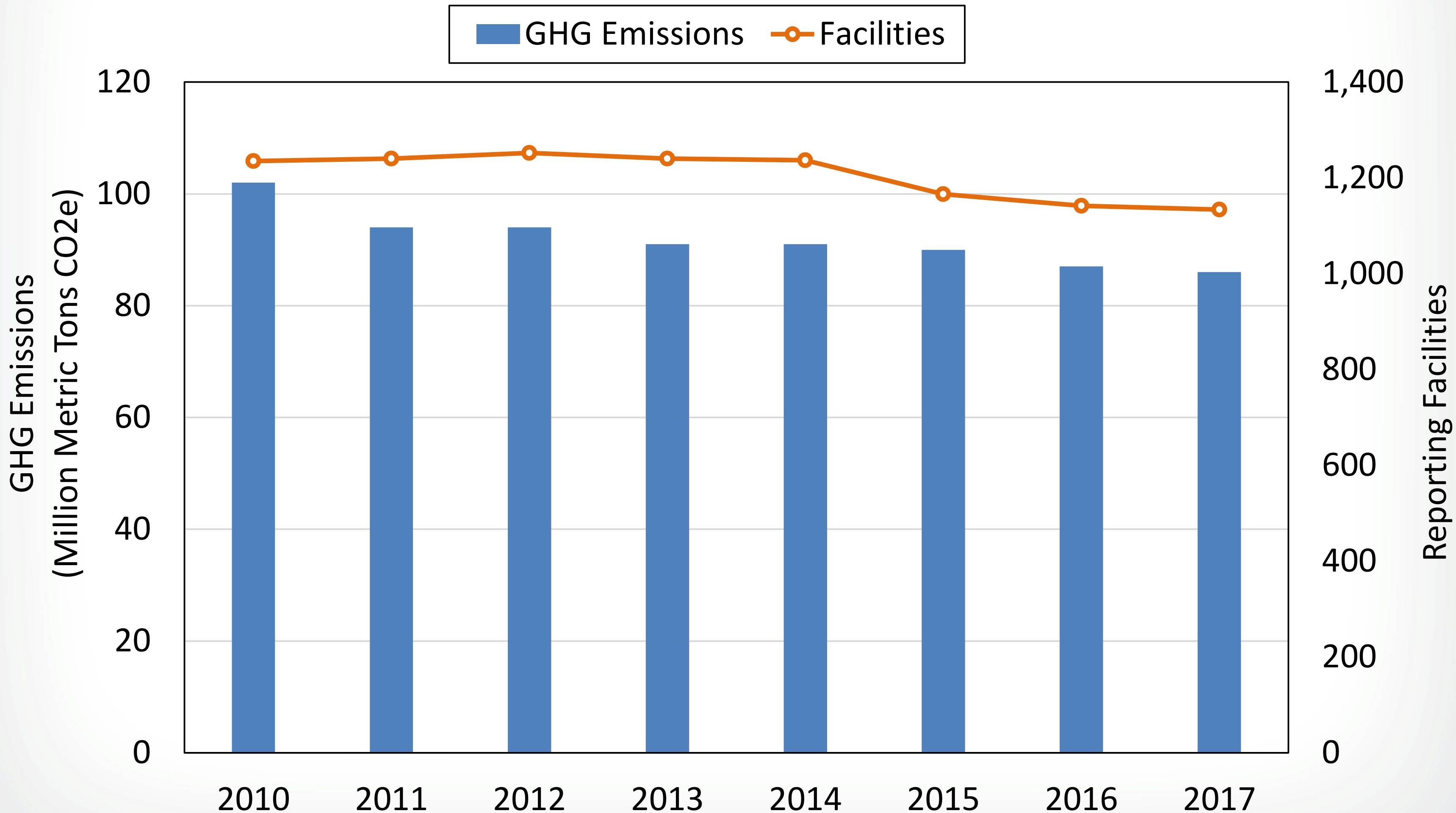
Impact of Food Waste Diversion on Landfill Gas and Leachate from Simulated Landfills

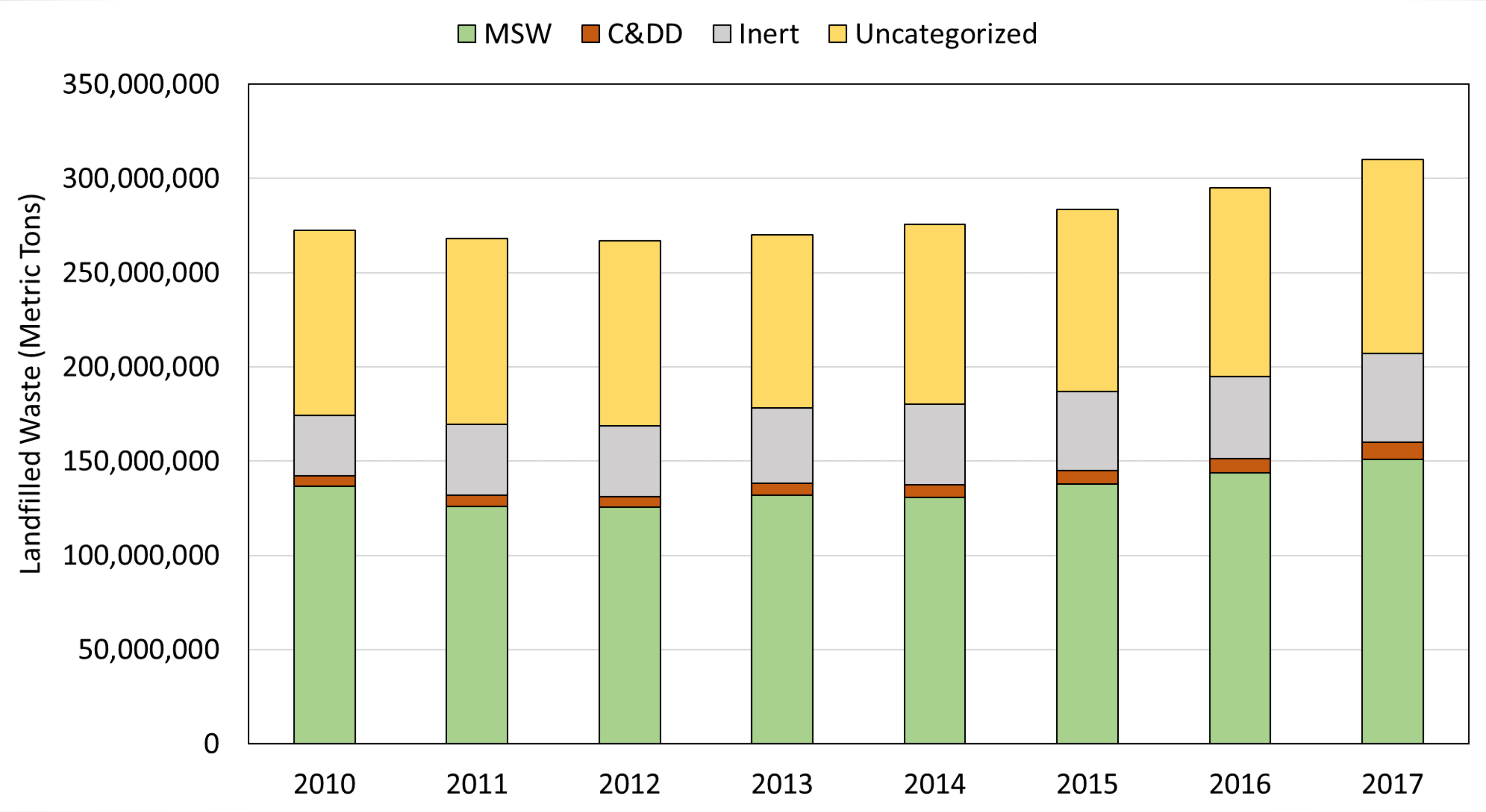
Max J Krause, PhD
Oak Ridge Institute for Science and Education
Thabet Tolaymat, PhD, PE
Environmental Protection Agency, Office of Research & Development

The views expressed in this presentation are those of the authors and do not necessarily represent the views or policies of the U.S. Environmental Protection Agency

GHG Reporting Program – MSW Landfills



Landfill disposal is increasing



Waste 101

- Municipal solid waste (MSW) is common, household garbage
  - Food
  - Paper and packaging
  - Clothes
  - Plastics
  - Glass
- MSW is generated at homes, businesses, hotels, conferences, etc.
- In the US, 80% of MSW is landfilled
  - 20% is incinerated

Food waste in states

- **Vermont**
  - 2020 residential ban on food waste disposal
  - https://www.miltonindependent.com/vt-prepares-to-scrap-food-waste/
- **Massachusetts**
  - Commercial Food Material Disposal Ban
  - MassDEP regulations ban disposal of food and other organic wastes from businesses and institutions that dispose of more than one ton of these materials per week.
  - https://www.mass.gov/guides/commercial-food-material-disposal-ban
  - https://www.wbur.org/news/2019/06/05/massachusetts-food-waste-ban
- **California**
  - Mandatory Commercial Organics Recycling
  - https://www.calrecycle.ca.gov/recycle/commercial/organics

Landfill GHG Emission Factors

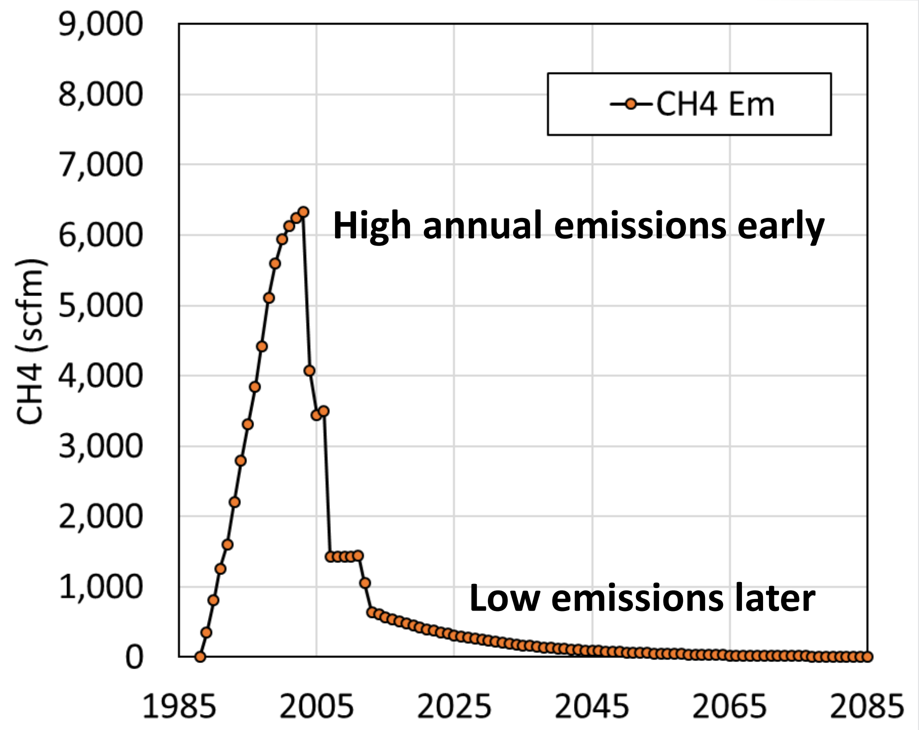
- L_0 – methane generation potential (m^3 CH_4/Mg waste)
  - Volume of methane per ton of garbage landfilled

- k – methane generation rate constant (yr^{-1})
  - Rate at which that garbage decays in a landfill

Modeling Landfill CH4 Generation and Emissions

- Generation
  - First-Order Decay kinetics
- Collection = assume or measure
- Oxidation = (Gen – Col)*OXF
- Emissions = Gen – Col – Ox

$$Q_{CH_4} = \sum_{i=1}^{n} \sum_{j=0.1}^{1} k L_o \left(\frac{M_i}{10} \right) e^{-k t_{ij}}$$



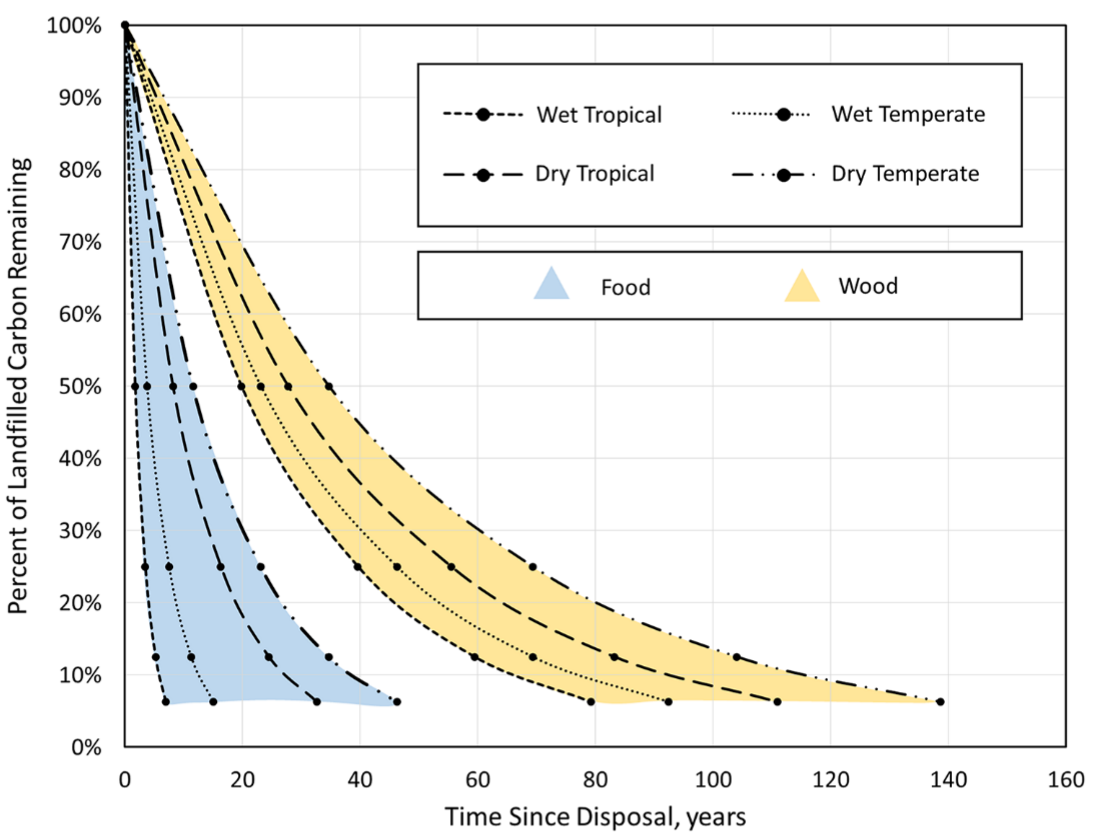
MSW Component Decay Rates

Waste	Climate	Half-life (yr)
MSW	Wet	12.2
MSW	Dry	34.7

Waste	Climate	Half-life (yr)
Food waste	Dry	11.6
Wood	Dry	34.7
Paper	Dry	17.3

Waste	Climate	Half-life (yr)
Food waste	Wet	3.7
Wood	Wet	23.1
Paper	Wet	11.6

Data source: US EPA - GHGRP, 2010

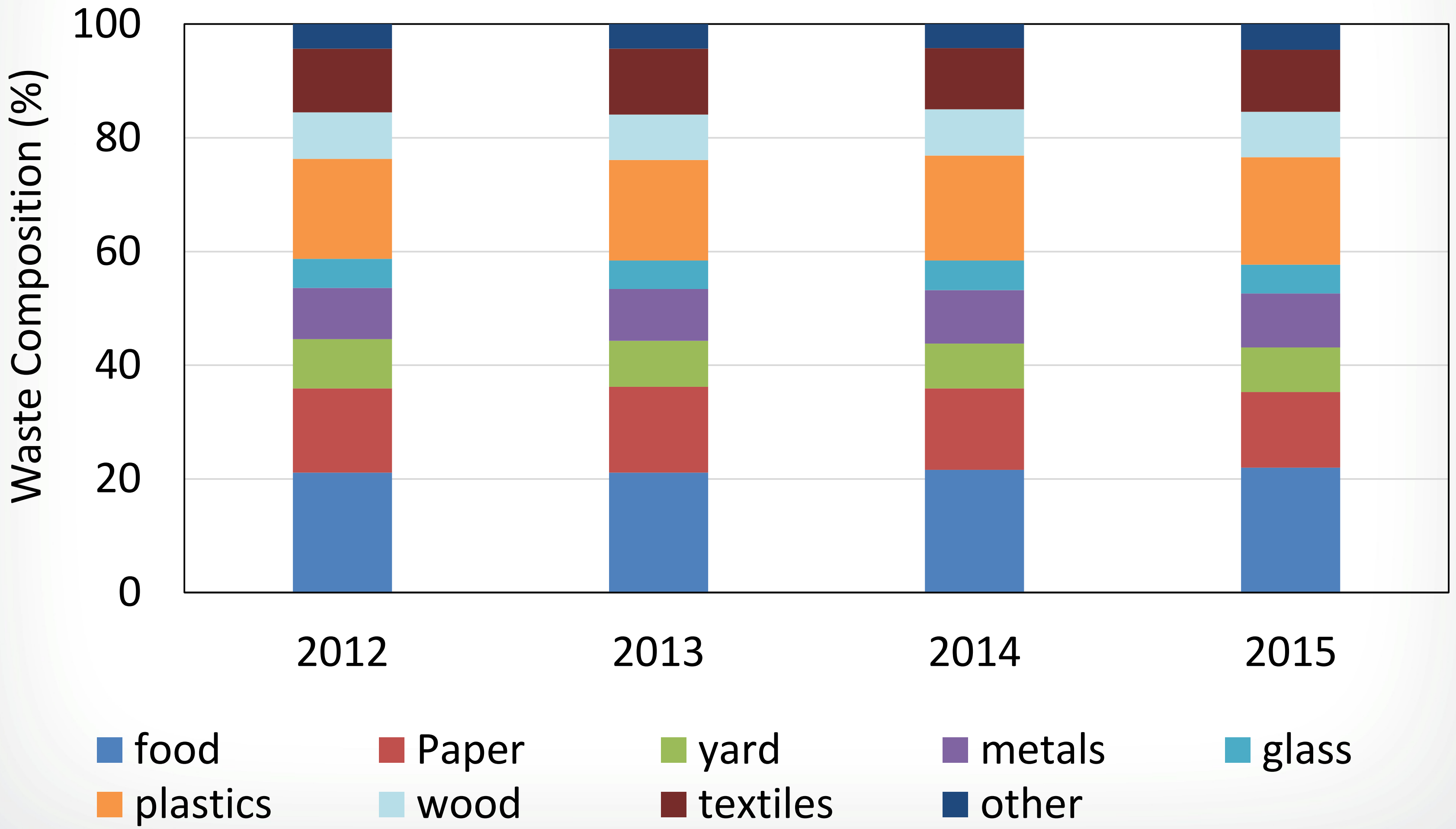


Data source: Intergovernmental Panel on Climate Change, 2006

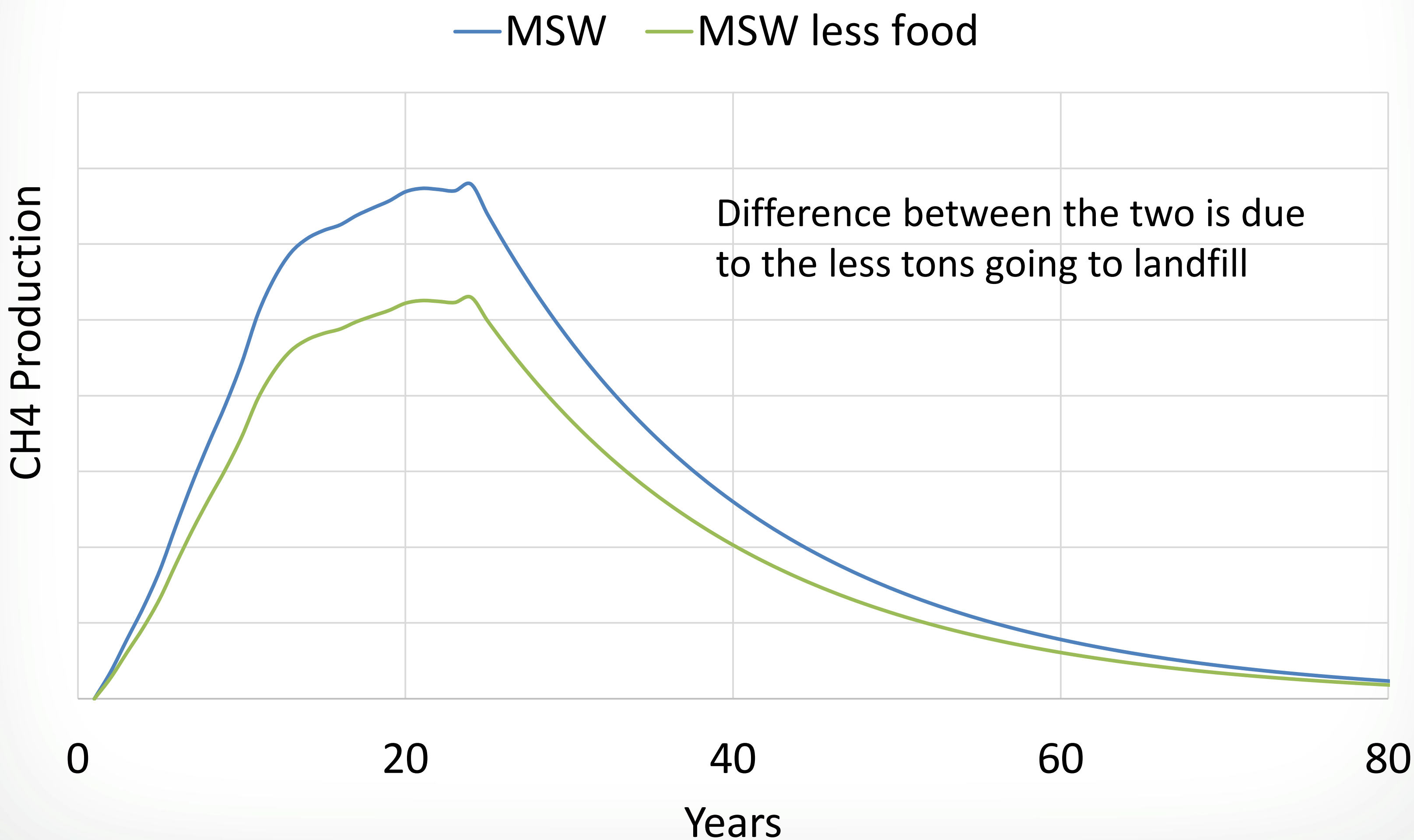
What's the problem?

- Food contains:
  - lots of moisture
  - Nutrients (N, P, S)
    - Nitrogen
    - Phosphorous
    - Sulfur
  - Degrades quickly
- Model assumes each waste stream decays independently of the others

Composition hasn't changed



Model food waste diversion without changing emission factors



Is our modeling practice correct?

- Can we accurately model landfill diversion programs with the model? ← Seems unlikely

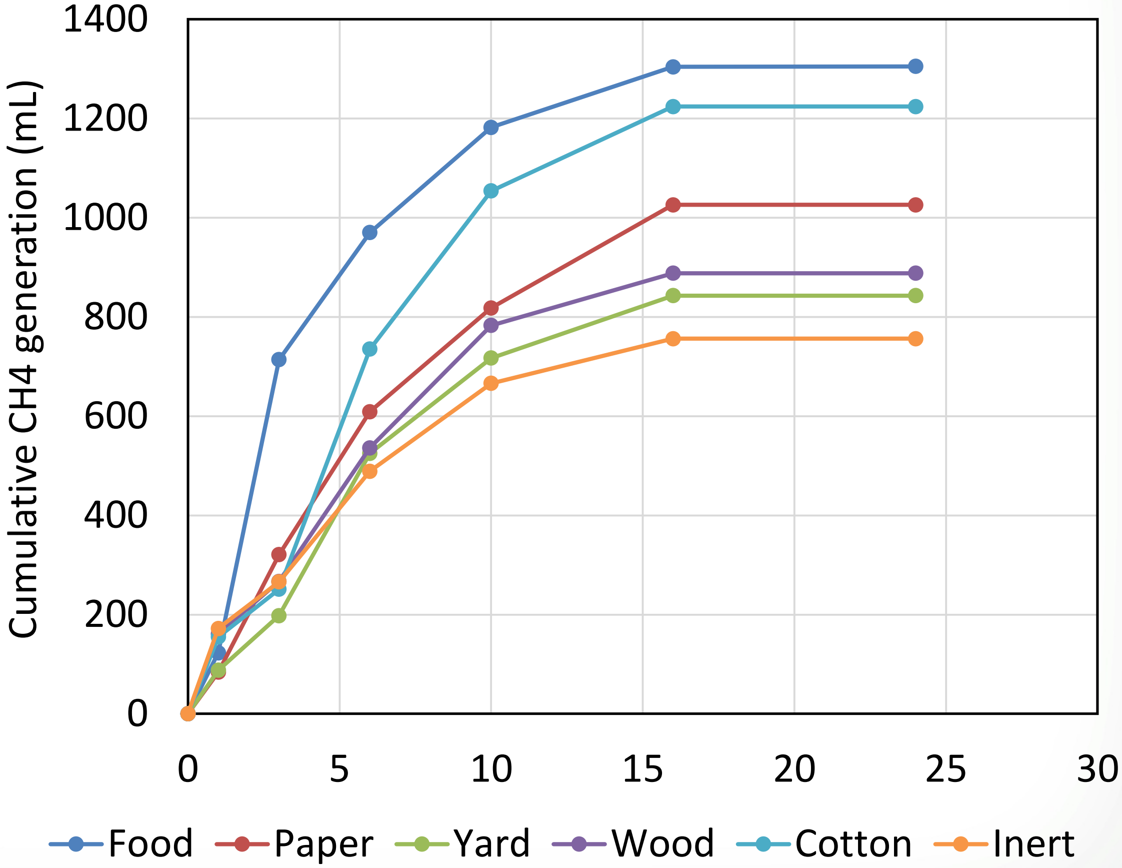
What's the solution?

- Examine new emission factors

Biochemical methane potential assays

plastics **paper** **food**

Biochemical methane potentials



Getting L_0 from BMP

MSW	Waste Composition (%)	Moisture (%)	Mass of water	Mass of solid	BMP (mL CH4/g dry mass)	mL CH4	L_0
food	22	65	14.3	7.7	580	4466	
Paper	13.3	5	0.7	12.6	142	1794	
yard	7.8	50	3.9	3.9	88	343	
metals	9.5	0	0.0	9.5		0	
glass	5.1	0	0.0	5.1		0	
plastics	18.9	0	0.0	18.9		0	
wood	8	30	2.4	5.6	59	330	
textiles	10.9	5	0.5	10.4	114	1180	
other	4.5	5	0.2	4.3	0	0	
	100		**22.0**	**78.0**		**81.1**	**63**

$$\frac{81\ mL\ CH4}{g\ dry\ waste} \times \frac{78\ g\ dry\ waste}{100\ g\ wet\ waste} = \frac{63\ \text{mL CH4}}{g\ wet\ waste}$$

$$L_0 = \frac{63\ \text{m}^3\ \text{CH}_4}{g\ wet\ waste}$$

Getting L_0 from BMP w/o food waste

MSW	Waste Composition (%)	Moisture (%)	Mass of water	Mass of solid	BMP (mL CH4/g dry mass)	mL CH4	L_0
food	0	0	0	0	0	0	
Paper	13.3	5	0.7	12.6	142	1794	
yard	7.8	50	3.9	3.9	88	343	
metals	9.5	0	0.0	9.5		0	
glass	5.1	0	0.0	5.1		0	
plastics	18.9	0	0.0	18.9		0	
wood	8	30	2.4	5.6	59	330	
textiles	10.9	5	0.5	10.4	114	1180	
other	4.5	5	0.2	4.3	0	0	
	78.0		**7.7**	**70.3**		**46.8**	**42**

$$\frac{46.8\ mL\ CH4}{g\ dry\ waste} \times \frac{70.3\ g\ dry\ waste}{78.0\ g\ wet\ waste} = \frac{42\ \text{mL CH4}}{g\ wet\ waste}$$

$$L_0 = \frac{42\ \text{m}^3\ \text{CH}_4}{g\ wet\ waste}$$

What did we learn?

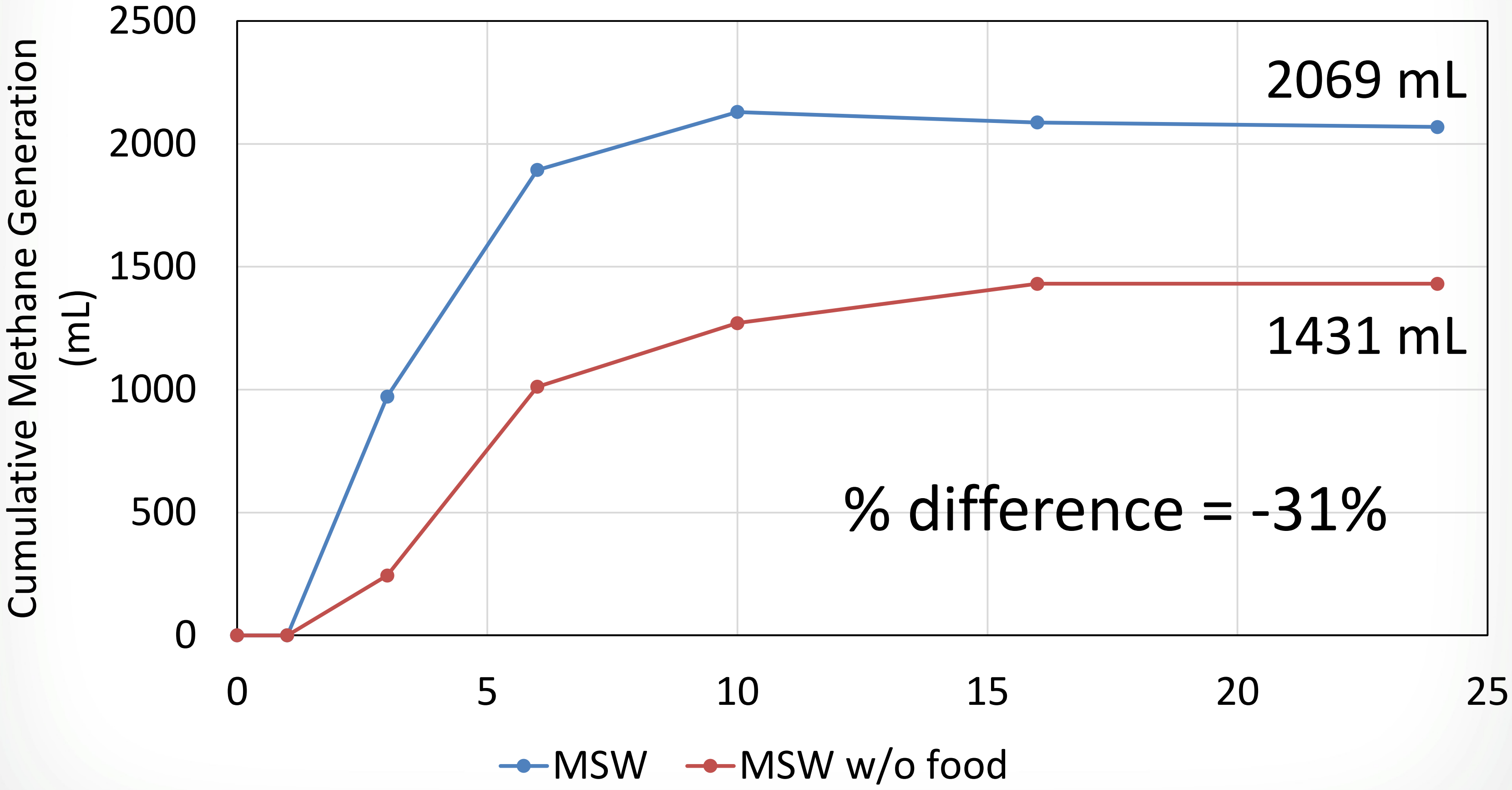
- MSW with food waste (normal MSW)
- L_0 = 63 m^3/Mg waste

- MSW without food waste (future MSW stream)
- L_0 = 42 m^3/Mg waste

Could expect a 33% decrease in L_0 with diversion of all food waste from landfills

Let's just throw them all in a reactor and see what happens.

Let's run a mix of each: with and w/o food waste



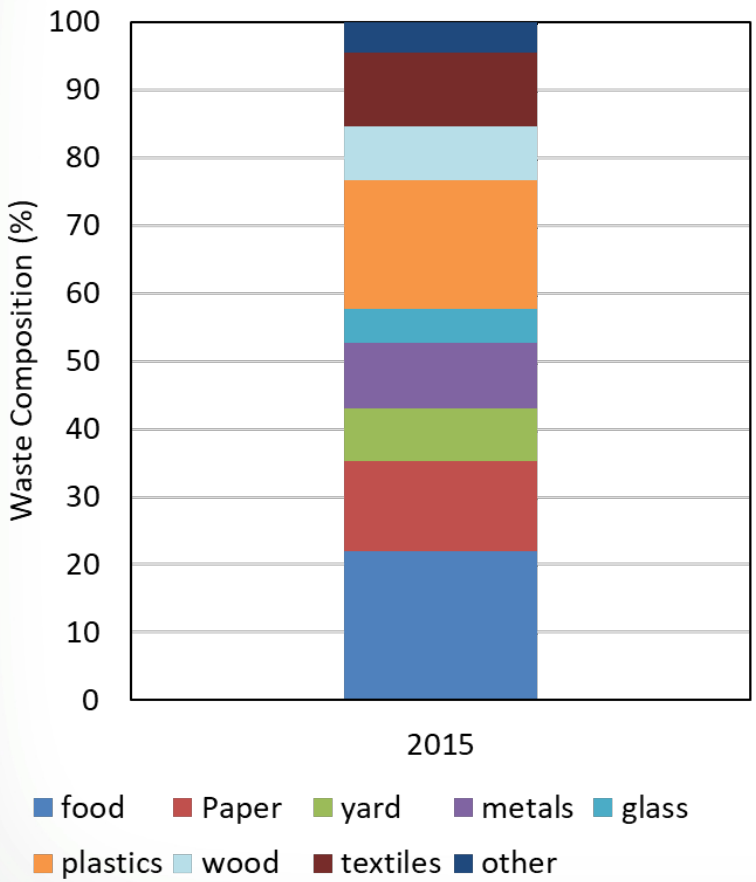
BMPs are good for one thing

- Determining the ultimate amount of methane we can generate from a material

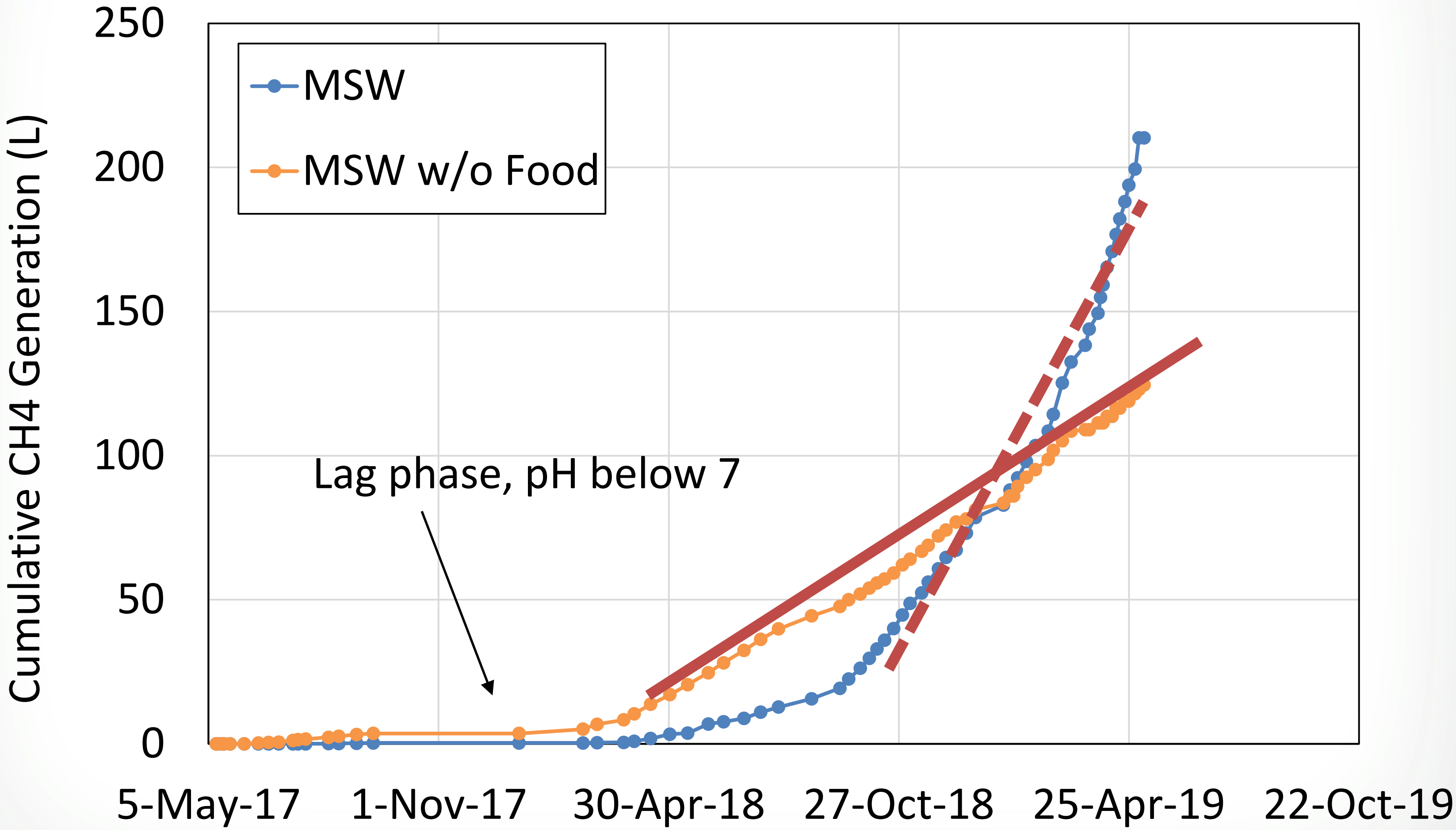
- BMPs are substrate-limited
  - Excess moisture
  - Neutral pH
  - All nutrient req'mts

- Bad for estimating the rate of decay

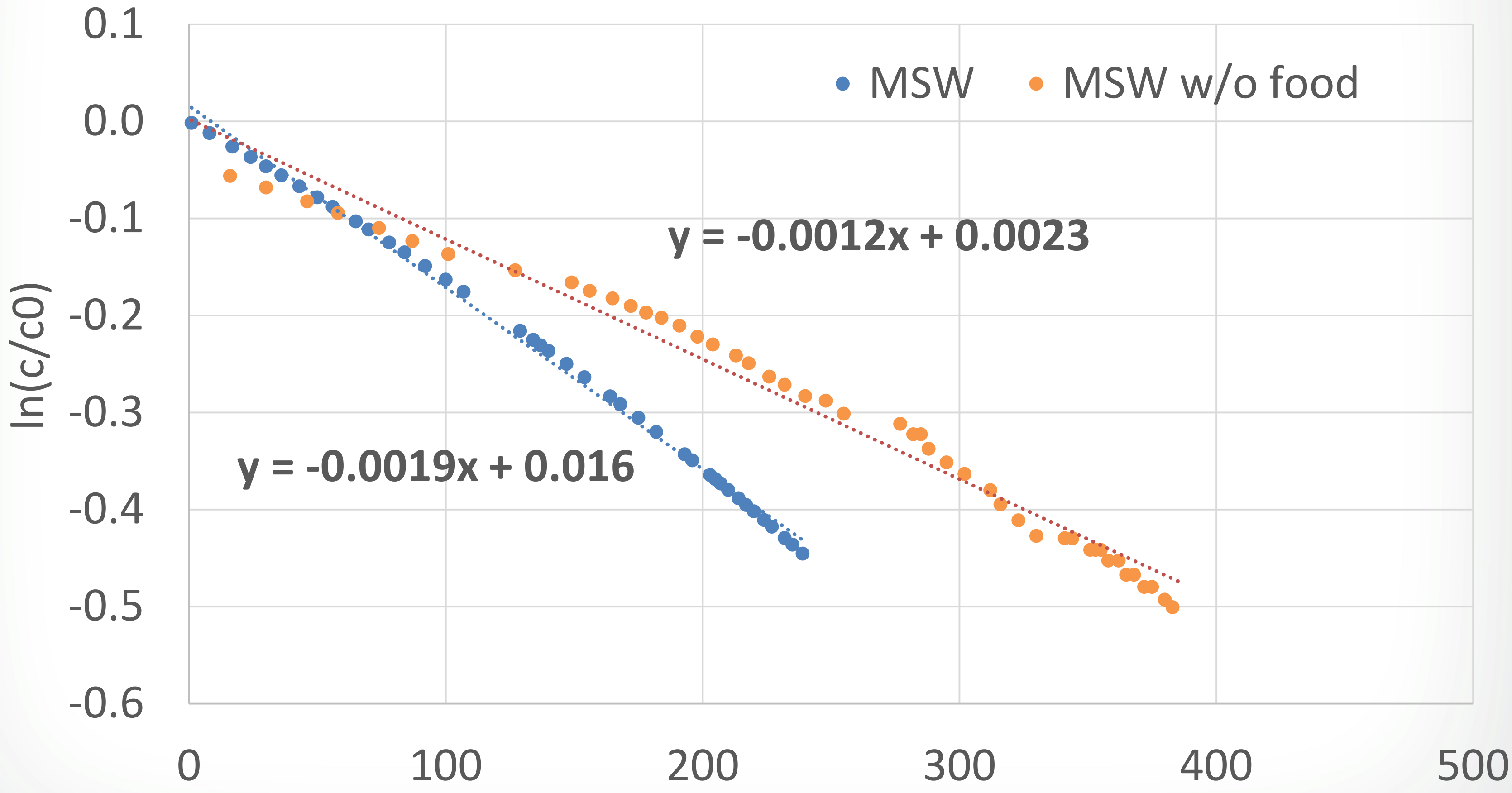
How do we do we estimate decay?



Simulated Landfills CH4 generation

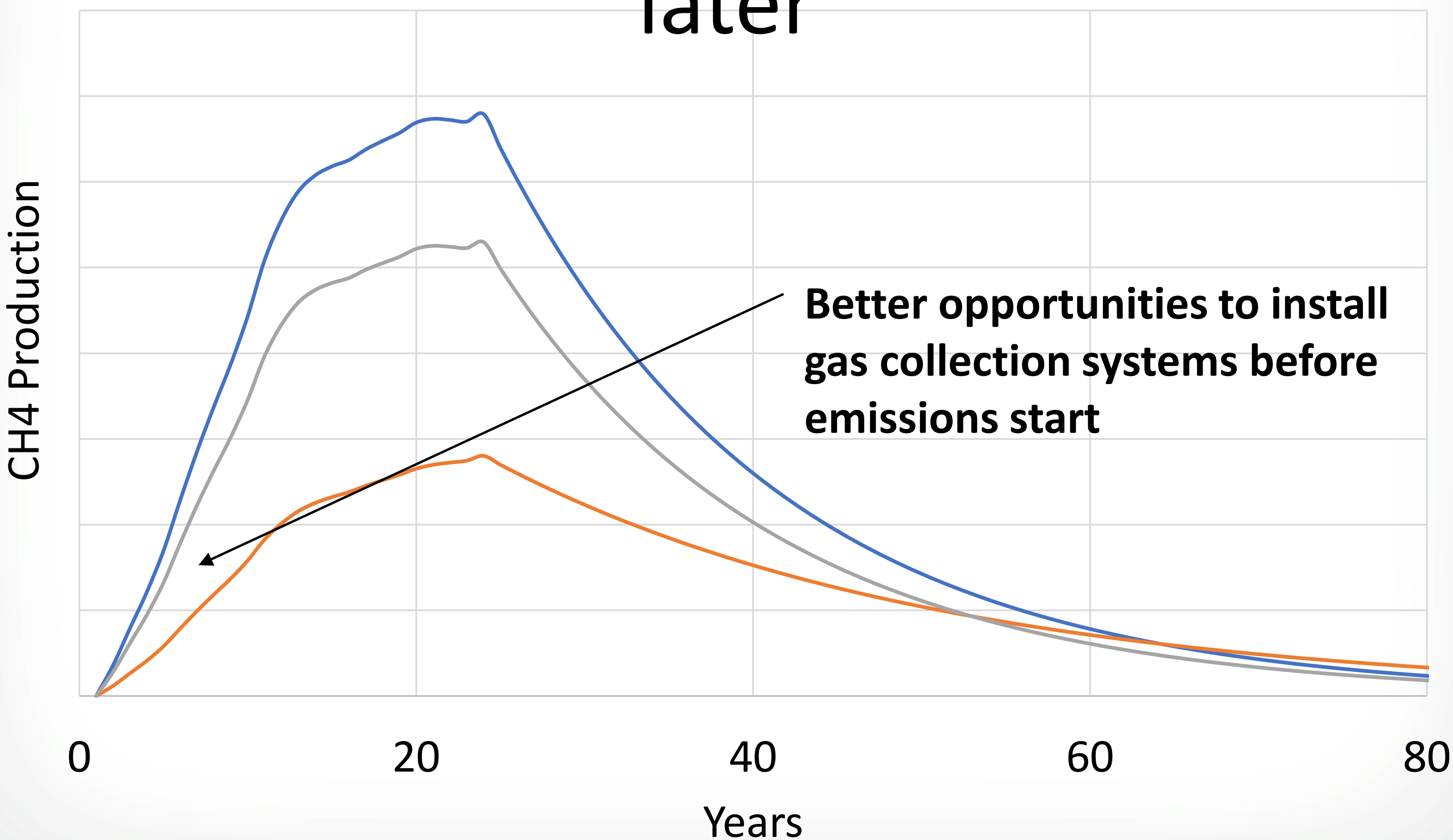


Linear regression to get k



Carbon Half-life = 365 days **Carbon Half-life = 578 days**

No-food emission factors: less emissions up front, more emissions later



Conclusions

- Removing food waste reduces methane potential (L_0) by 33% and slows the rate (k) of decay by 37%
  - AP-42 Inventory:
  - $L_0 = 100$
  - $k = 0.04$
- Broader effects for
  - Energy recovery
  - Emissions of NMOCS
  - Leachate quality and quantity
  - Slope stabilization

Questions

Max J. Krause, PhD

krause.max@epa.gov

Materials Management Branch

National Risk Management and Research Laboratory

Office of Research & Development

US Environmental Protection Agency