Spatial Characterization of Methane Greenhouse Gas Emissions from Landfills and Livestock in California

Joshua Hatch, Cornell University
Global Climate Change Education Program

Lawrence Berkeley National Laboratory
Marc L. Fischer, Environmental Energy Technologies Division

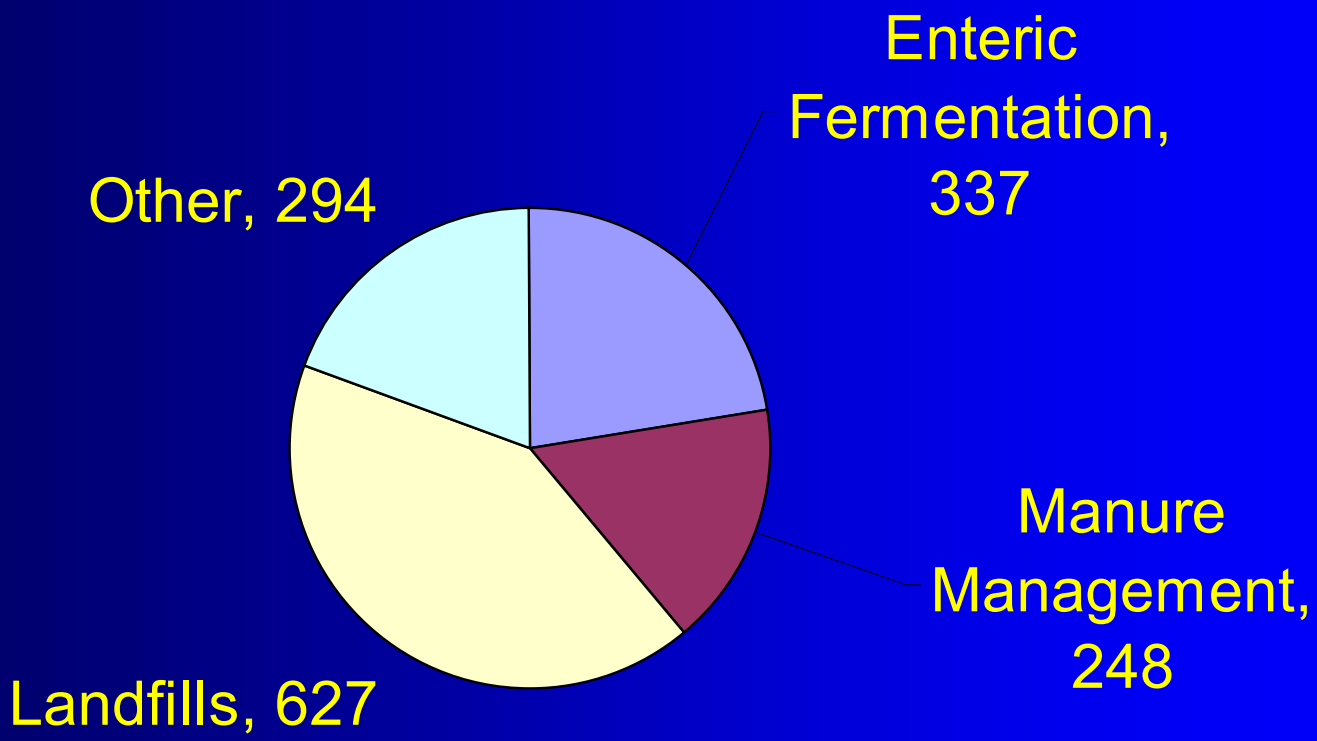
Project Motivations

- Accurately quantify methane emissions in California from landfills and livestock
- Validate/refute estimates from the California Energy Commission's *Inventory of Greenhouse Gas Emissions and Sinks*, 2002
- Develop spatiotemporal map of methane emissions in California to better understand sources
- Assess current and future greenhouse gas mitigation efforts
- Develop estimates needed for further research by inverse modeling methods
- Determine best spots for future location of atmospheric measurement towers
- Close the resource loop for solid waste (the cradle to cradle approach)

The “Cradle to Cradle” Approach

- New paradigm for achieving sustainable society
- Suggests that we should find creative ways to make use and reuse of all products of our society in order to close the resource loop
- Methane is a high energy gas, already combusted by our society for heating and electrical needs
- California’s landfill and manure methane emissions can be easily captured for energy production, thus further utilizing landfill gas as a resource and reducing GHG emissions

Existing Estimates of California's Methane Emissions (kMT)



Franco 2002. Inventory of Greenhouse Gas Emissions and Sinks from 1990-1999. California Energy Commission: Public Interest Energy Research.

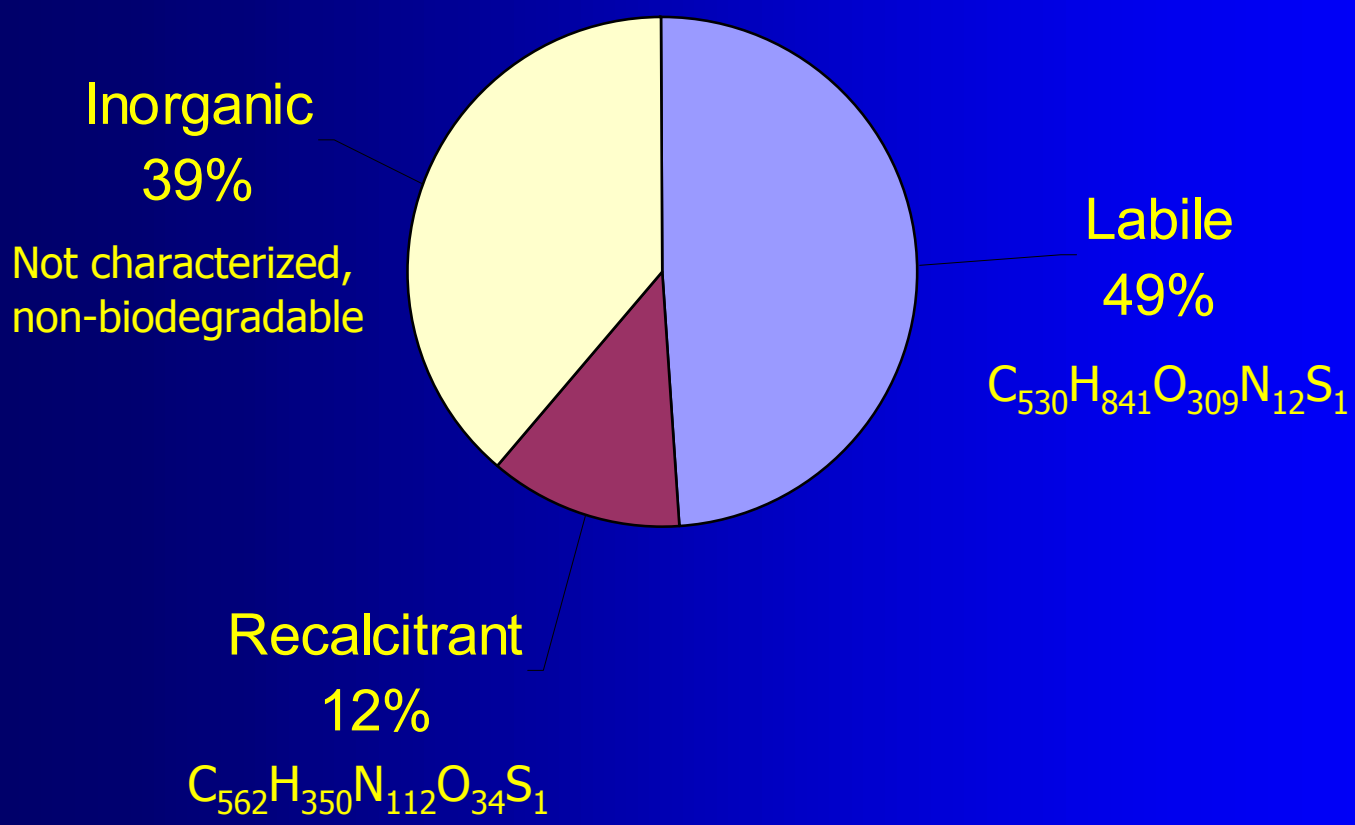
Landfill Methane Emissions

- Landfills are the largest source of methane emissions in California (627 kMT), making up 41.6% of total methane emissions
- Methane is produced by methanogenic bacteria during degradation of the organic components of garbage
- Organic components of waste decay exponentially, governed by a two-term first order decay reaction (Findakakis 1979)

Estimation Methods for Landfill Methane Emissions

- Determine the fraction of California's waste stream that is organic and is available for methane production
- Further categorize organic components of California's waste as quick decay or labile (i.e. food wastes) or slow decaying or recalcitrant (i.e. yard waste, textiles)
- Calculate mean chemical formulas for Labile and Recalcitrant portions of California's waste
- Use stoichiometry and the mean chemical formulas of California's waste to determine the total potential methane generation per unit of California waste
- Estimate methane emissions from each year's addition of solid waste to each landfill in California and sum to determine the methane production for a given year, from a given landfill, and repeat for all

Characterization of California's Solid Waste for 1999



Governing Stoichiometry, Decay Functions and Formulas

- Balanced Reactions:
  - Labile: $C_{530}H_{841}O_{309}N_{12}S + 175H_20 \rightarrow 288CH_4 + 242CO_2 + 12NH_3$
  - Recalcitrant: $C_{350}H_{562}O_{112}N_{34}S + 179H_20 \rightarrow 205CH_4 + 146CO_2 + 34NH_3$
- Total Annual Methane Emissions (moles/Mg waste)

  (for waste deposited t years ago)

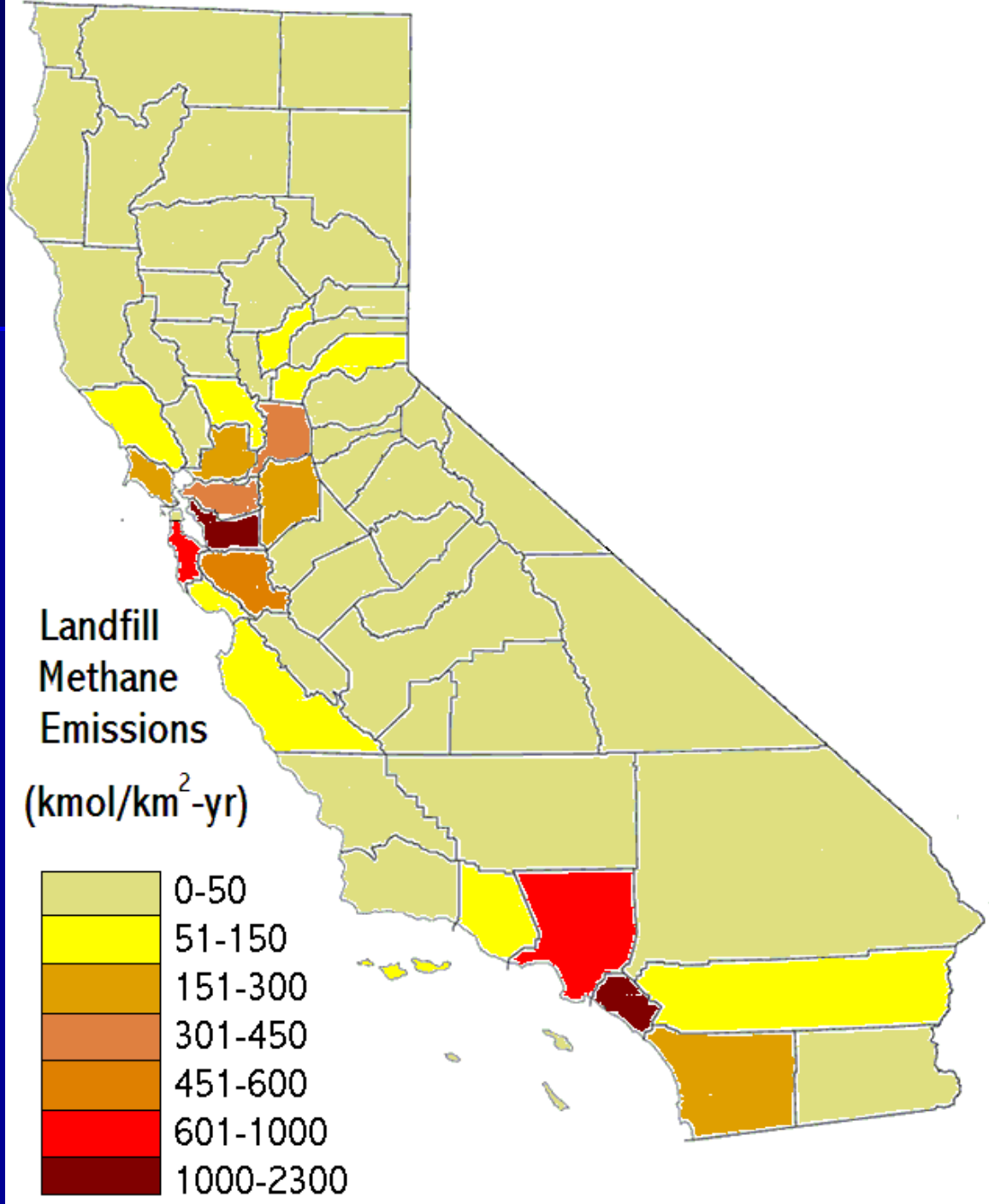
  $b(t) = 37.6e^{-0.139t} + 1.84e^{-0.023t}$
- Total Methane Emissions from a given landfill in 1999

  $CH_4(1999) = \Sigma\ (b(1999-t_i)*M_i)$

  where M_i = tonnage for year i (Mg) and t_i = year

Spatial Map of California's Landfill Methane Emissions by County

- Spatial distributions of Landfill Methane Emissions closely resemble population distribution
- The location of emissions are thus conveniently situated near where energy demand is greatest, increasing the viability of power generation



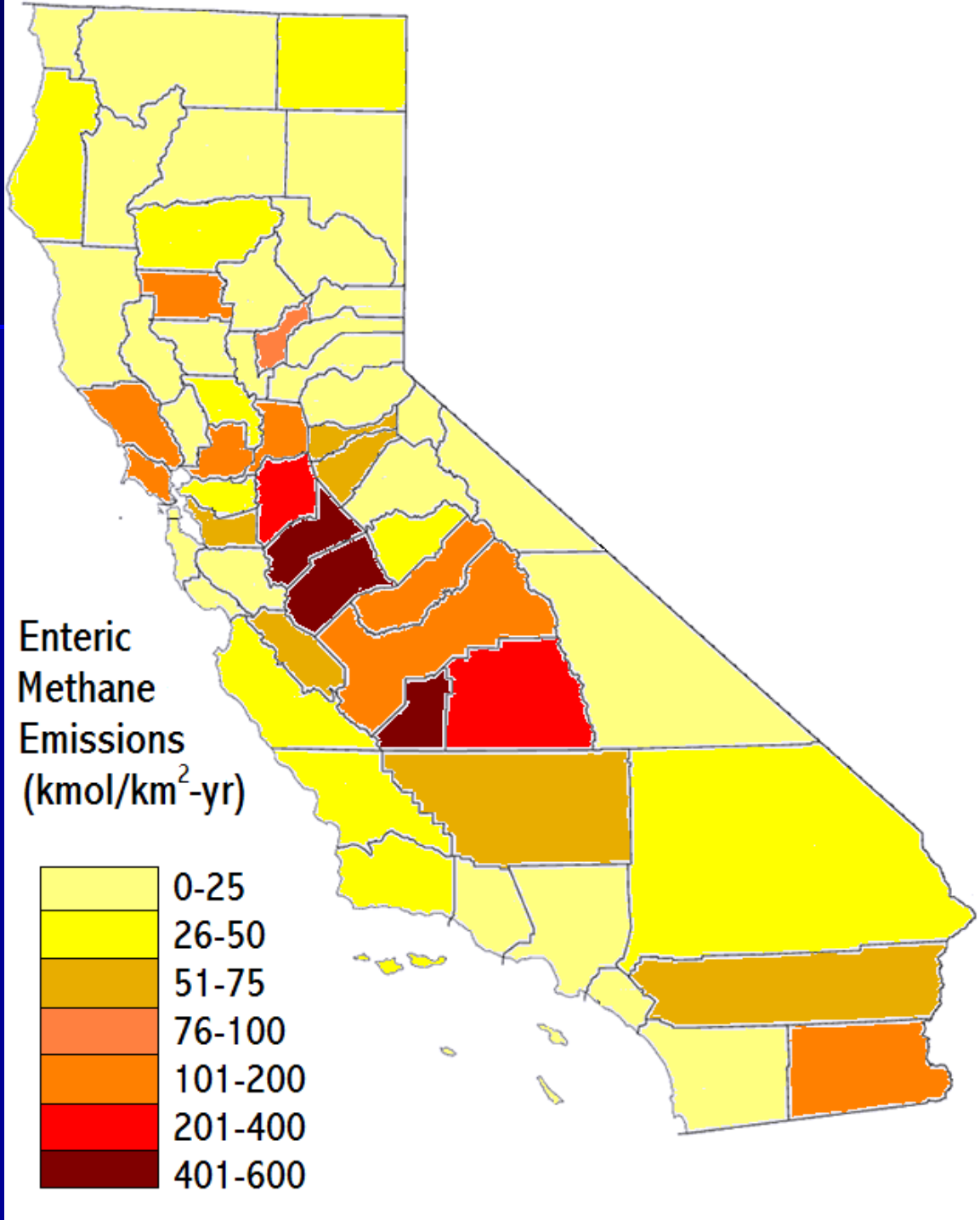
Livestock Methane Emissions

- Agricultural livestock are the second largest source of methane in California (586 kMT), making up 38.8% of total methane emissions
- Enteric Fermentation (337 kMT) and Manure Management (248 kMT) are the two components of livestock methane emissions

Spatial Map of California's Livestock Enteric Methane Emissions by County

Note: Assuming that the ratio of manure and enteric methane emissions is constant spatially, you can convert this map to total livestock methane emissions by multiplying by 12/5

Ratio from Franco (2002)



Livestock Methane Emissions

- Are dominated by cattle, which account for 98% of total livestock emissions
- Heavily concentrated in central, valley region of California
- Manure management emissions have great potential for mitigation via anaerobic digestion in a bioreactor
- Enteric Fermentation emissions have little potential for mitigation

Implications

- Mitigation of landfill methane gas would not only reduce the release of this strong GHG, but in the case of energy production, also offsets other GHG emissions from other electricity production
- California's landfill methane, if completely captured and used for energy production, could produce 3.0GW of electricity
- California's total electricity demand for 2003 was 31.6GW, implying that total capture and conversion of landfill methane could provide nearly 10% of California's energy demand
- Also, could reduce air pollution if electricity generation that is offset is produced by a "dirtier" methods, such as the combustion of coal

Implications (continued)

- Mitigation and treatment of livestock manure would not only reduce CH_4 emissions, thus reducing global warming, but would also reduce ammonia emissions
- Ammonia emissions are a greater concern for human health, as ammonia combines with nitrates to form ammonium nitrate aerosols, which have adverse affects on human health
- The central valley of California has some of the worst ammonium nitrate pollution problems in the country
- Agricultural emissions of methane and ammonia were greatest in the central valley of California, suggesting mitigation could help alleviate the air pollution in this problem area

Acknowledgements

- Marc L. Fischer, my mentor
- Jeff Gaffney and the GCEP Staff
- Lawrence Berkeley Laboratory
- Also:
  - Douglas Haith, Cornell University
  - California Energy Commission
  - California Integrated Waste Management Board
  - Public Interest Energy Research