Landfill Gas Modelling: Estimation of Landfill Gas Decay Rate Constants and Yields for Individual Waste Components

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Introduction

- Prediction of landfill gas production and collection is critical
  - Financial viability of gas recovery projects
  - Estimates of landfill carbon footprint
    - Landfill gas dominates other aspects of landfill operation (construction, operation, closure, leachate management)
  - How does methane production change with changing waste composition?
    - Yard waste diversion
    - Increasing diversion of food waste

Landfill Gas Modeling

$$Q_n = k \cdot L_0 \cdot \sum_{i=0}^{n} \sum_{j=0.0}^{0.9} \frac{M_i}{10} \cdot e^{-k \cdot t_{i,j}}$$

- **Q_n** is annual methane generation for a specific year t (m^3 CH_4/yr);
- **k** is first order decay rate constant (1/yr)
- **L_0** is total methane potential (m^3 CH_4/ton of waste);
- **M_i** is the annual burial rate (wet tons)
- **t** is time after initial waste placement (yr);
- **j** is the deci-year time increment

Landfill Gas Emissions Model (LandGem)
http://www.epa.gov/ttn/catc/products.html#software

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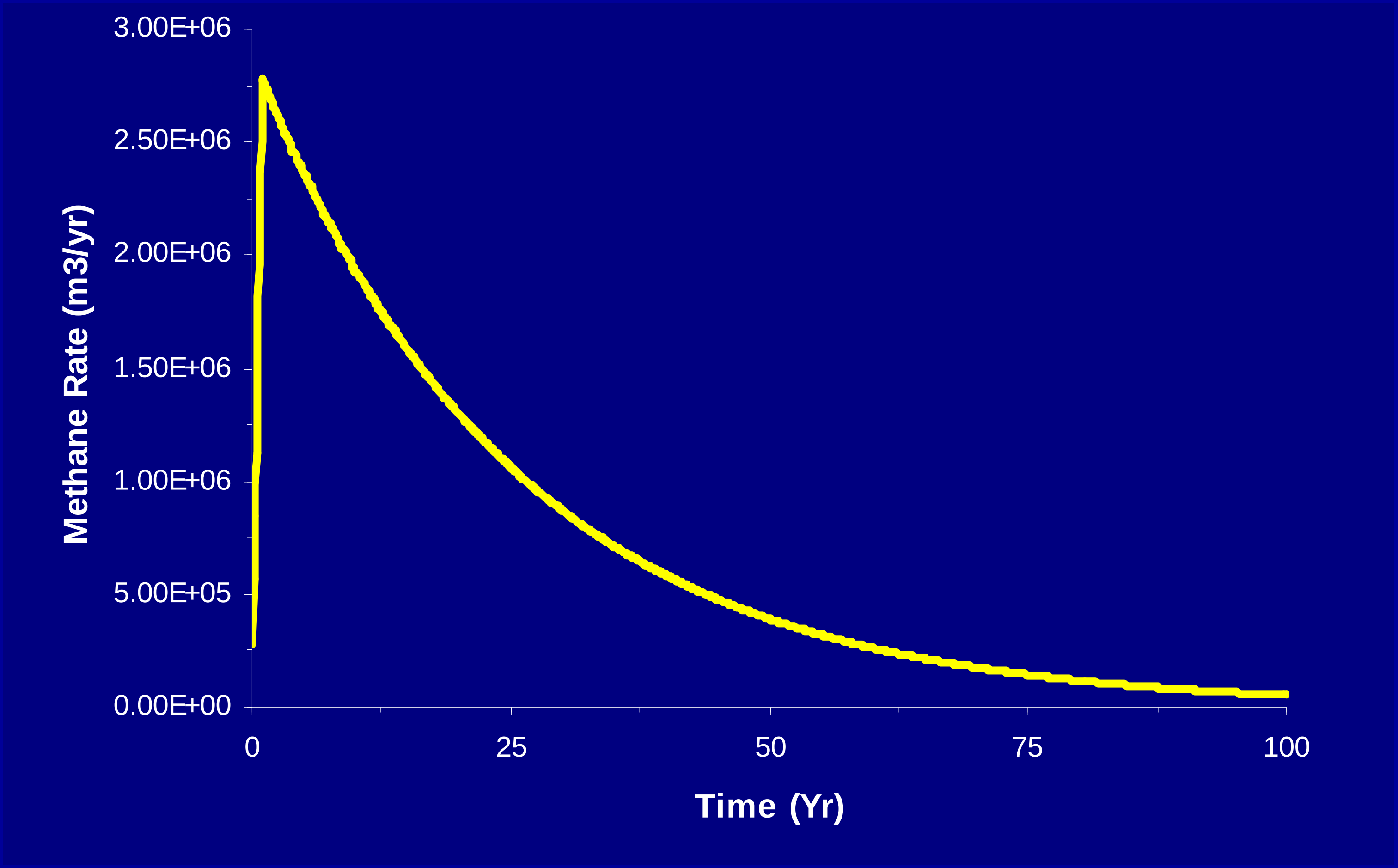
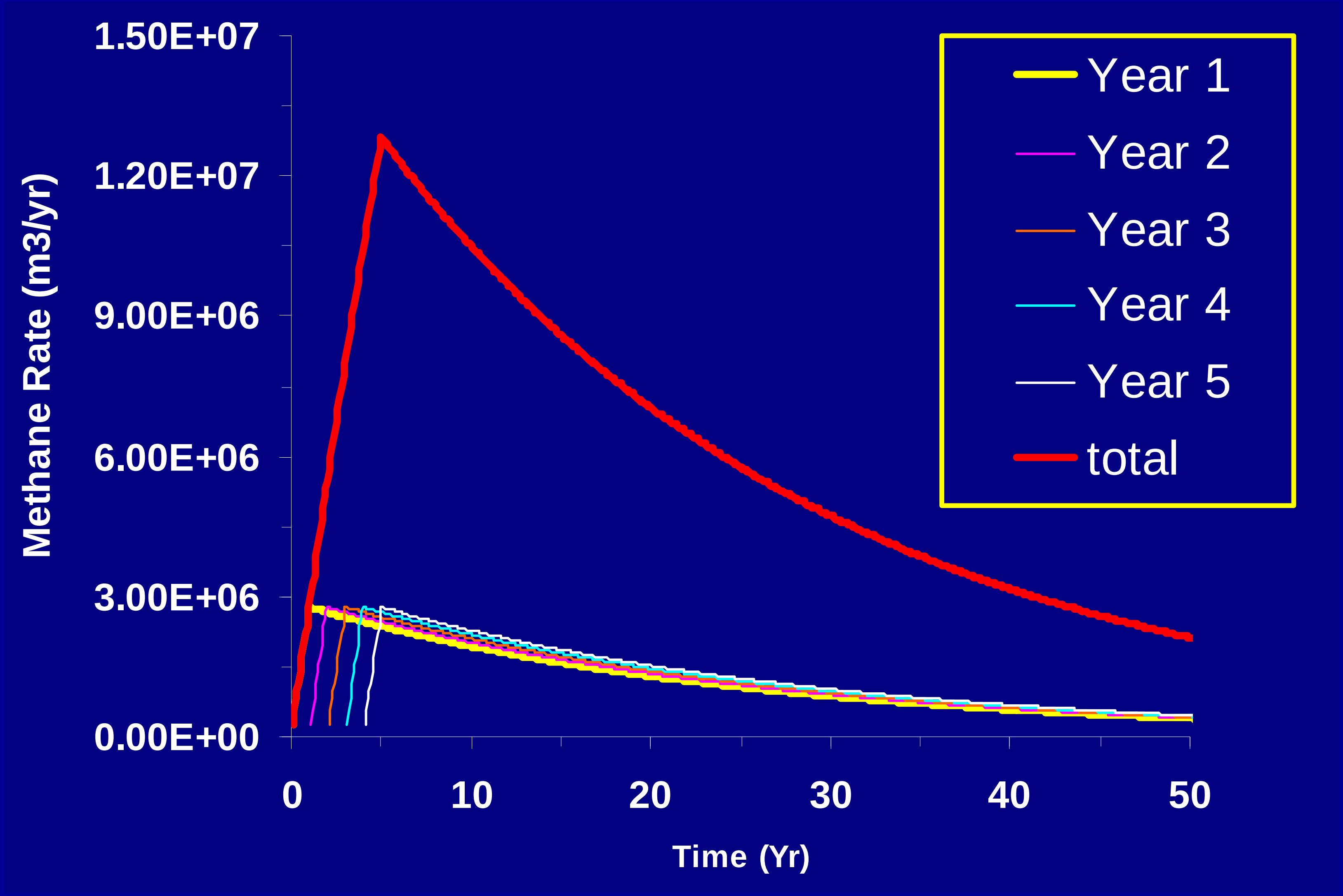
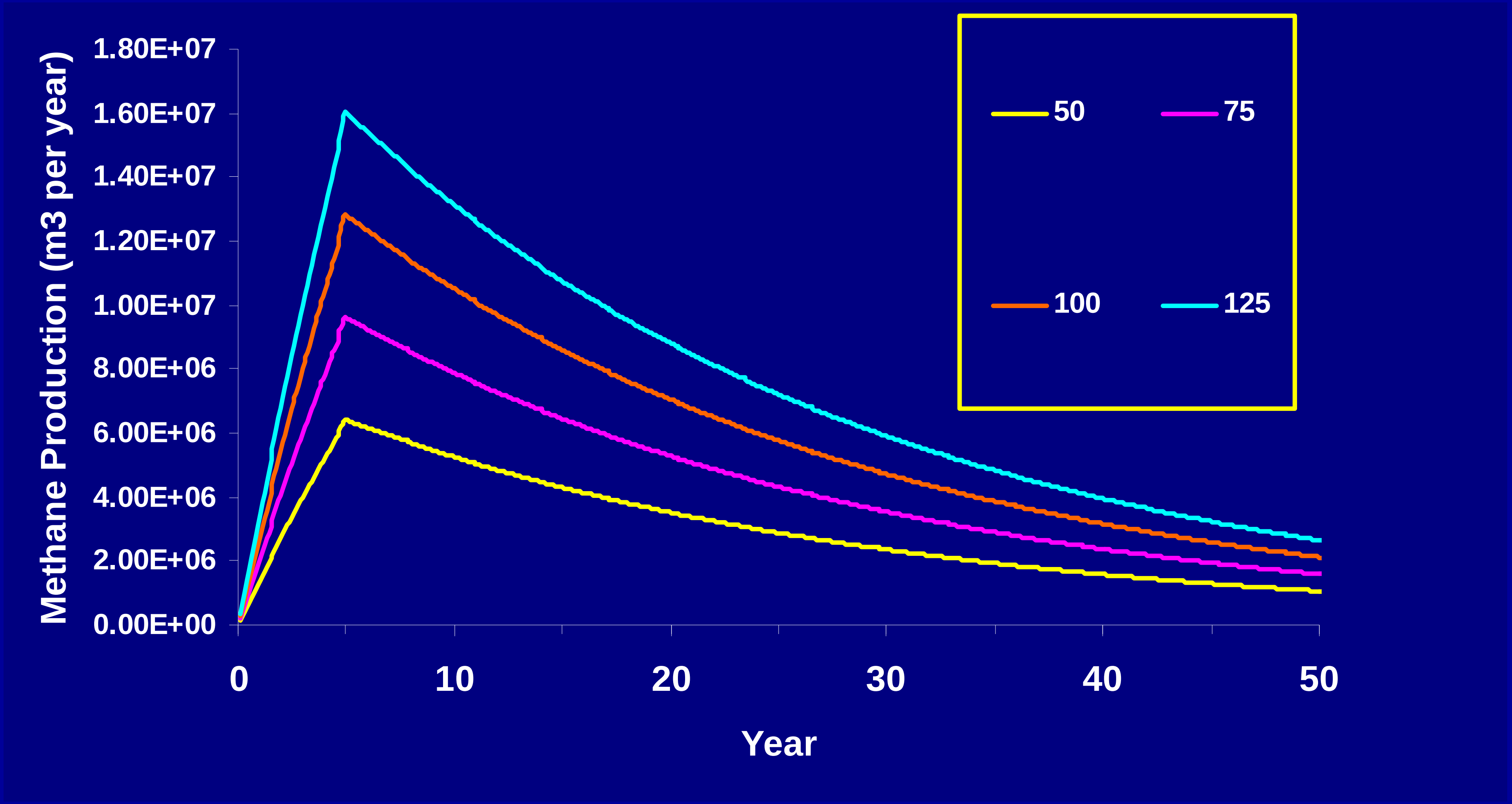
Methane Production Rate Curve for One Years Waste



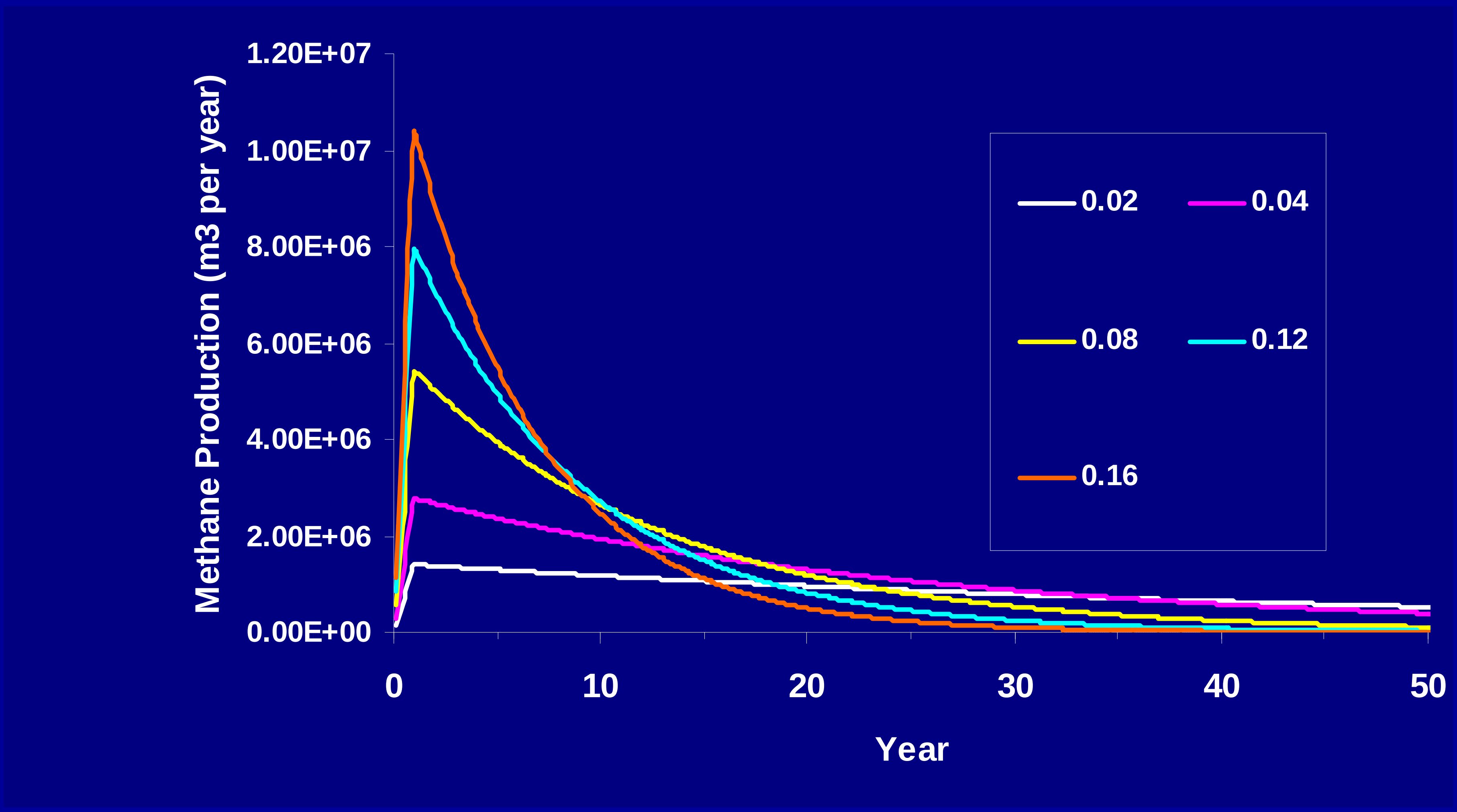
Methane Production Rate Curve for Five Years Waste



Effect of L_0 on Methane Production



Effect of Decay Rate (k) on Methane Production



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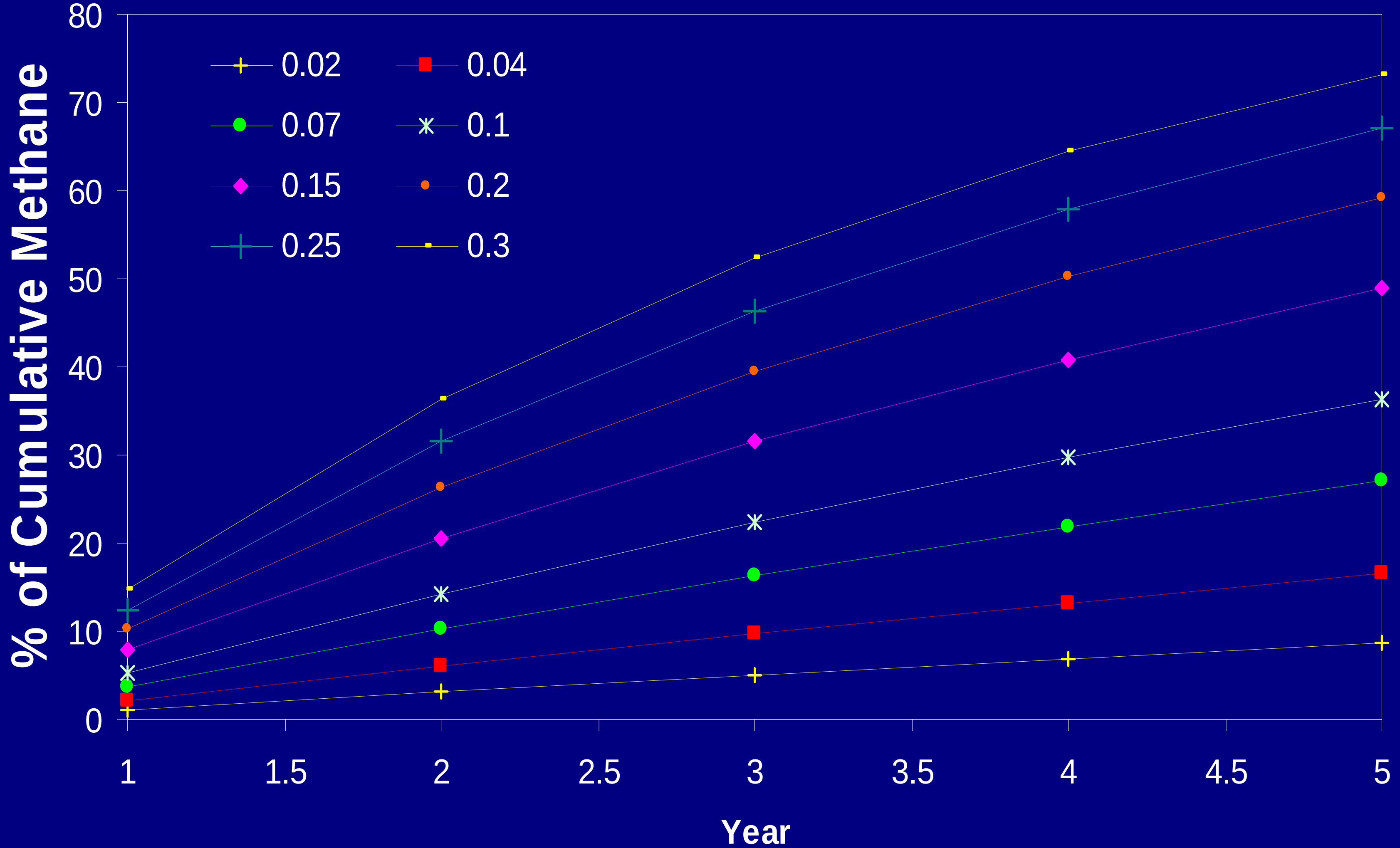
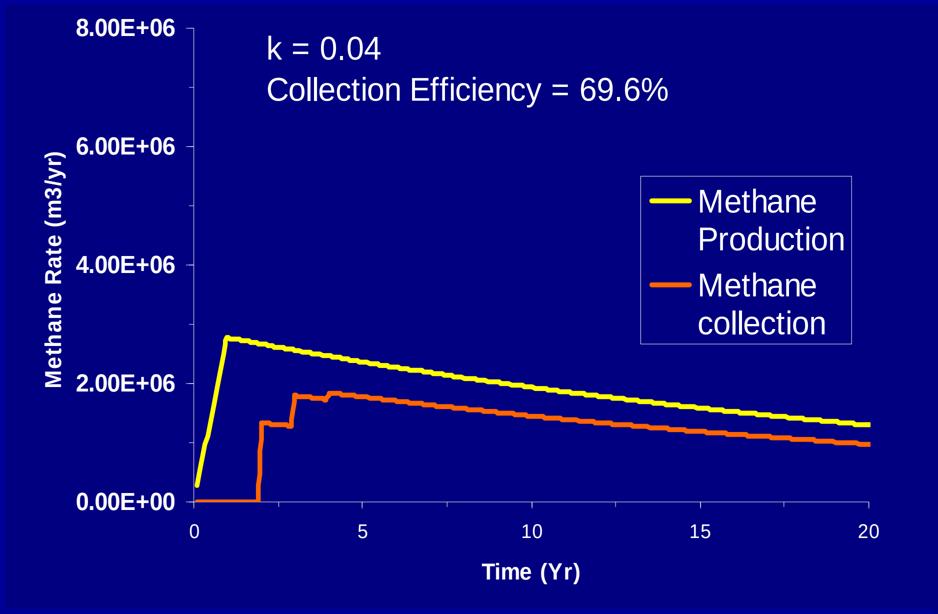
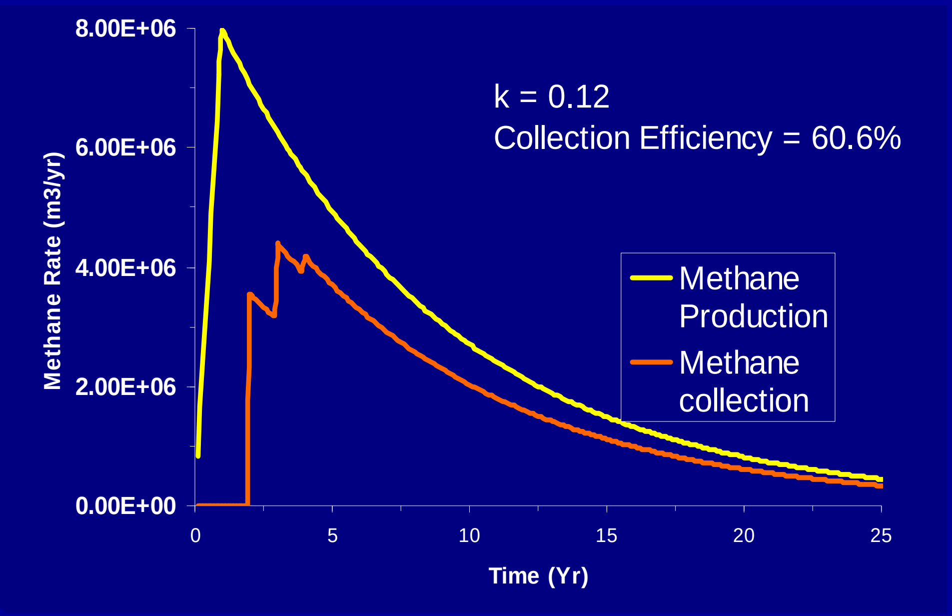


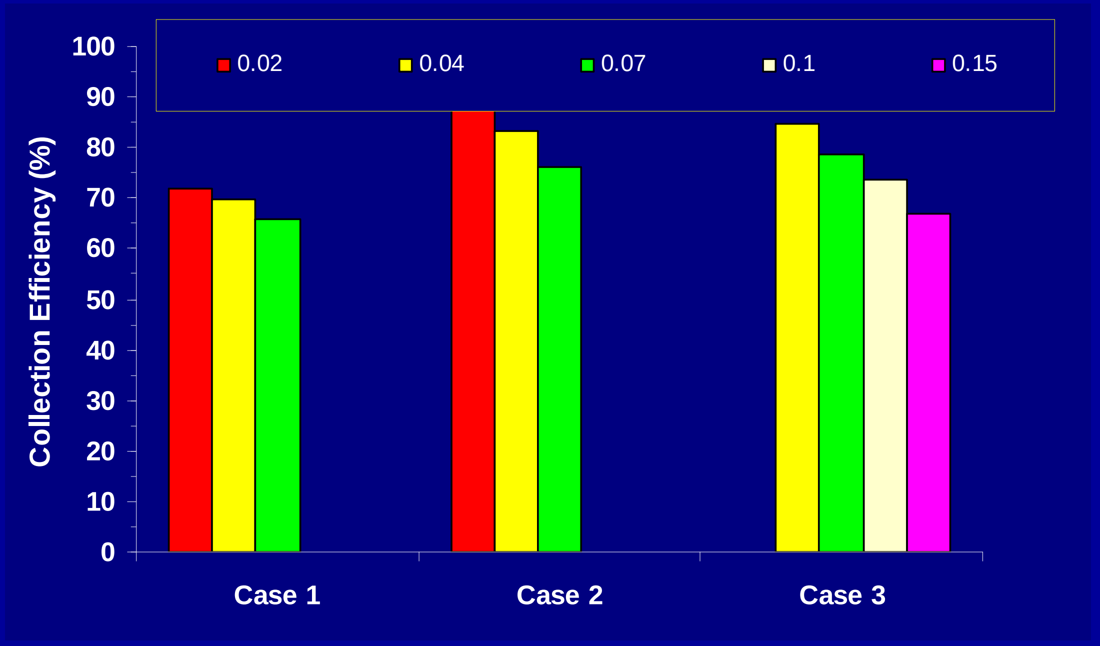
Effect of Decay Rate on Gas Collection





Temporally Averaged Collection Efficiencies (Barlaz et al., 2009)

Case 1: Phased in collection	**Years 1-2: 0%** **Year 3: 50%** **Year 4: 70%** **Years 5-100: 75%**
Case 2: Phased in collection with improved cover	**Years 1-2: 0%** **Year 3: 50%** **Year 4: 70%** **Years 5-10: 75%** **Years 11-100: 95%**
Case 3: Aggressive Gas Collection; Bioreactor Operation	**Years 1-2: 25%** **Year 3: 50%** **Year 4: 70%** **Years 5-10: 75%** **Years 11-100: 95%**



Derivation of Decay Rates for Individual Waste Components

- The decay rate has a significant influence on the amount of gas that can be collected for a given gas collection scenario

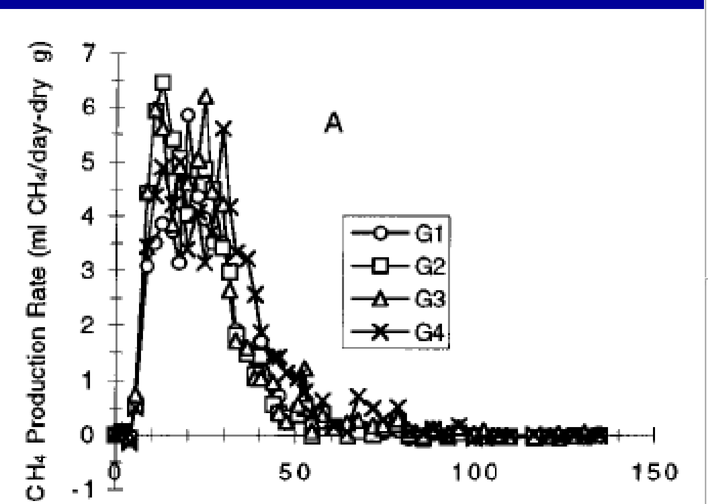
Derivation of Decay Rates for Individual Waste Components

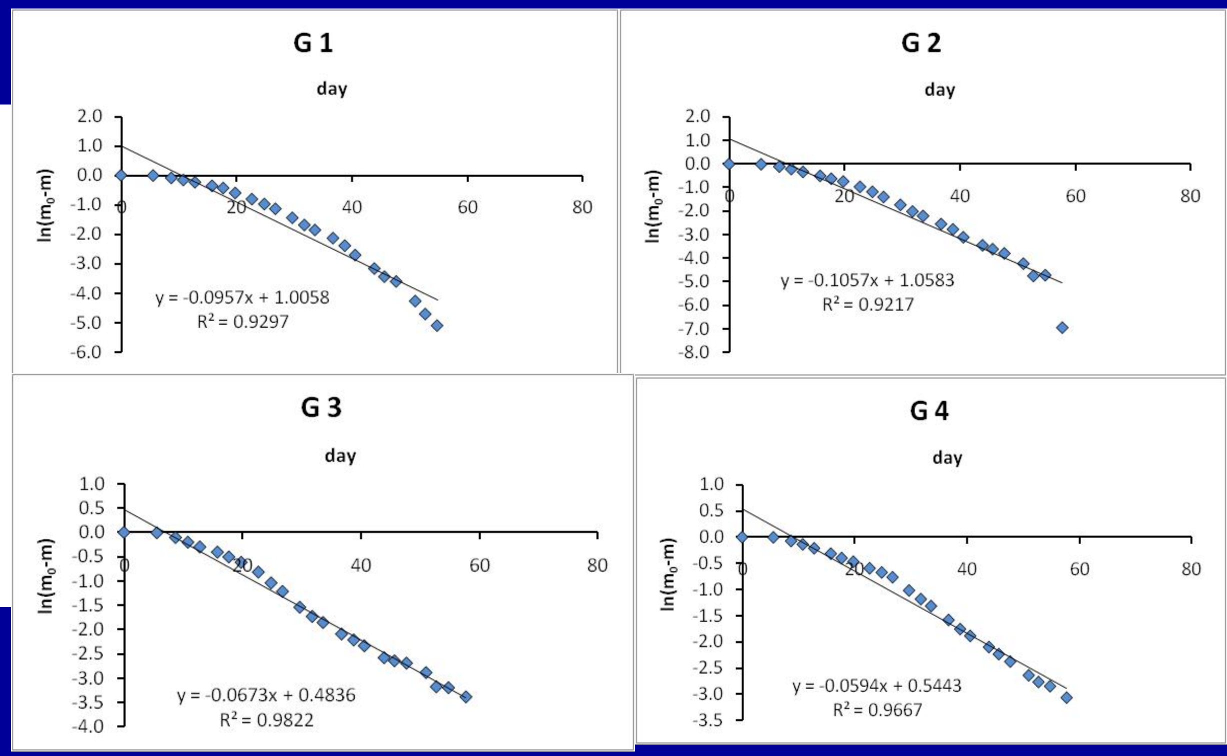
- We have to rely on laboratory data to get rates for individual waste components
- We need a method to scale this to the field
- The method proposed here assumes:
  - the bulk MSW decay rate is known
  - the average of the decay rates for individual waste components, weighted by their waste composition, is equal to the bulk MSW decay rate

Lab-Scale Reactors for Measurement of Methane Yield

- Conditions to maximize decomposition
  - Temperature: 35°C
  - Leachate neutralization and recirculation
  - Monthly monitoring of nutrients: target concentrations
    - NH_3-N 100 mg of N/L
    - PO_4-P 5 mg of P/L

Lab-Scale Data





Decay Rates for Waste Components Calculated from Lab-Scale Reactors

Component	Average[a] (yr^{-1})	Standard Deviation	Correlation Coefficient
Office paper	3.08	1.03	0.93, 0.92, 0.97, 0.95
Grass	31.13	9.32	0.93, 0.92, 0.98, 0.97
Branches	1.56	0.30	0.96, 0.95, 0.95
Newspaper	3.45	0.47	0.97, 0.95, 0.91, 0.93
Corrugated Containers	2.05	0.07	0.92, 0.91, 0.92, 0.94
Food	15.02	0.30	0.98, 0.97, 0.97, 0.96
Leaves	17.82	4.28	0.99, 0.99, 0.98
Coated Paper	12.68	4.13	0.99, 0.99, 0.99, 0.95

a. Data are the average of 4 replicates except in the cases of leaves and branches where 1 reactor leaked and was excluded from the data set.

Conversion of Lab Rate to Field Rate

$$f \times \sum_{i=1}^{n} k_{lab,i} \times (wt.\ fraction)_i = 0.04$$

- $K_{lab,i}$ is the average decay rate from the lab reactors
- Wt. fraction is the composition
- 0.04 is the assumed decay rate and we will vary for different scenarios
- f is a fitting factor and the only unknown

Conversion of Lab Rate to Field Rate

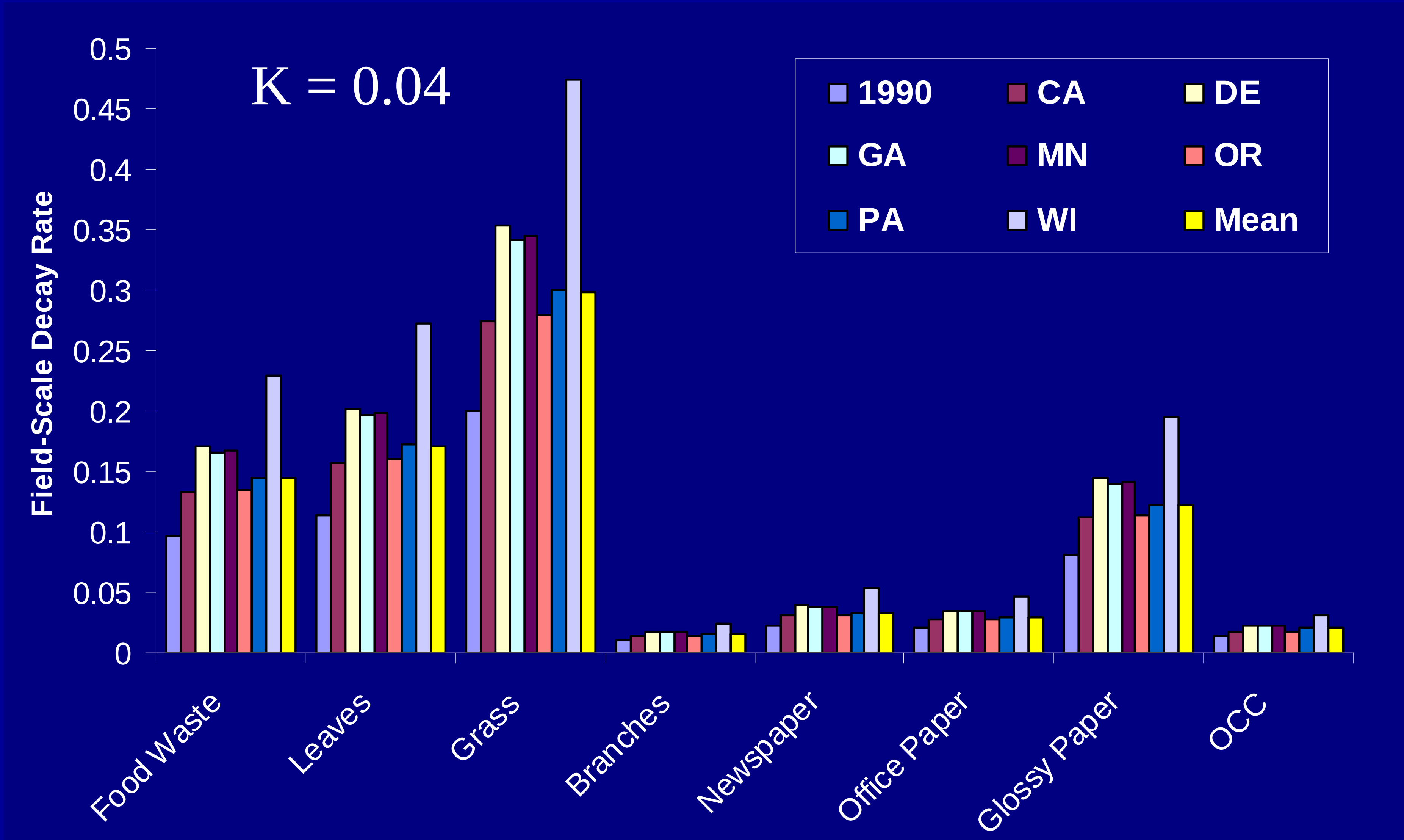
$$f \times \sum_{i=1}^{n} k_{lab,i} \times (wt.\ fraction)_i = 0.04$$

- Once f is determined, $K_{field,i}$ is determined as:

$$k_{field,i} = f \times k_{lab,i}$$

- $K_{field,i}$ is specific to an assumed bulk MSW decay rate (e.g., 0.04)

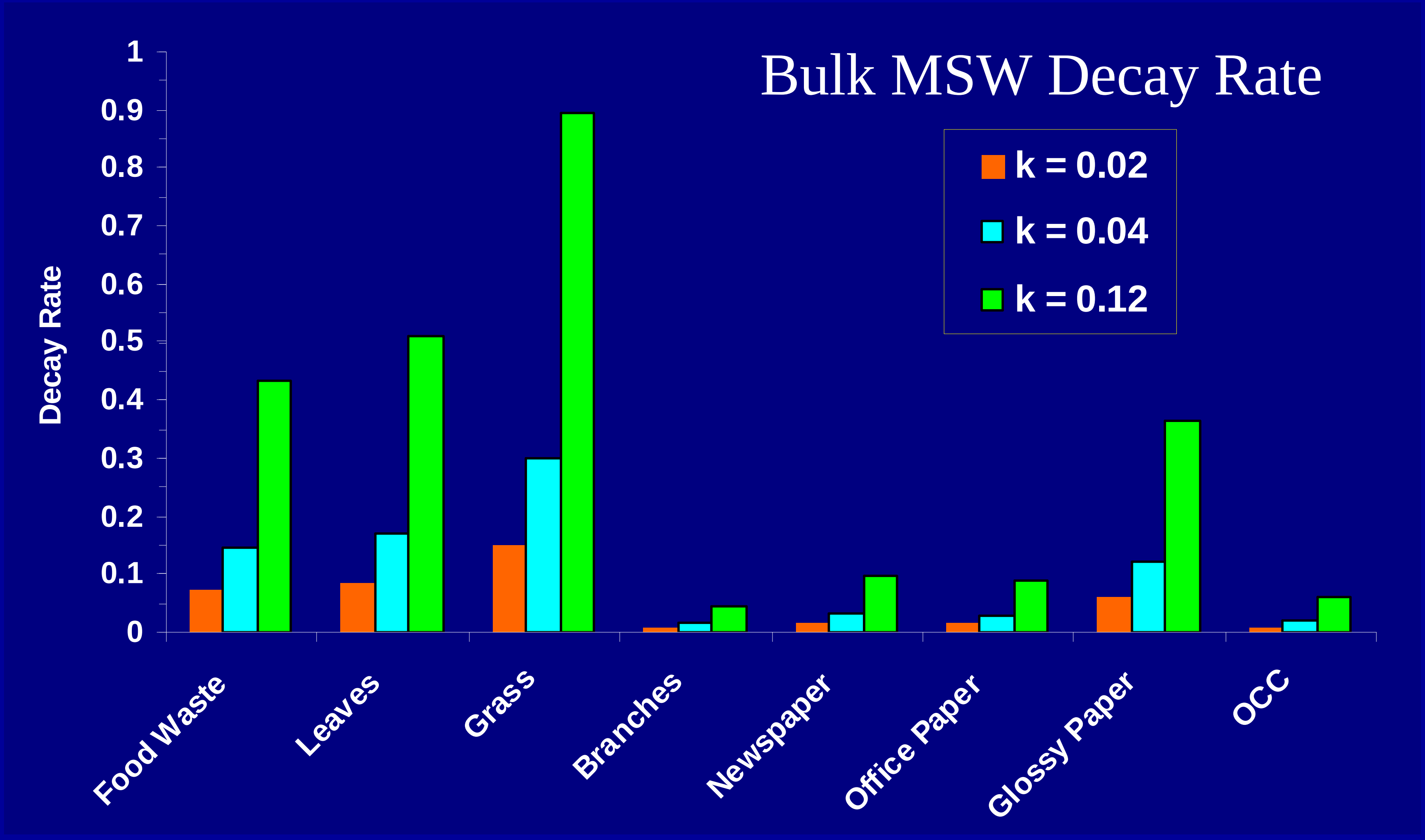
Calculated Field-Scale Decay Rates for Waste Components



Decay Rate Observations

- Food waste, grass and leaves are the highest
  - the magnitude of the decay rate is governed by the length of time that methane was produced
    - a material with a low methane yield but methane generation is complete <100 days (e.g., leaves) will exhibit a high decay rate
- As illustrated, decay rates were calculated for multiple waste compositions. The standard deviation (normalized by the mean) was ~ 27%.
- Uncertainty in the assumed bulk MSW decay rate remains

Calculated Field-Scale Decay Rates for Waste Components



Explore the Effect of Waste Diversion on Methane Production

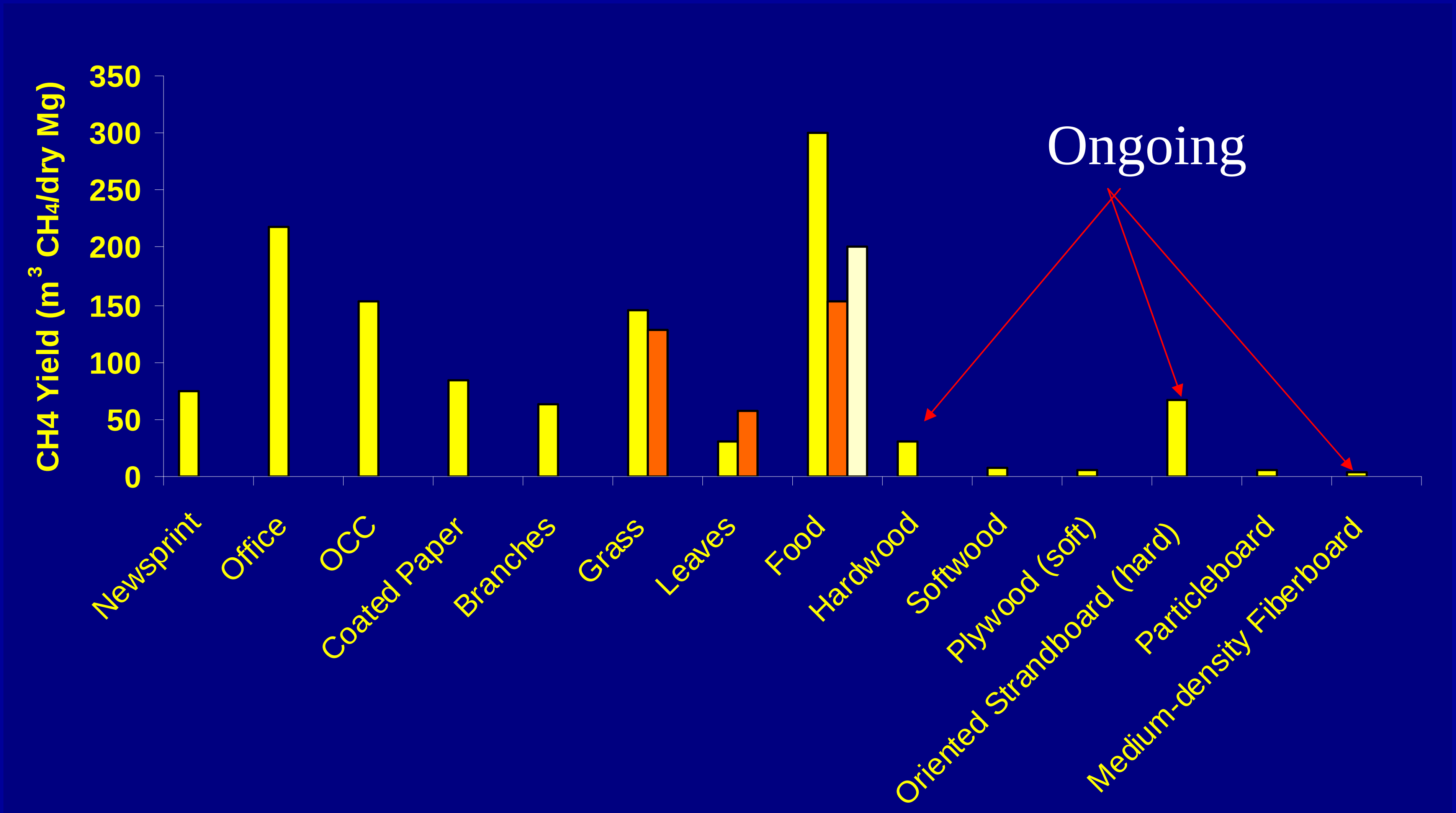
Case 1: Base Case (1 million metric tons/yr for 20 years)

Case 2: 100% diversion of yard waste (930,000 ton/yr)

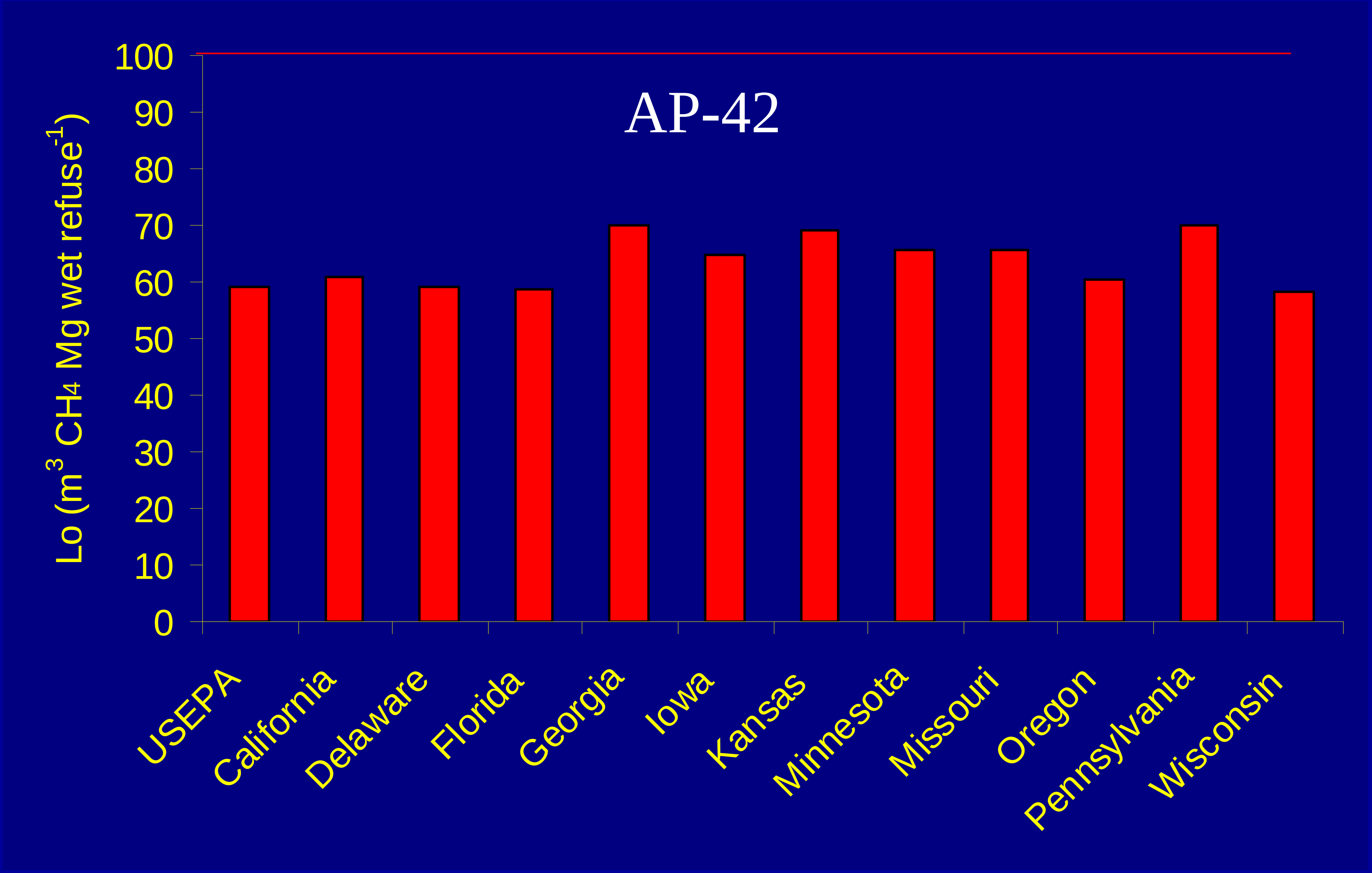
Case 3: 100% diversion of yard waste and food waste (800,000 ton/yr)

Case 4: 90% diversion of yard waste and 50% diversion of food waste (870,000 ton/yr)

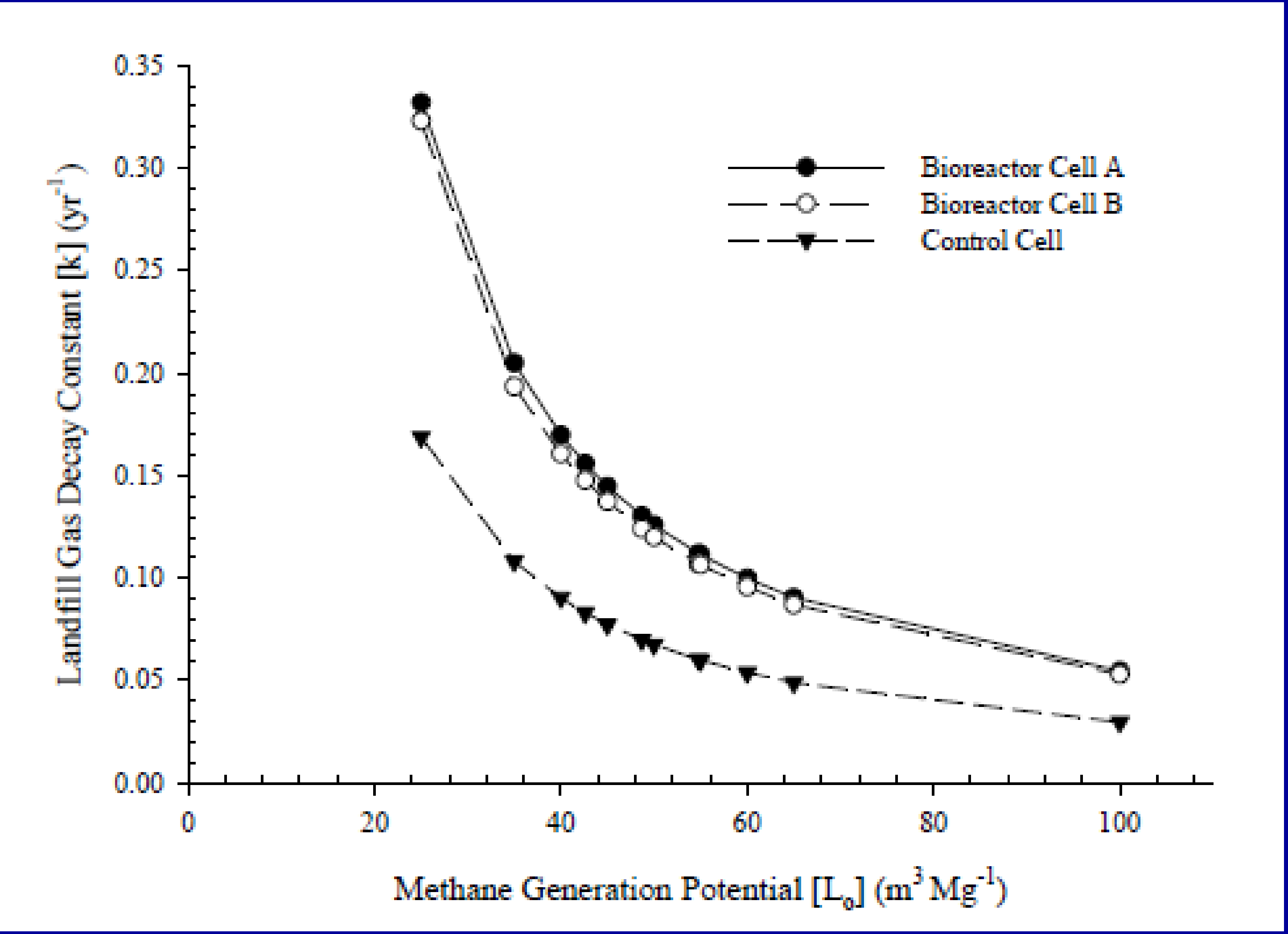
Requires knowledge of both k and L_0



Estimate of Bulk MSW L_0 from Waste Composition Data



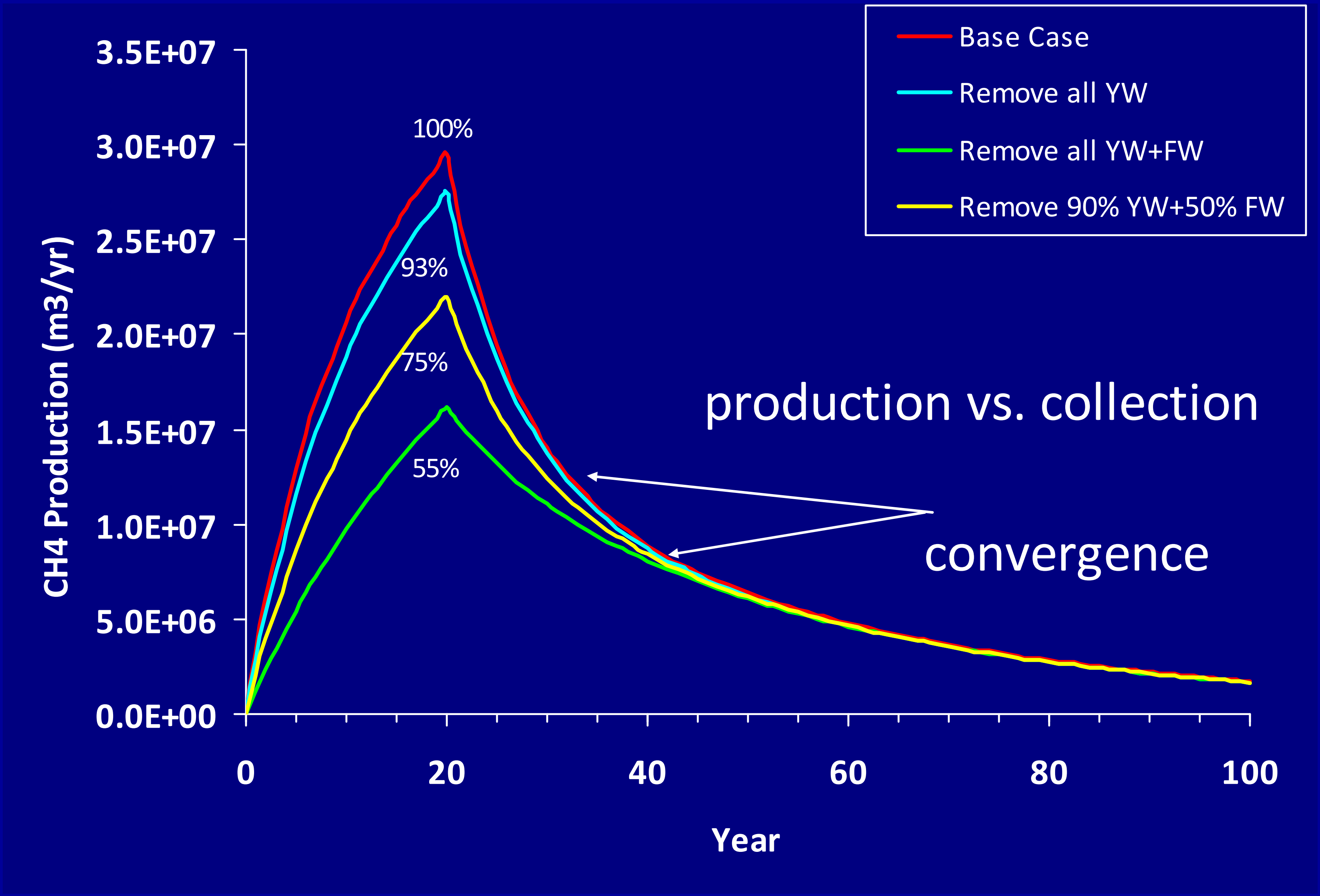
Effect of Assumed L_0 on Estimate of k from Methane Collection Data



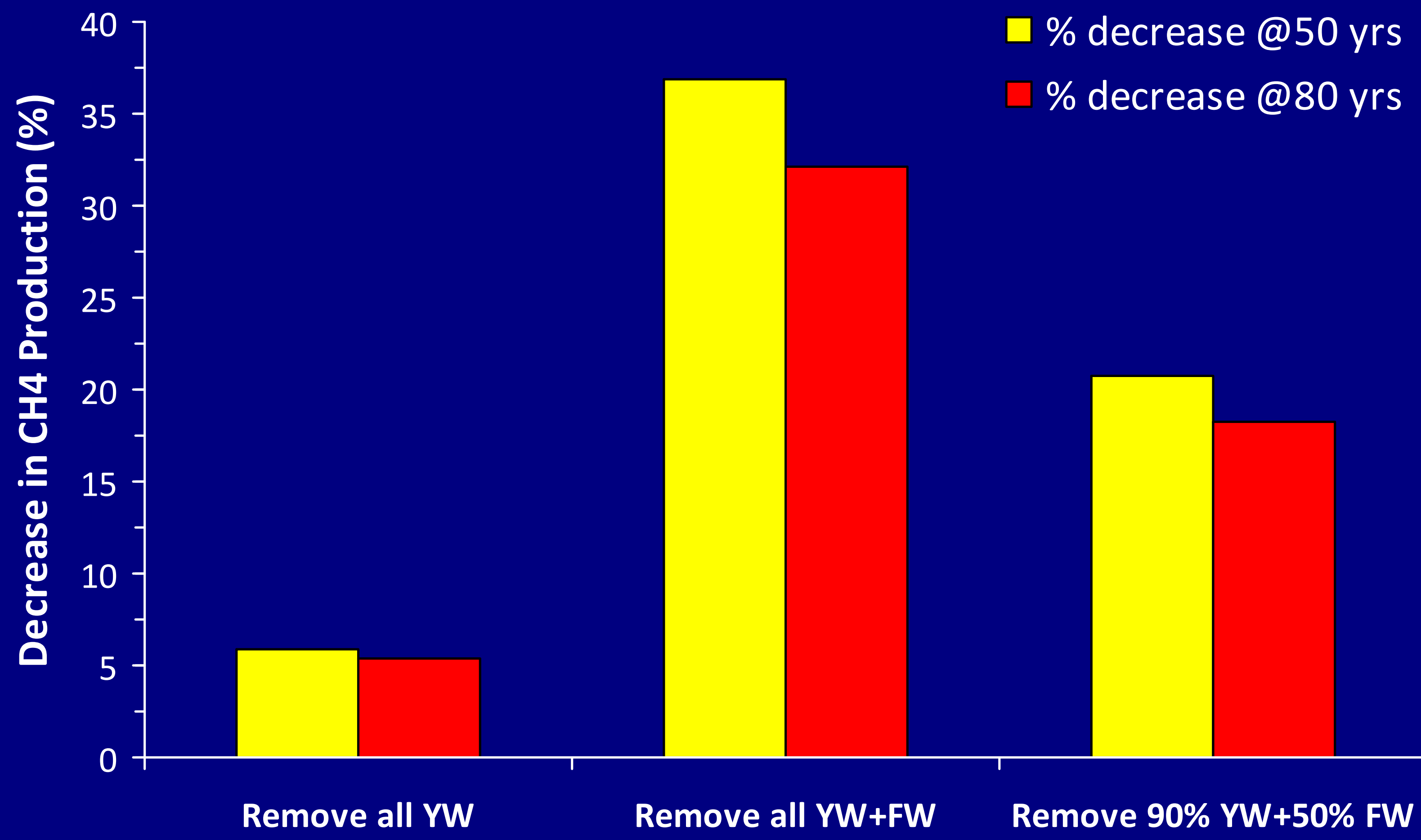
Requires knowledge of both k and L_0

Component	K	L_0 (m^3/dry Mg)	Moisture Content (%)	L_0 (ft^3/wet lb)
Branches (30%)	0.015	62.6	30	0.70
Grass (30%)	0.3	144.4	60	0.93
Leaves (40%)	0.17	30.6	30	0.34
Food waste	0.14	300.7	70	1.45
MSW	0.04	100	20	1.28

Effect of Diversion on Methane Production Rate



Effect of Diversion on Cumulative Methane Production



Acknowledgements

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Questions

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