Regional Prediction of LFGTE Potential: Florida Case-Study

Hamid Amini

Debra Reinhart

University of Central Florida

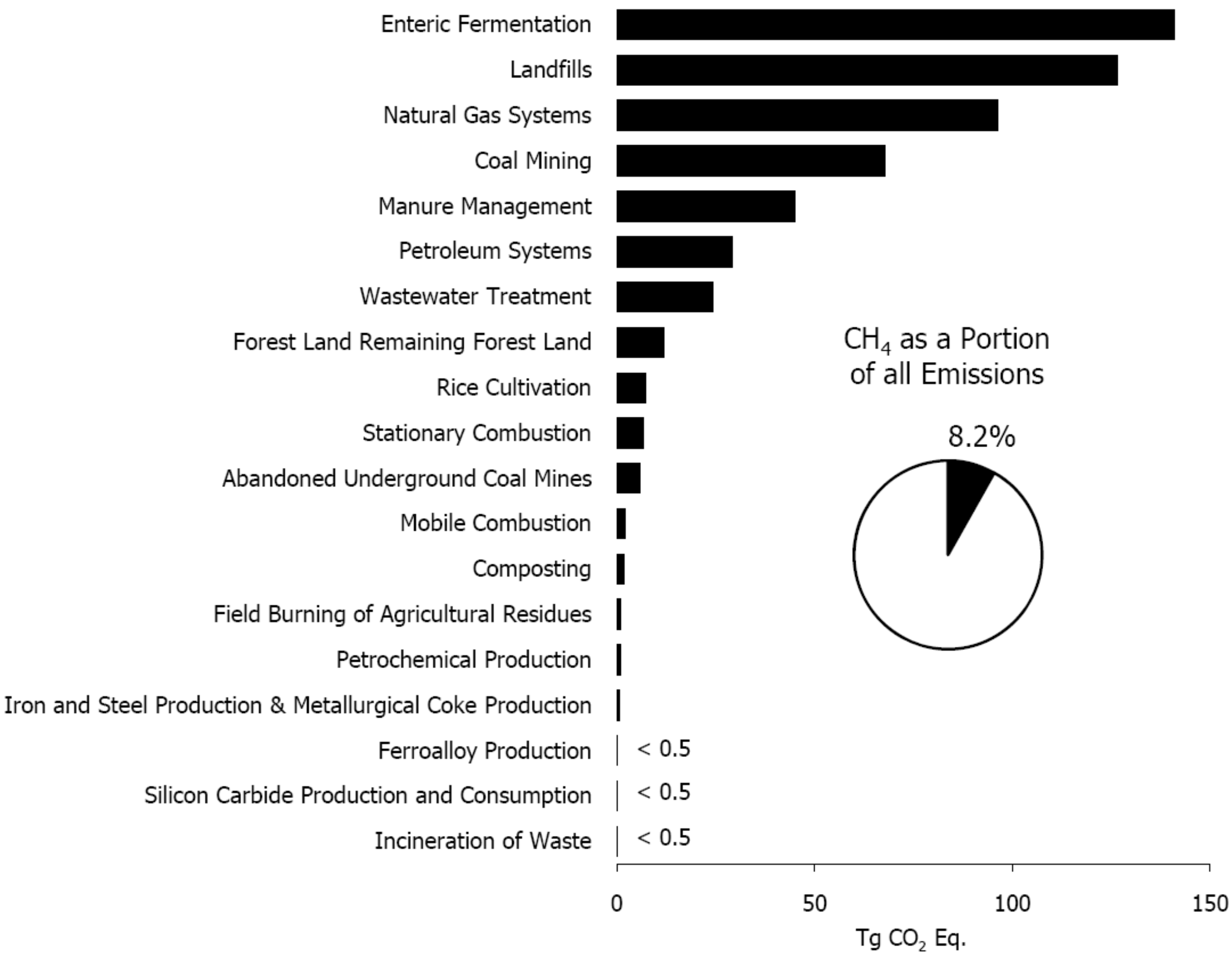
Project Objectives

- Predict Florida LFG and LFGTE production potential
- Improve the viability of LFGTE projects through case study analysis

Waste Generated GHGs

- LFG is generated from the anaerobic decomposition of MSW, consisting of:
  - CH_4, 50-60%
  - CO_2, 40-50%
  - Other trace gases, <1%
- Methane believed to be of higher importance, due to:
  - Landfill CO_2 emissions are biogenic
  - CH_4 has a GWP of 21 greater than CO_2

US CH_4 Emission Sources



US EPA (2010); "Inventory of US greenhouse gas emissions and sinks: 1990-2008," EPA 430-R-10-006

LFGTE Projects

- LFG has a energy value of 18-22 MJ/m^3, due to methane content
- Across the United States, as of July 2010:
  - 518 operational LFGTE projects, 1615 MW electricity production and 3000 Mm^3 direct thermal use annually
  - 520 other potential landfills, 1200 MW electricity production potential annually
- As of January 2010, 33 states had established RPSs almost all considering LFGTE as a renewable energy resource

Florida MSW & LFGTE

- About 60% of Florida MSW, over 16 million tonnes, was landfilled in 2007
- Most of the 64 active landfills collect LFG, but only 16 landfills operate or support a LFGTE facility, with annual design capacity of:
  - 61 MW of electricity production, and
  - 39 Mm^3 to direct thermal use

LFG Collection Modeling

- First-order model (modified LandGEM)

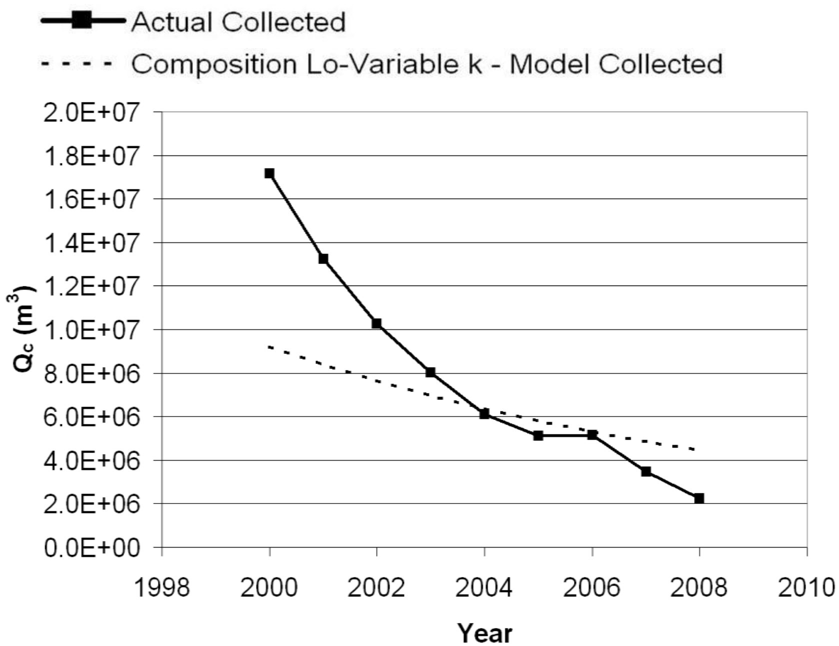
$$Q_c = \sum_{i=1}^{n} \sum_{j=0.1}^{1} \eta_{iz} \alpha k \left(\frac{M_i}{10} \right) L_{0_i} e^{-kt_{zj}}$$

where:

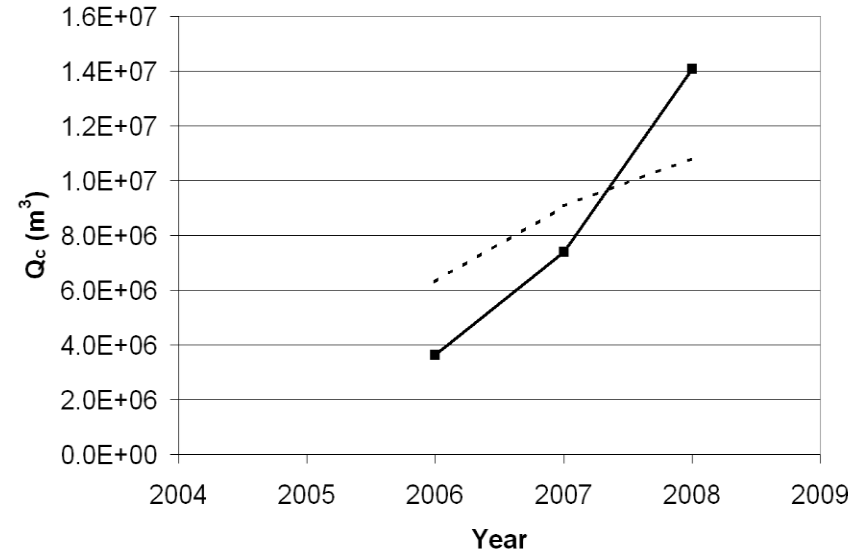
- Q_c = Annual collected LFG flow rate, $m^3 yr^{-1}$
- k = Methane generation rate constant, yr^{-1}
- M_i = Disposed waste tonnage in year i, Mg
- L_{0i} = Methane generation potential of M_i, m^3 CH_4.Mg^{-1} waste (wet basis)
- t_{zj} = Age of j^{th} section of waste M_i in year z, yr
- α = Inverse ratio of methane content
- z = Time period of LFG generation from M_i, yr
- η_{iz} = Collection efficiency in year z from M_i, fraction

Case-Study Landfills

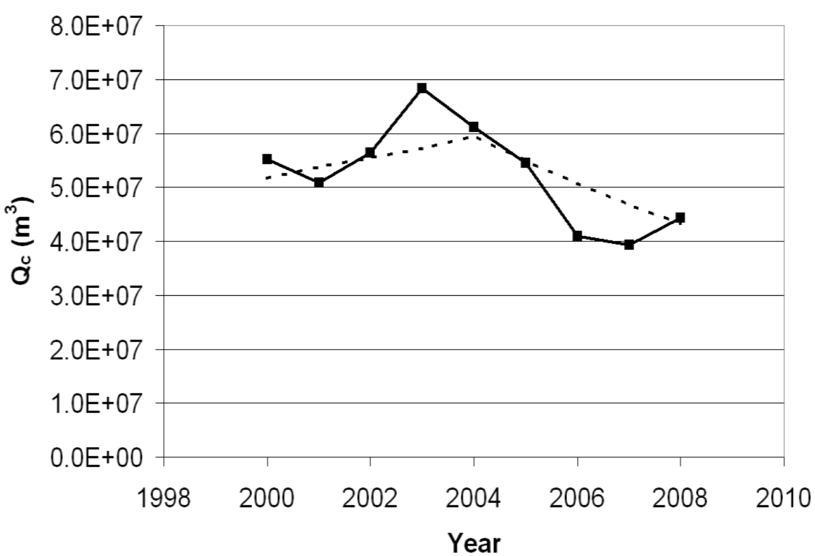
Landfill	Waste Type	Year Opened	Year Closed	Operational Practice	LFG Collection System
Landfill 1	MSW	1985	Open	Traditional	Active; Vertical wells + Horizontal trenches
Landfill 2	MSW	1978	Open	Traditional	Active; Vertical wells
Landfill 3	MSW	1972	1999	Traditional, Wet-cell	Active; Vertical wells
Landfill 4	MSW + C&D	1977	Open	Traditional	Active; Vertical wells + Horizontal trenches
Landfill 5	MSW	1986	Open	Traditional, Bioreactor	Active; Vertical wells



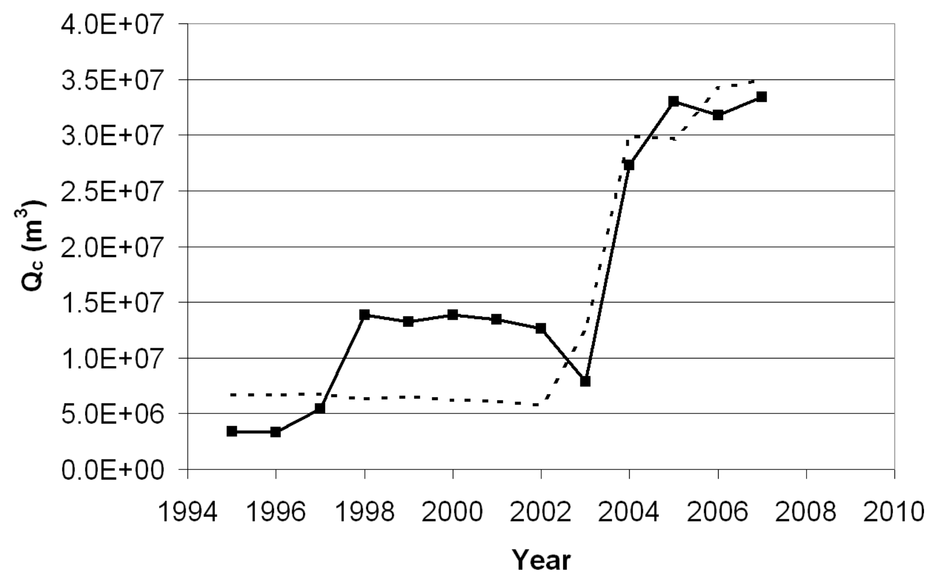
Landfill 1 – Phase 1



Landfill 1 – Phase 2



Landfill 3



Landfill 4

Uncertainty

- Oracle Crystal Ball was used to study the uncertainty in the first order model, based on uncertainties in L_0 and k
  - Crystal Ball uses Monte-Carlo simulation method to calculate range of variations and probabilities

Florida LFG & LFGTE Potential

- Base-case assumptions:
  - LFG Generation:
    1. Study period: 1991-2035 (1991 start year of FDEP data)
    2. k_{bulk}=0.08 yr^{-1} for traditional landfilling operation
    3. L_0 from 2007 disposed waste composition data for each County
    4. M from1991-2007 data; extrapolated to future based on population growth
    5. Methane content on average 50% over the study period
    6. LFG generation model uncertainty applied

Fast vs. Moderate LFG Generation Rate

- Food waste decompose much faster than other MSW components
- LFG collection modeling based on:

$$Q_{c_{total}} = Q_{c_{food\_waste}} + Q_{c_{other\_waste}}$$

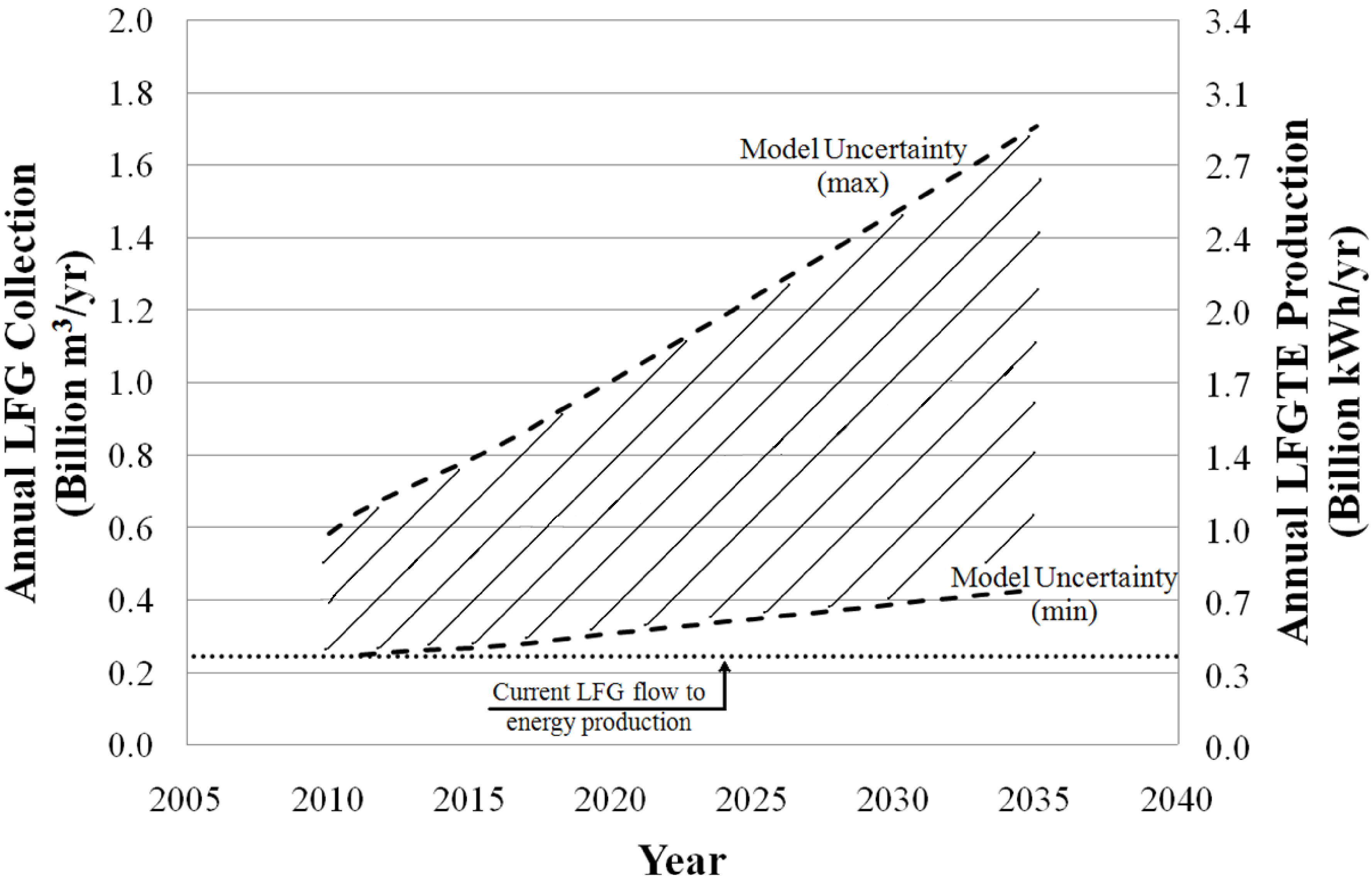
  - $k_{food\_waste} = 0.26\ yr^{-1}$
  - $k_{other\_waste} = 0.06\ yr^{-1}$

Florida LFG & LFGTE Potential

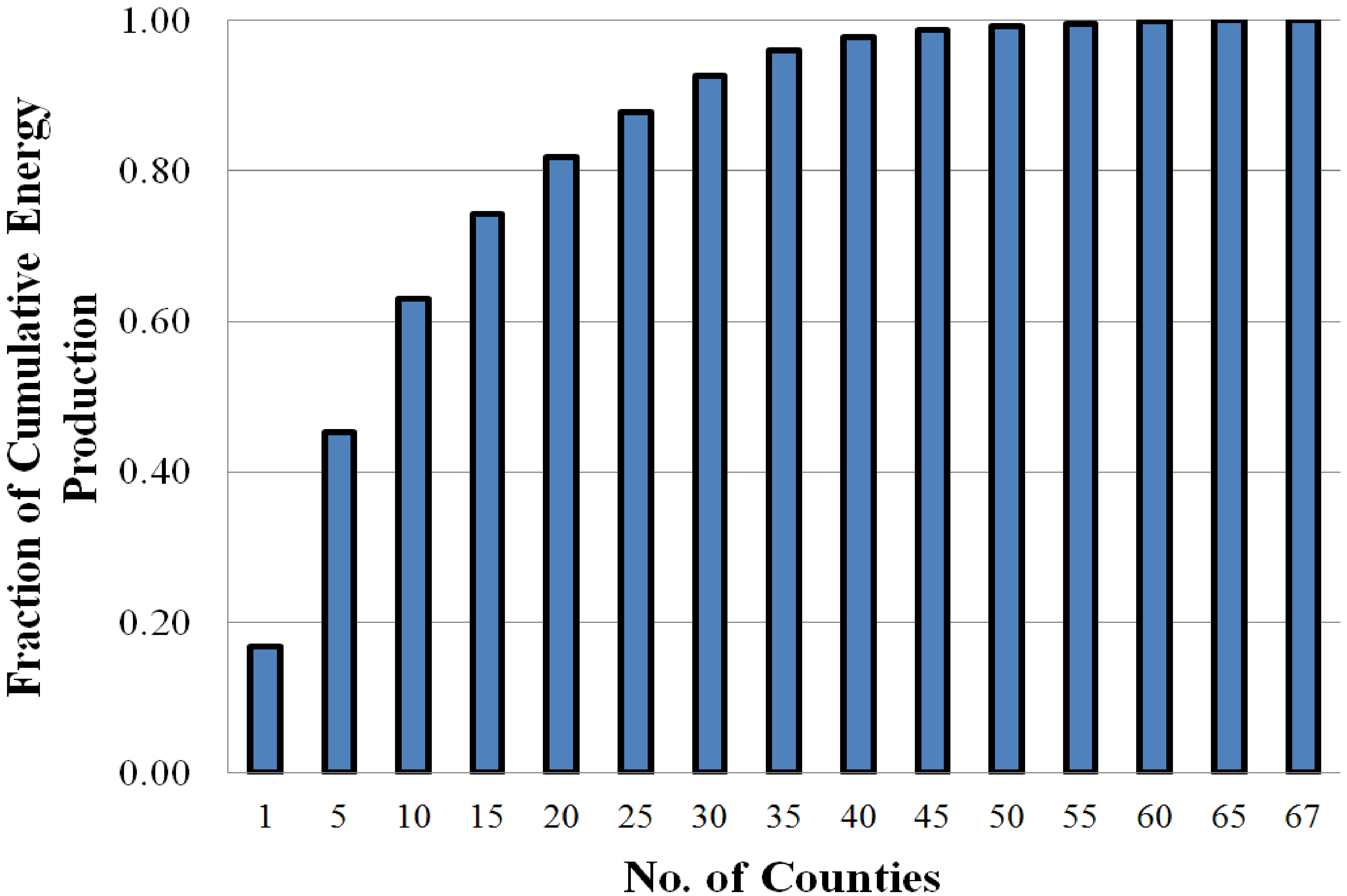
- Base-case assumptions:
  - LFG collection:
    1. Start gas collection after five years
    2. Average LFG collection efficiency at 0.75 from 2010 to 2035
  - LFGTE production:
    1. All Florida landfills operate a LFGTE facility
    2. Utilization ratio (φ_1) of 0.90
    3. Electrical efficiency (φ_2) of 0.35 (typical for IC engines)
    4. Energy content (ε) of 5.2 kWh/m^3 LFG (~18,000 Btu/m^3 CH_4)

$$E_g = \varepsilon \times \varphi_1 \times \varphi_2 \times Q_c$$

Current vs. Future Potential



LFGTE vs. Counties



Operation Strategies

- With application of horizontal trenches/blankets, LFG collection and LFGTE production can be started much earlier in the lifetime
- Bioreactor operation (adding liquid to optimize moisture content) can enhance LFG generation, thus increase energy production over a fixed timeframe

Sensitivity Analysis

Scenario	k_1, k_2	LFG collection start year	LFG collection efficiency	Utilization ratio	Electrical efficiency
Scenario 1. Base case	0.26, 0.06	6	0.75	0.90	0.35
Scenario 2. Early gas collection	0.26, 0.06	3	0.75	0.90	0.35
Scenario 3. Bioreactor operation	0.48, 0.11	3	0.90	0.90	0.35
Scenario 4. Improved utilization ratio and electrical efficiency	0.26, 0.06	6	0.75	1.00	0.50
Scenario 5. Optimized energy production	0.48, 0.11	3	0.90	1.00	0.50

Sensitivity Analysis

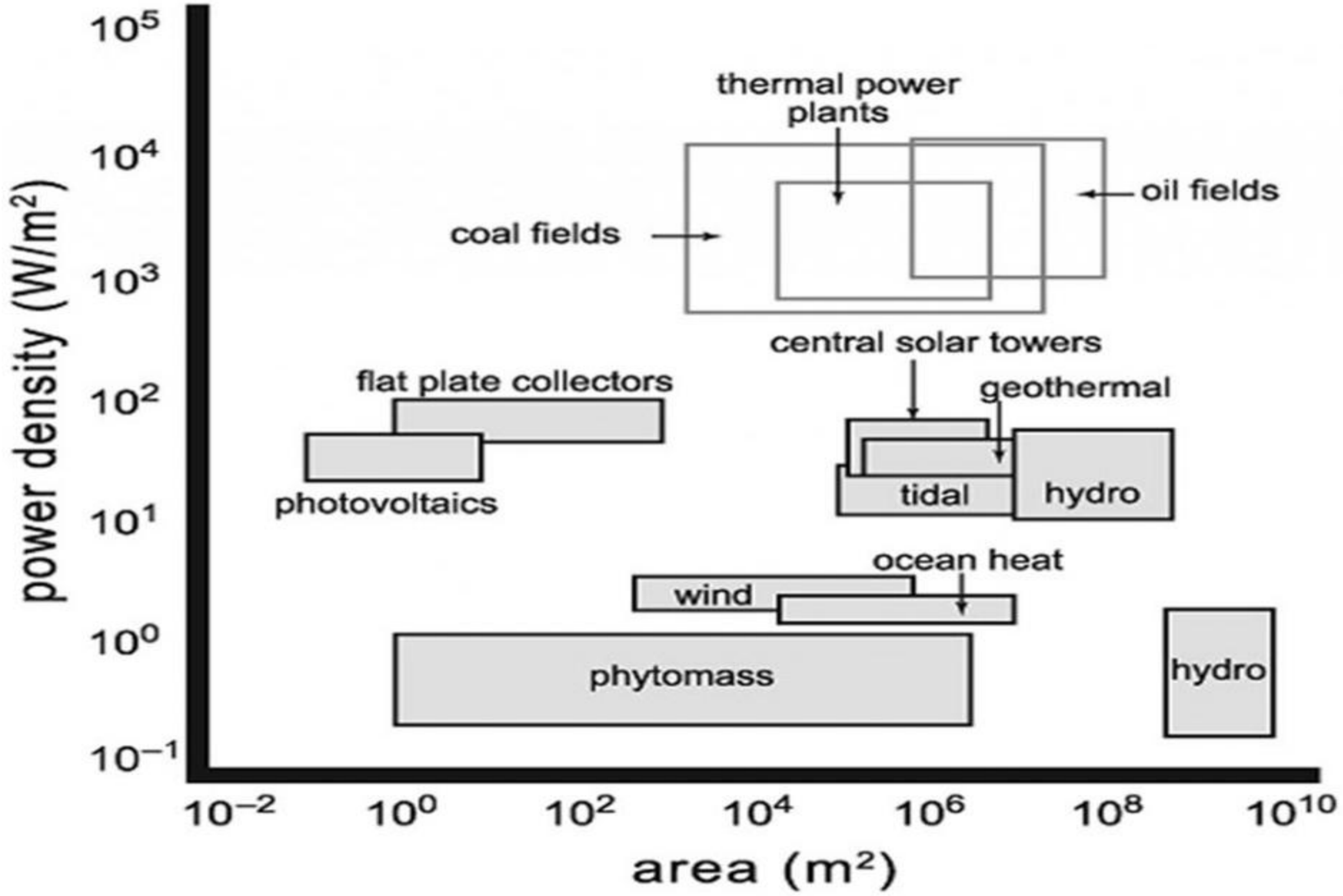
Scenario	Cumulative LFG collection, Billion m^3 (uncertainty range)	Cumulative LFGTE production, Billion kWh (uncertainty range)
Scenario 1. Base case	19 (9-29)	32 (14-48)
Scenario 2. Early gas collection	25 (13-37)	42 (22-61)
Scenario 3. Bioreactor operation	34 (20-47)	56 (34-78)
Scenario 4. Improved utilization ratio and electrical efficiency	19 (9-29)	35 (16-54)
Scenario 5. Optimized energy production	34 (20-47)	89 (53-123)

University of Central Florida

Results

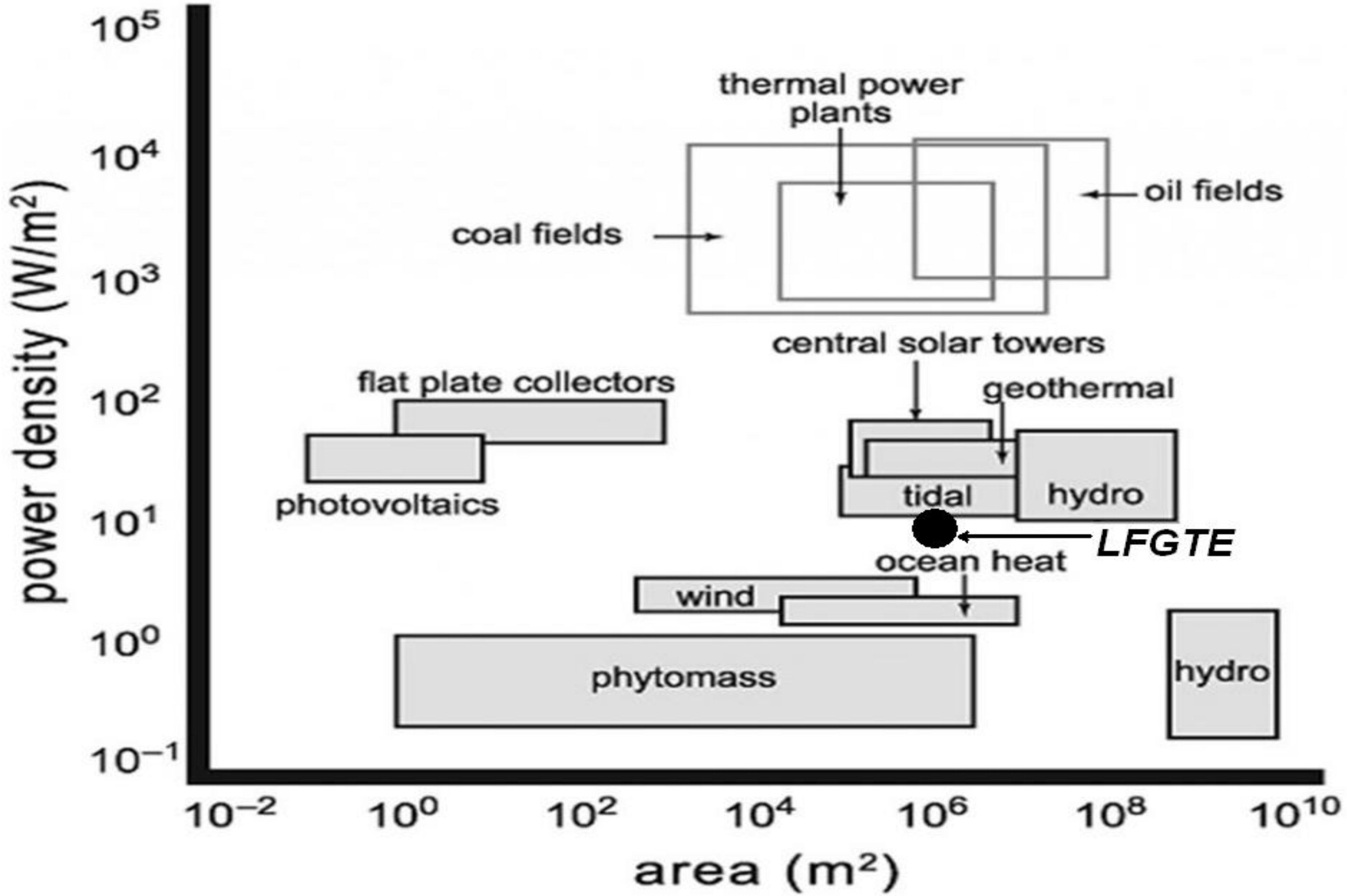
- Presently about 50% of Florida LFGTE potential is being produced
- Florida LFGTE production can be four times greater than current production level, in 2035
- Statewide LFGTE power density (base-case) was estimated as 5.3 W/m^2 in 2010, increasing to 13.6 W/m^2 in 2035 (annual average of 9.5 W/m^2)

Power Density



Smil, V. (2010); "Energy transitions: History, requirements, prospects," Santa Barbara, California: Praeger, c2010

Power Density



Smil, V. (2010); "Energy transitions: History, requirements, prospects," Santa Barbara, California: Praeger, c2010

Results (Continued)

- Early LFG collection can increase LFGTE production by 32%
- Operating all landfills as bioreactor landfills can increase LFGTE production by 80%
- Optimizing LFG collection and LFGTE production can increase energy production by a factor of 2.8

Conclusions

- Florida landfills operators can prevent over 290 MT eCO_2 fugitive GHG emissions in the next 25 years
- About 90 billion kWh of electricity can be generated from Florida LFGTE projects by 2035, equivalent to:
  - removing some 90 million vehicles from Florida highways, or
  - eliminating the need for about one billion barrels of oil, from offshore drilling or importing from foreign countries

Acknowledgements

- The Environmental Research & Education Foundation (EREF)
- The Hinkley Center for Solid & Hazardous Waste Management (HCSHWM)
- The case-study landfill officials

Questions?

University of Central Florida