Characterizing greenhouse gas emissions from woody biomass:

A literature review

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1. Problem Identification

Decomposition of organic material represents a significant carbon flux from the biosphere to the atmosphere. One type of organic material whose decomposition and emission behavior has gone largely unexplored is ***timber harvest residue***. A by-product of the timber industry, this material is either left on site to decompose or is further processed into chips or pellets, transported to facilities and piled in open-air conditions. In piles, the combination of reduced average particle size and piling can lead to in-pile anaerobic conditions. ***These conditions foster growth of methane-producing microbes.***

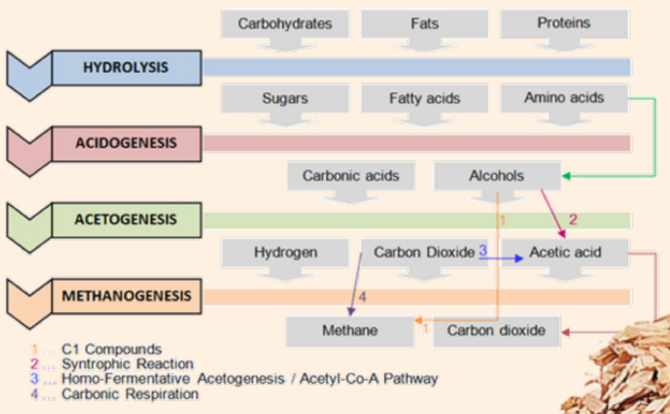
2. Motivation

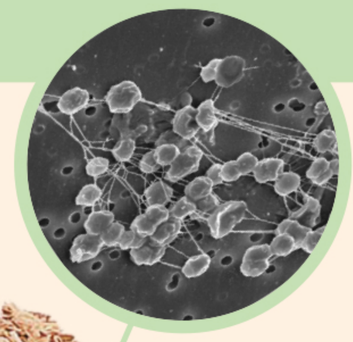
Research concerning emissions associated with electricity supply chains has received increasing amounts of attention, motivated by international efforts to reduce GHG emissions. California's utility policies promote the use of woody biomass for electricity production; however, the net carbon intensity of bioelectricity is uncertain. ***If stockpiles of residual timber material (specifically woodchips) are emitting CH4, then interim storage phases could represent a significant source of emissions, when estimating net carbon intensity of supply networks.***

3. Literature Review

We undertook a literature review to better understand the dynamics of decomposition and emission formation within piles of woodchips. This review aimed to:

1. Investigate methods that have been previously employed to measure emissions from residual timber stockpiles. Both laboratory and field based experimental designs were included in our scope. As literature is limited on this subject, we also included methods used for:
    - Landfills
    - Compost heaps
2. Compile reported CO_2 and CH_4 emission factors (or other emission metrics) from decomposition of residual timber material, as well as compost with the intent of running an analysis on these values.
3. Probe the mechanism that drives solid to gaseous carbon transformation within woodchip pile heaps, and specifically the mechanism for CH_4 formation. Research suggests that this could be due to either:
    - Chemical conversion (auto-oxidation of fatty lipids)
    - Biological conversion (methanogenesis from microbial activity)





Upper right- **Figure 1: Methanogen**s. Credit: Maryland Astrobiology Consortium, NASA, and STScI.
Upper left- **Figure 2: Overview of anaerobic methane pathway.** Credit: TherChem.

4. Key Findings

1. For *in situ* measurement of gaseous emissions from woodchip stockpiles, we found the following methods most commonly sited:

'Small-Scale' Methods	'Total Emission' Methods
(measurement area limited to a few meters squared)	*(measurement area encompasses piles)*
• Static and dynamic chamber methods	• Integrated horizontal flux (IHF) technique
• Funnel technique	• Dynamic plume method
• Gradient method	

Most studies agreed that emission of CH_4 was spatially inhomogeneous, and that the data obtained from small scale methods could not be relied upon to predict total flux of CH_4 emitted, across stockpile surfaces.

Andersen et al. (2010) and Whittaker et al. (2016) noted that CH_4 emission patterns can probably be described via the 'chimney effect' or by convective transport.

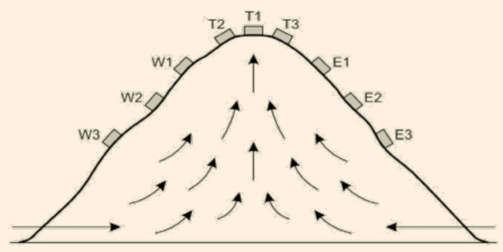


Figure 1: Conceptual schematic of the 'Chimney Effect'.
Credit: Andersen et al. (2010)

Table 1: Field study GHG emissions and concentrations from woody refuse piles

Source	*Measurement Technique*	*Refuse Type*	*CO_2 Emission Metric*	*CH_4 Emission Metric*
Biomass Technology Group (2000)	Static Chamber	Woodchips	-	4340 mg $m^{-2}hr^{-1}$
Pier & Kelly (1997b)	Static chamber	Sawdust	4553 mg $m^{-2}hr^{-1}$	1.68 mg $m^{-2}hr^{-1}$
		Wood shavings	-	101.3 mg $m^{-2}hr^{-1}$
Whittaker et al. (2016)	Gradient method	Woodchips	60,000 ppm	1633 ppm

Table 1: Tabulated values from of the researched papers. Fluxes are reported as averages across samples and concentrations are reported as the absolute peak concentration across samples. Flux units were converted to make values comparable.

2. ***Our literature review revealed that experimental designs differed considerably between studies, making direct comparison of results difficult***. There was a high degree of variability between the reported values, indicating that differences in experimental designs could have affected results. See **Table 1** for a sample of documented values.

3. Most literature agreed that CH_4 formation within woodchip stockpiles is likely ***primarily driven by a biological mechanism, namely pile colonization by methanogens. Studies also suggested that the presence of methanotrophs (methane oxidizing microbes) has the potential to significantly reduce CH_4 concentrations as the gas moves through piles (Andersen et al., 2010, Biomass Technology Group, 2000, Pier & Kelly, 1997b, Whittaker et al. 2014), resulting in lower surface emission.***

5. Going Forward

The information gained by this literature review will serve to inform our our next steps:

1. Development of an appropriate experimental design and measurement methodology for incubation studies. Controls of interest are oxygen (O_2) level, moisture and temperature.
2. Conduction of these studies at the Schatz Lab.
3. Continuing to explore appropriate methods for 'scaling up,' with the intent of eventually measuring total fluxes from large *in situ* piles.

In the larger scope, this review has indicated that there is a need for standardized measurement techniques, so data between studies is more comparable.

6. Sources

Andersen, J. K., Boldrin, A., Samuelsson, J., Christensen, T. H., & Scheutz, C. (2010). Quantification of greenhouse gas emissions from windrow composting of garden waste. *Journal of environmental quality*, *39*(2), 713-724.

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Pier, P. A., & Kelly, J. M. (1997). Measured and estimated methane and carbon dioxide emissions from sawdust waste in the Tennessee Valley under alternative management strategies. *Bioresource technology*, *61*(3), 213-220.

Whittaker, C., Yates, N. E., Powers, S. J., Misselbrook, T., & Shield, I. (2016). Dry matter losses and greenhouse gas emissions from outside storage of short rotation coppice willow chip. *Bioenergy research*, *9*(1), 288-302.

7. Acknowledgements

Funding provided by the CSU Agricultural Research Institute and match funding provided by the California Energy Commission through the California Biopower Impacts (CBI) Project and the Research Scholarly and Creative Activities grant through Humboldt State University.