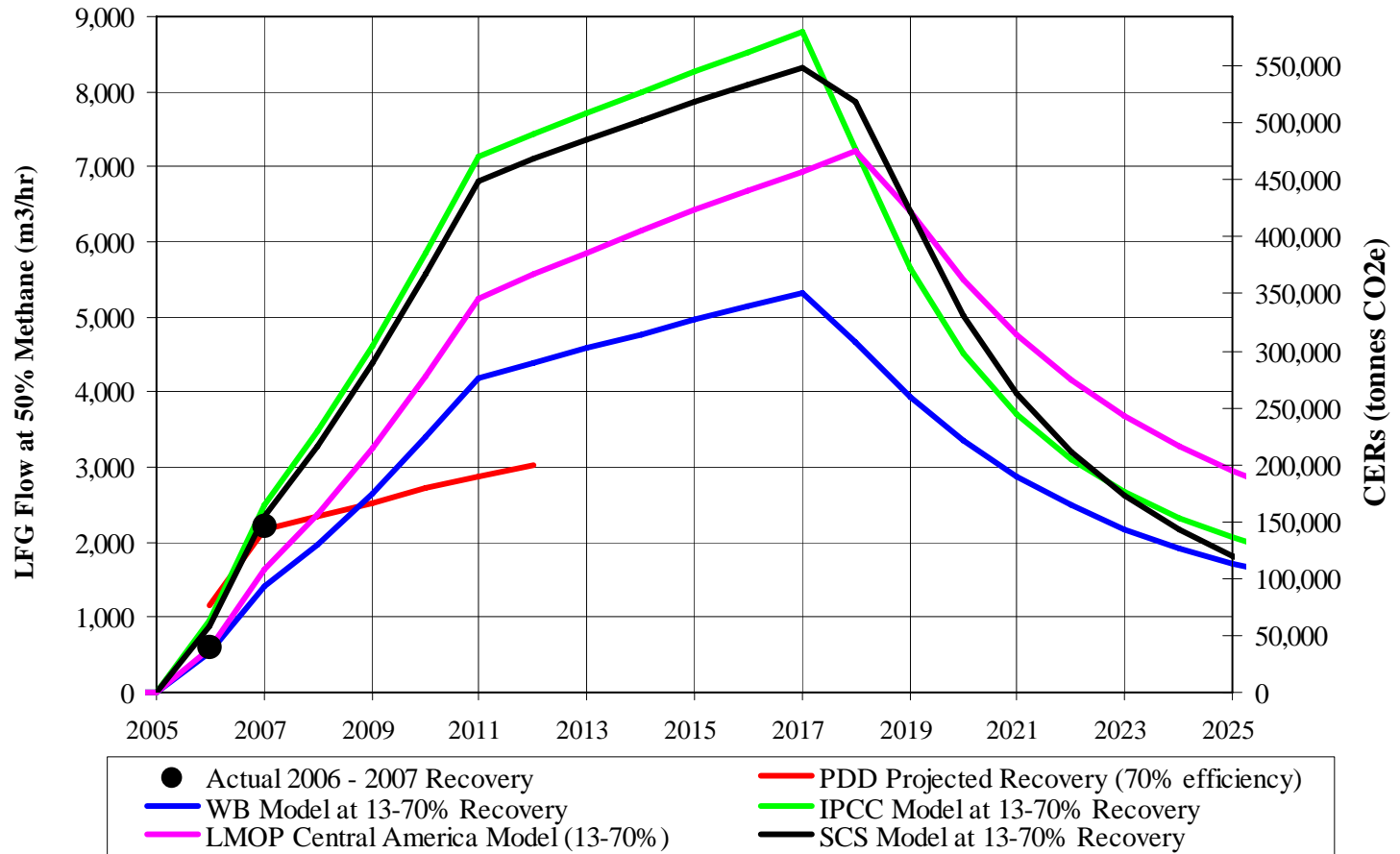


Nejapa Landfill, San Salvador, El Salvador

Year	Projected LFG Recovery (m³/hr at 50% CH₄)	Actual LFG Recovery (m³/hr at 50% CH₄)	Actual Recovery / Projected Recovery (%)
2006	1,148	596	52%
2007	2,169	2,218	102%

Nejapa Landfill Gas Curves

Figure 8. LFG Recovery Projections
Nejapa Landfill, San Salvador, El Salvador



Overly Optimistic Models or Under-Performing Projects?

- Summary of common model problems:
 - Model L_0 value too high
 - Use of simple first order decay model with high k value
 - High collection efficiency assumptions
 - Leachate problems not anticipated
- Full impact of site conditions not always predictable
 - e.g., Villa Dominico and Bandeirantes



Summary and Conclusions

- Monitoring data to date indicates that most LFG recovery projects are not meeting PDD expectations
- Shortfalls often result from inappropriate model assumptions rather than from project under-performance
- LMOP, IPCC, and SCS models better account for waste composition and site conditions
- Models need to apply:
 - Multiple k values account for rapid food waste decay
 - Conservative L_0 , MCF values and collection efficiency estimates to reflect site specific conditions

For More Information

- LMOP continuing to provide training to developing countries through M2M (www.methanetomarkets.org)
- For more information on LMOP's M2M programs, contact Brian Guzzone at guzzone.brian@epa.gov
- Information on World Bank's Landfill Gas to Energy Initiative available at: www.bancomundial.org.ar/lfg
- A link to the World Bank workshop on April 19, 2007 on project design vs. actual performance is at: <http://go.worldbank.org/AIKAGIXIN0>, or contact Chuck Peterson at cpeterson@worldbank.org
- Central America Landfill Biogas Model is available at: www.epa.gov/lmop/international.htm
- IPCC Model is available at: www.ipcc-nggip.iges.or.jp/public/2006gl/vol5.htm
- For more information about this presentation, contact Alex Stege at: astege@scsengineers.com