What are the Greenhouse Gas Emissions of Biofuels?

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International District Energy Association

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45 Years of Experience in Sustainable District Energy Systems

Agenda

- Drivers for interest in biofuels
- GHG basics
- Types of biofuels
- Assessing GHG emissions of biofuels
  - Life cycle assessment of emissions
  - Carbon stock analysis
  - Integrated analysis of woody biomass
- Liquid biofuels
- Biogas

Drivers

- GHG reductions strategies:
  - Building efficiency retrofits
  - Solar energy
  - Geoexchange
  - Other heat pump approaches
  - Fuel switching
- Trend toward electrification of energy infrastructure
- Counter-trends include goals of:
  - Dispatchable and resilient local electric and thermal energy
  - Avoidance of indirect carbon emissions through grid power
- Focus today: carbon reduction achievable through biofuels
- Biofuel strategies:
  - Solid biomass usually requires significant investment in new boilers
  - Switch to liquid or gaseous biofuels can often be accomplished using existing equipment

GHG basics

- GHGs are quantified as carbon dioxide equivalent (CO_2e)
  - CO_2
  - Methane (CH_4)
  - Nitrous oxide (N_2O)
- Global Warming Potential depends partly on time span
- GWP typically measured over 100-year period in CO_2e
- Intergovernmental Panel on Climate Change *Fourth Assessment Report:* 100-year GWPs are: CO_2, 1.0; CH_4, 25.0; N_2O, 298
- Controversy regarding GHG emissions of biofuels

Solid biomass

- Most common biofuel
- Recent potential district energy projects focus on logging residue
- Other woody biomass fuels include sawmill residues, urban waste wood, residues from wood products manufacturing, and whole tree harvesting
- Other solid biomass fuels include crop residues, energy crops and animal wastes

Liquid biofuels

- U.S. market driven by federal Renewable Fuel Standard & California Low Carbon Fuel Standard
- Biodiesel
  - Produced from vegetable oils and animal fats through a chemical process called transesterification
  - Most common feedstocks in the U.S. are soybean oil and yellow grease
- Renewable diesel
  - Can be produced from a range of feedstocks and technologies
  - Most common approach is hydroprocessing of fats, oils and greases react with hydrogen in the presence of a catalyst at high temperature and pressure
  - Cellulosic feedstocks can also be used
- Renewable fuel oil
  - Low-Btu biofuel for non-transportation markets
  - Pyrolysis of cellulosic feedstocks
- Bio-Residual Oil
  - Co-product of biodiesel production
  - Substitute for heavy fuel oil
  - Need stainless steel tanks and heated fuel lines

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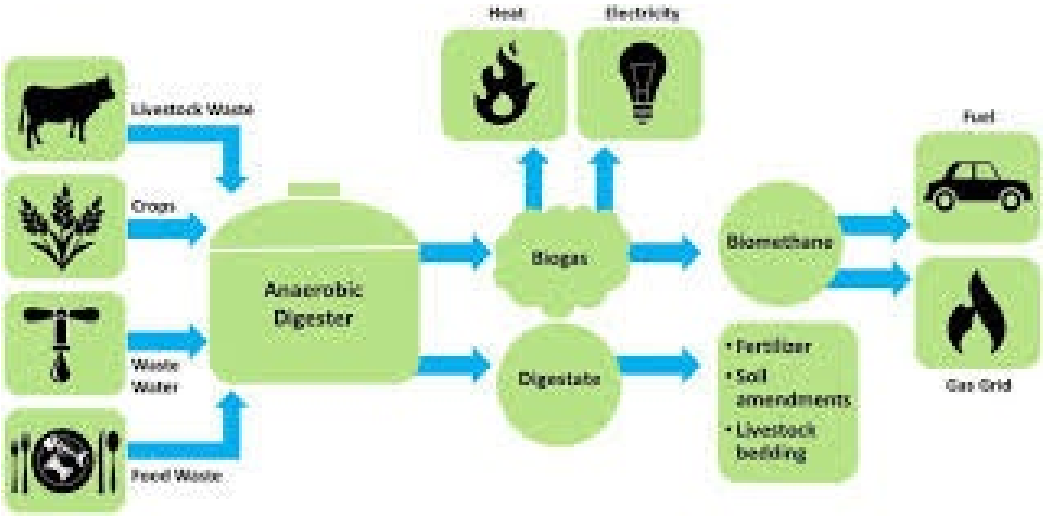
Biogas

- Feedstocks
  - Landfills
  - Animal waste
  - Crop residues
  - Municipal sewage
  - Municipal solid waste
- Technologies
  - Pyrolysis
  - Anaerobic digestion
- “Renewable natural gas”
- Limited production, most of which goes to transportation due to RFS and CARB incentives



Life cycle assessment

- “Cradle-to-grave” emissions from:
  - Extraction or cultivation & processing
  - Transportation
  - Byproduct disposal
  - Coproduct utilization
  - Combustion emissions

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Life cycle assessment

1. What are the energy inputs required to grow and harvest the biomass?
2. What processing is required to convert the biomass to a usable fuel, and where will the processing take place?
3. How far will the biomass be transported to a processing site and/or point of use?
4. How long will biomass material be stored at each step in the process, and what are the storage conditions?
5. What are the emissions from combustion of the fuel?

Life cycle assessment

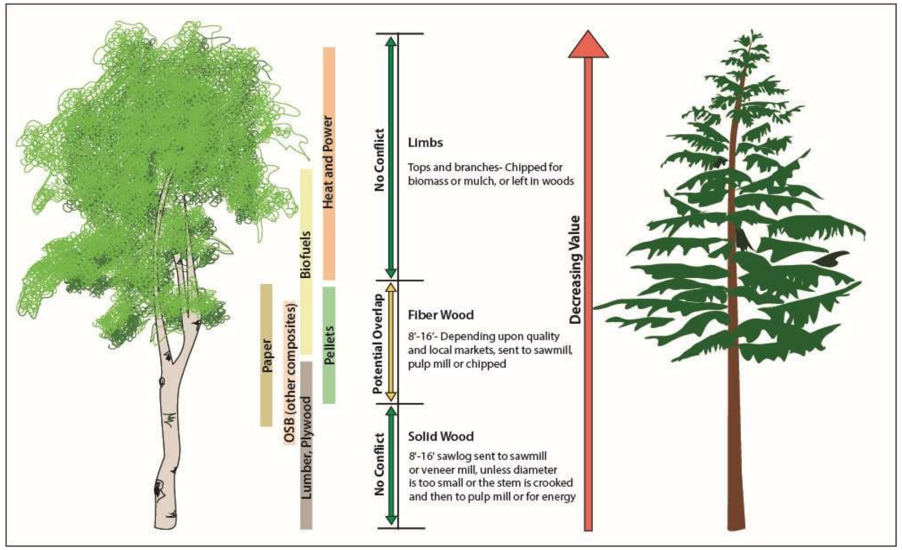
6. What is the efficiency of boiler or other equipment used to convert fuel to usable heat and/or power?
7. What is the ash content of the biomass, and how far will ashes be transported for disposal/use?
8. What impact does harvesting or removal of biomass for energy have on the long-term carbon stock of the land?
9. What are the indirect land use impacts, i.e., does use of the land for producing fuel crowd out other land uses, and what impact does displacement of those uses have on greenhouse gas emissions?
10. What is the analysis time frame?

Carbon stock analysis

- Assess future changes in the "carbon stock" of the forest or agricultural land as a result of harvesting biomass for energy
- Response depends on many variables, e.g.:
  - Plant species
  - Climate (including temperatures and moisture)
  - Vegetation density
  - Harvesting practices
- Carbon stock analysis addresses both regrowth (sequestering carbon) and decay of dead wood

Woody biomass

- Manomet study* generated controversy
- Results usually cited were focused on the potential to generate electricity using biomass harvested by cutting down productive forests in Massachusetts



- Regarding use of logging residues, the Manomet study concluded:

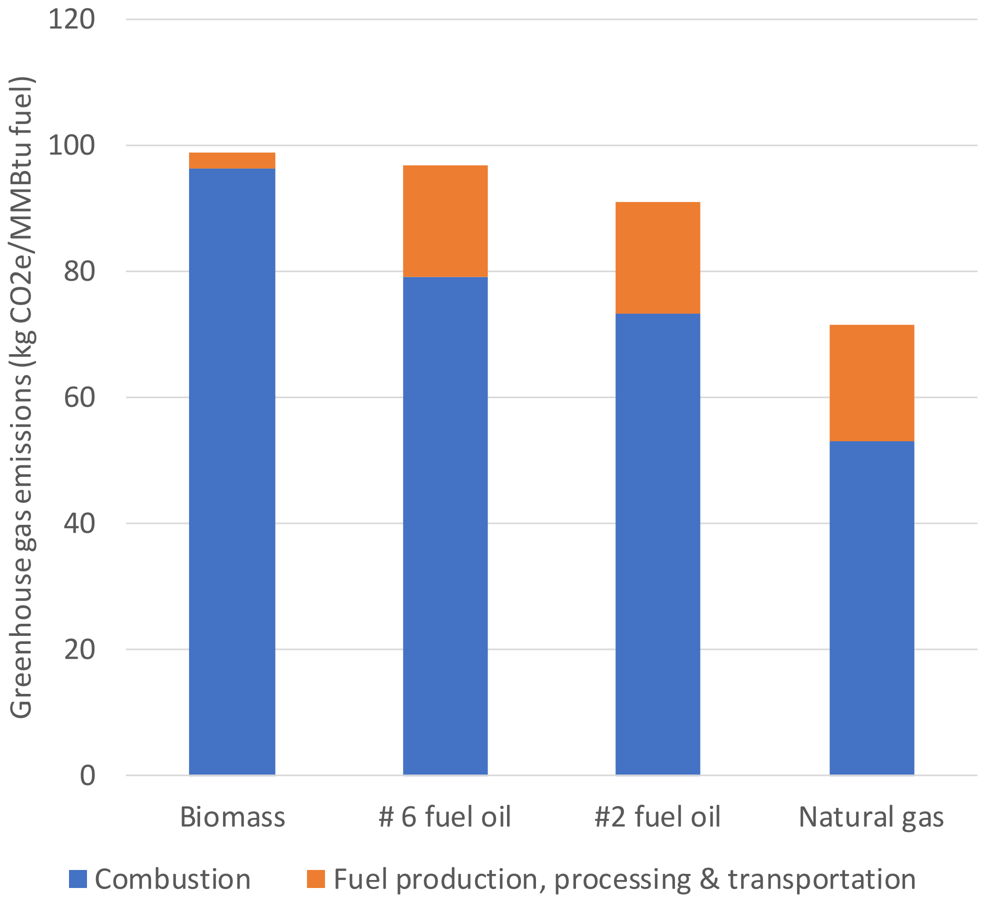
> *“The removal of tops and limbs generally has little impact on stand level carbon dynamics in Massachusetts forests. Tops and limbs that are not removed during a harvest decay quickly, generally within 10 years. If tops and limbs are a small proportion of the total harvest, then new growth will compensate for the removal within 10 years as well.”*

* ”Biomass Sustainability and Carbon Policy Study,” Manomet Center for Conservation Sciences, June 2010

Illustration courtesy of Innovative Natural Resource Solutions, LLC

Integrated analysis of woody biomass

Life cycle analysis (without carbon stock)



Source: ”Biomass Sustainability and Carbon Policy Study,” Manomet Center for Conservation Sciences, June 2010

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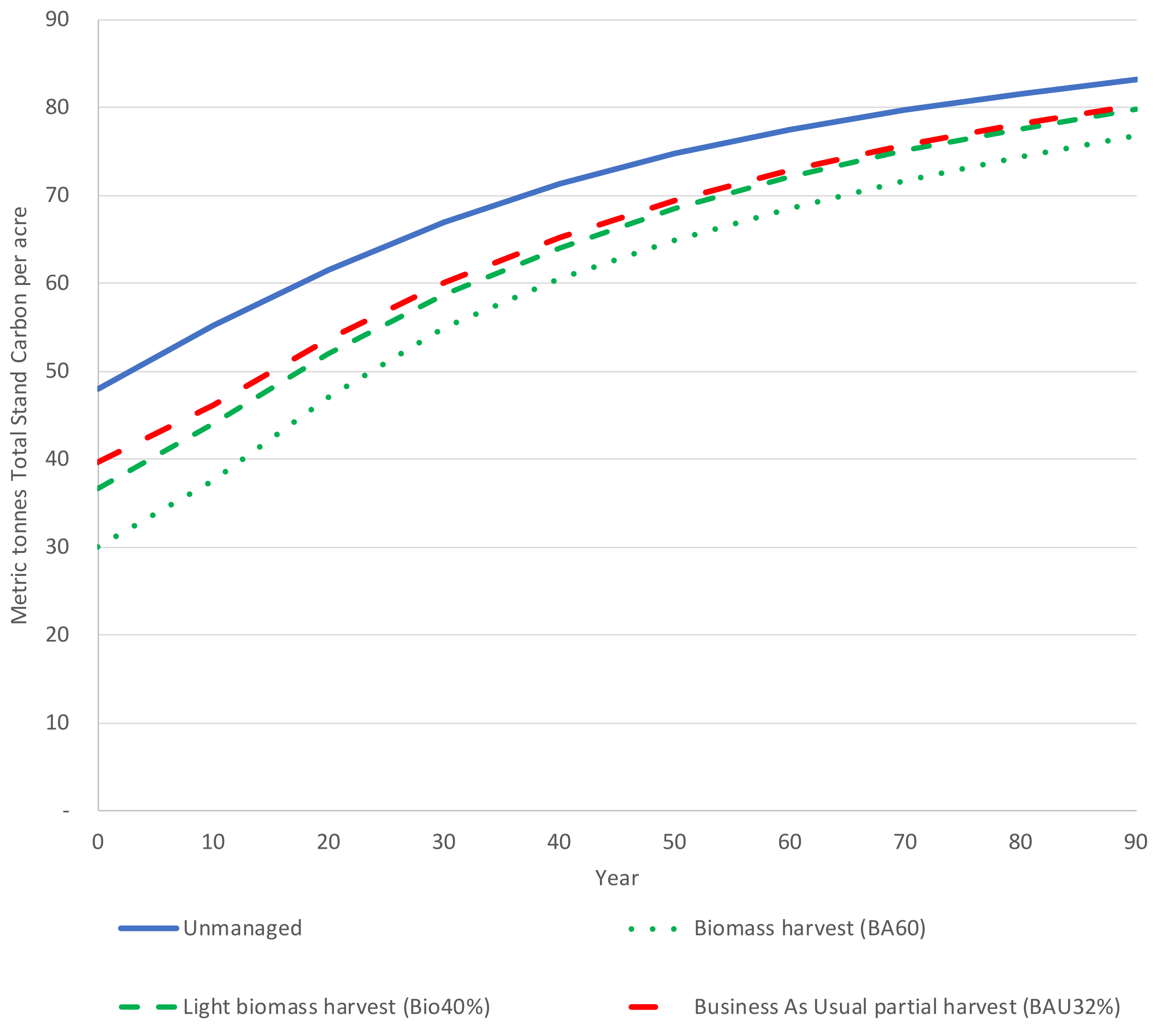
Integrated analysis of woody biomass



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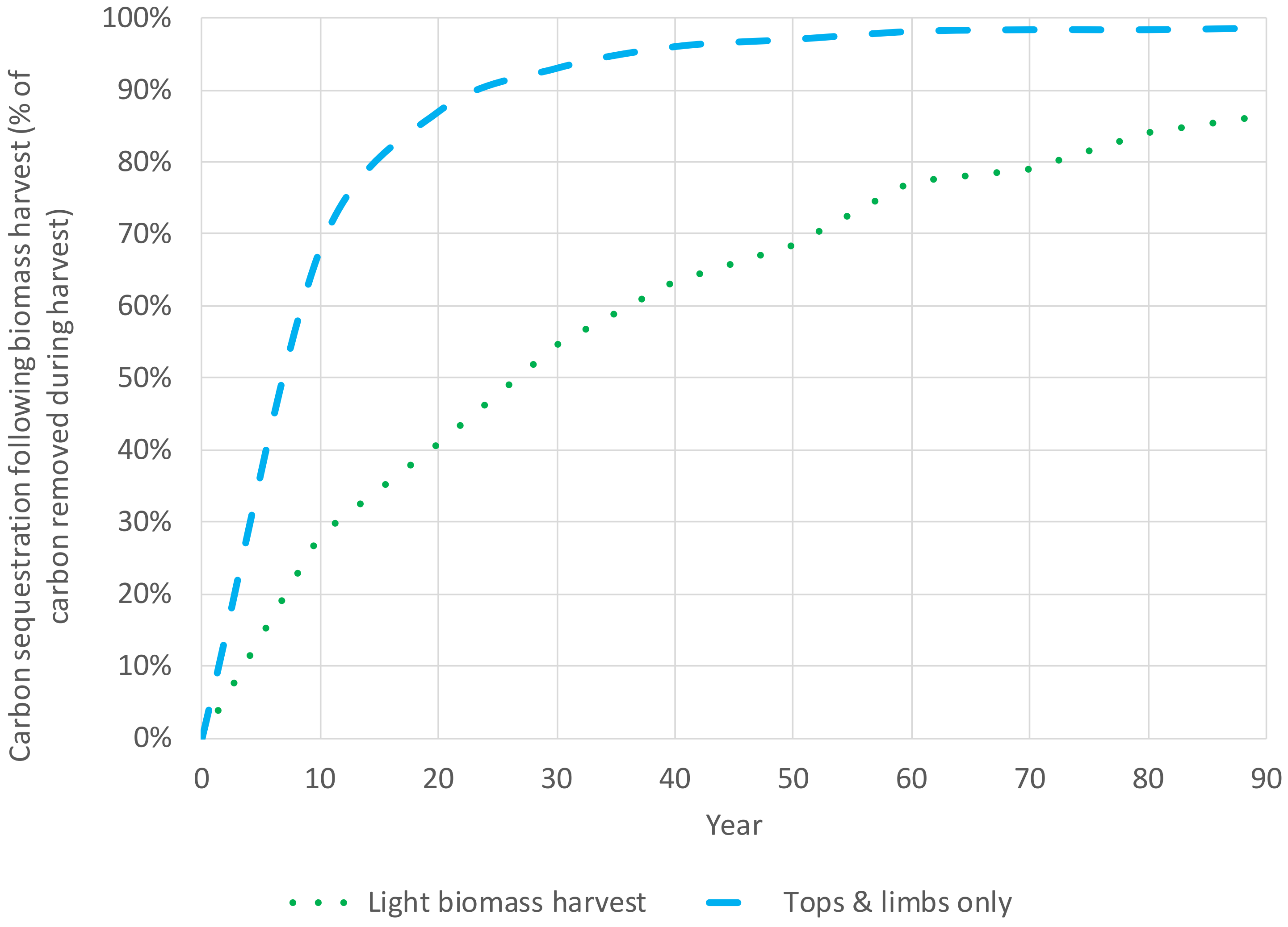
Integrated analysis of woody biomass



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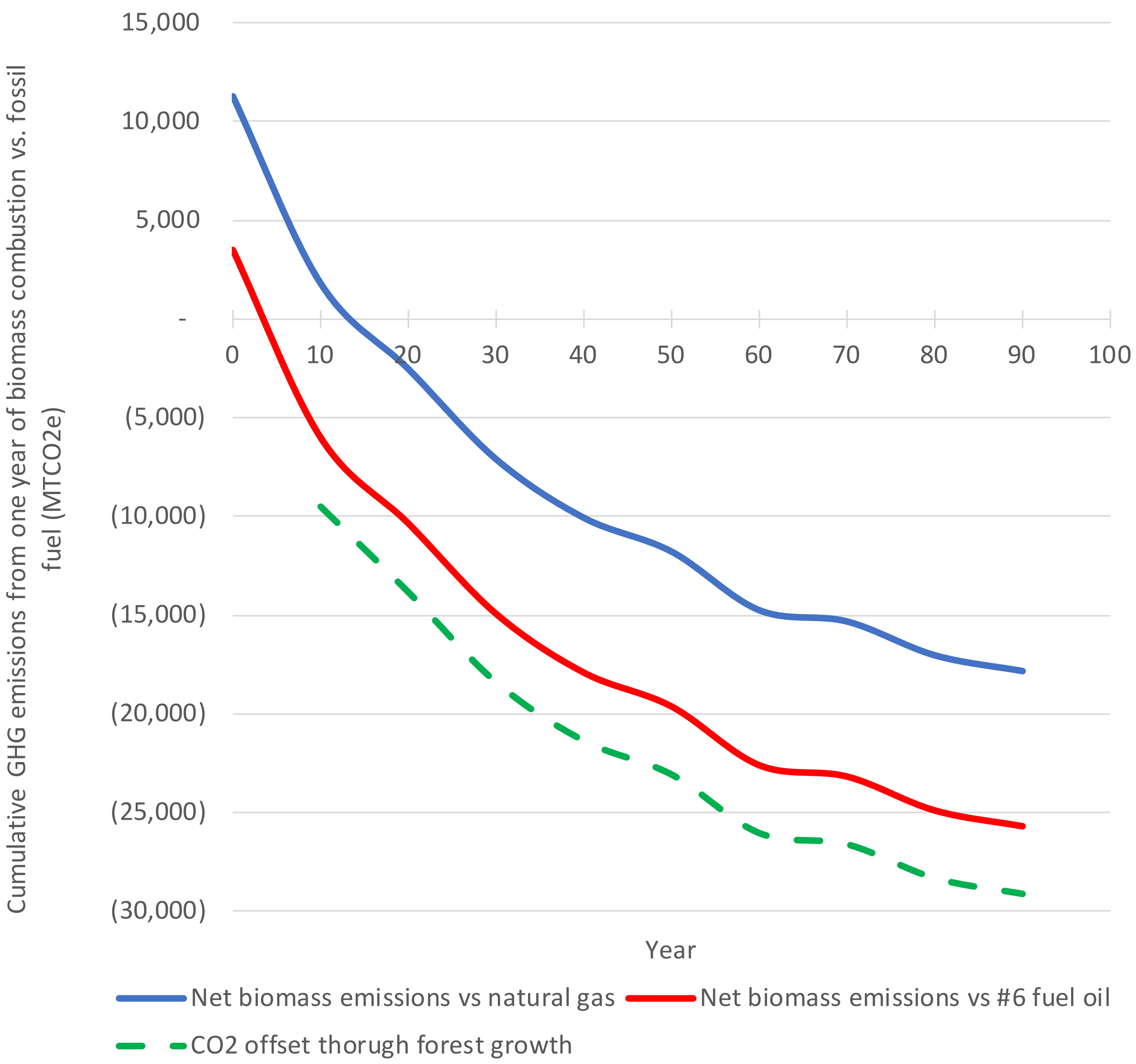
Integrated analysis of woody biomass



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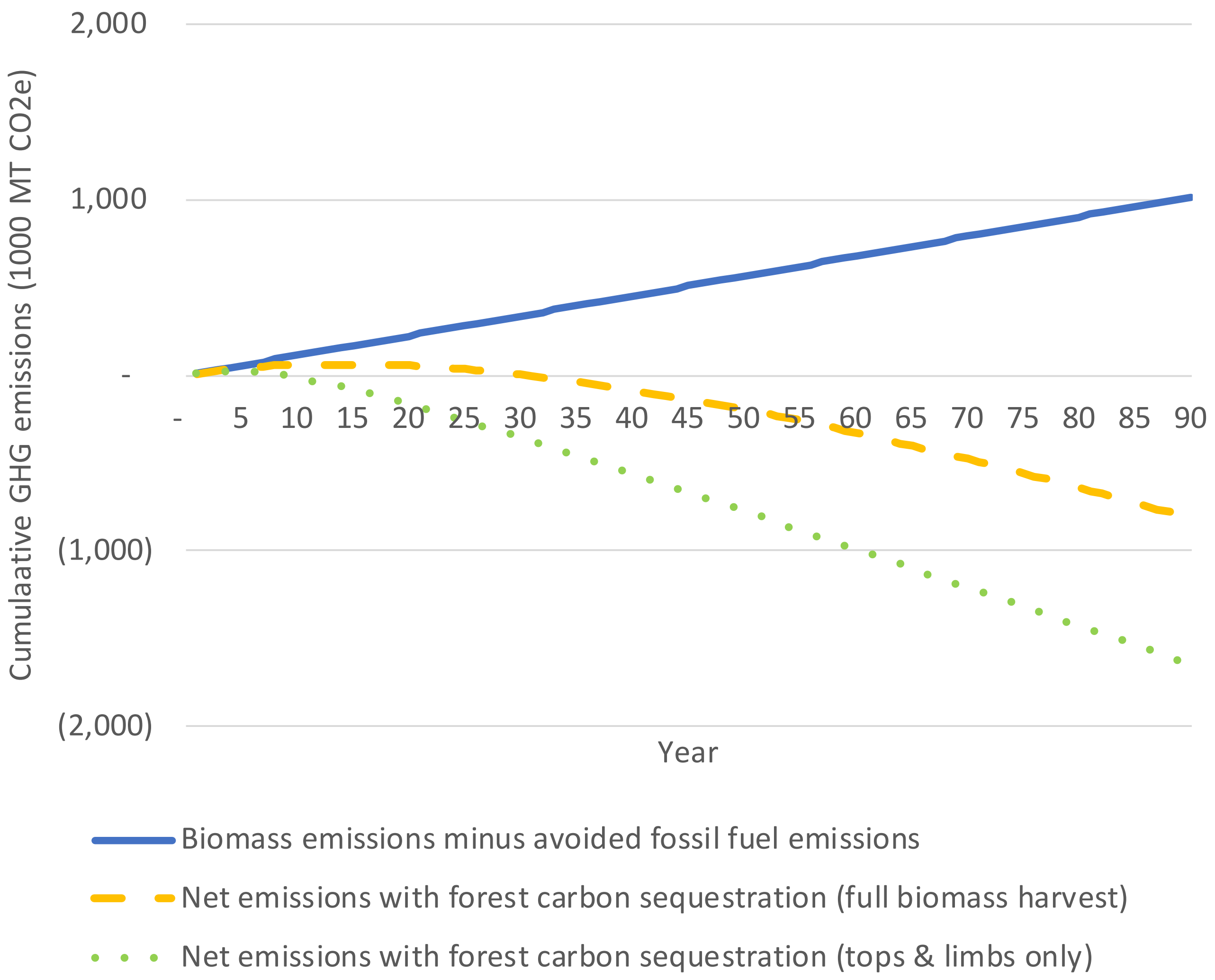
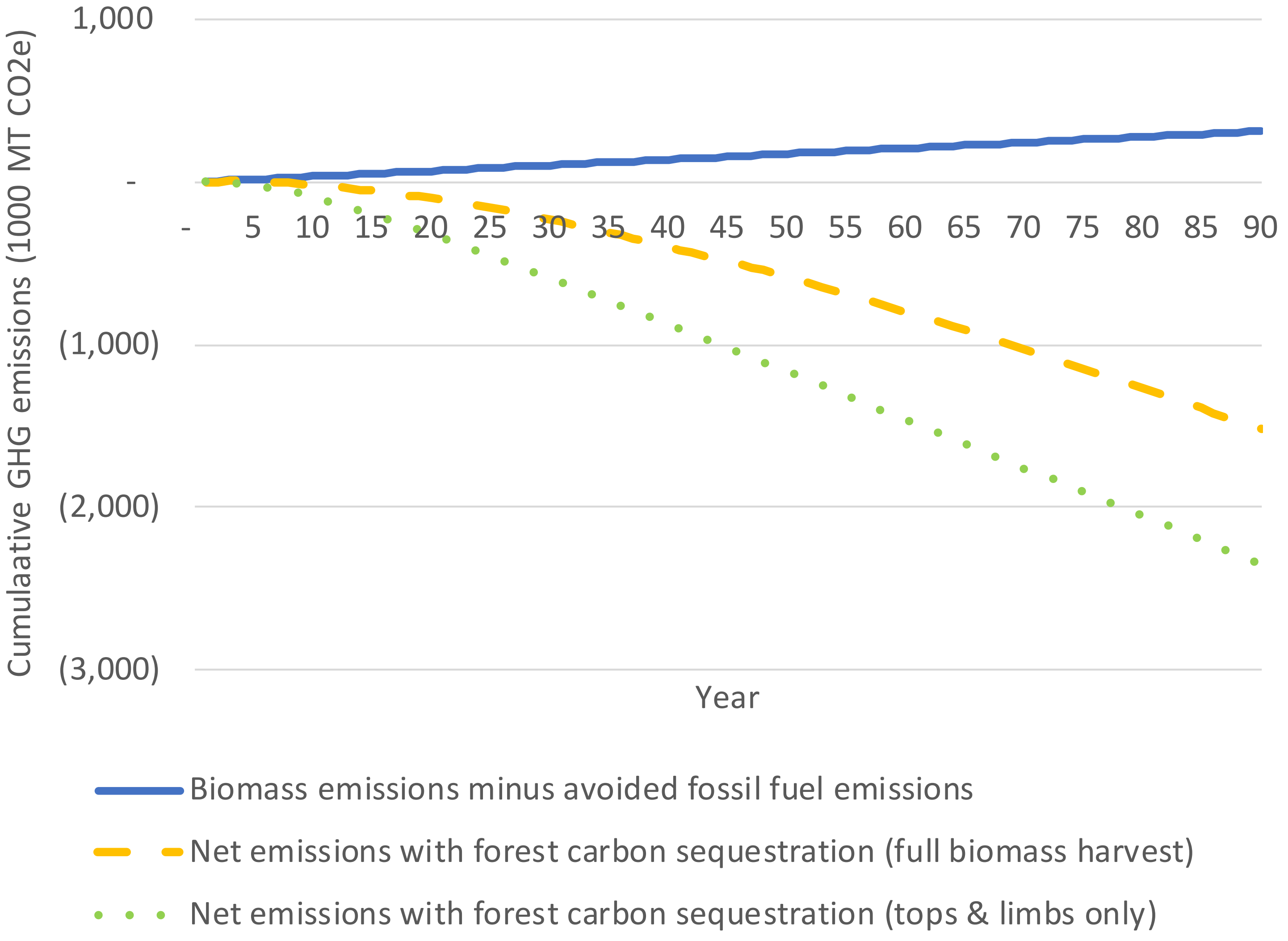
Integrated analysis of woody biomass compared to natural gas



Integrated analysis of woody biomass compared to #6 fuel oil



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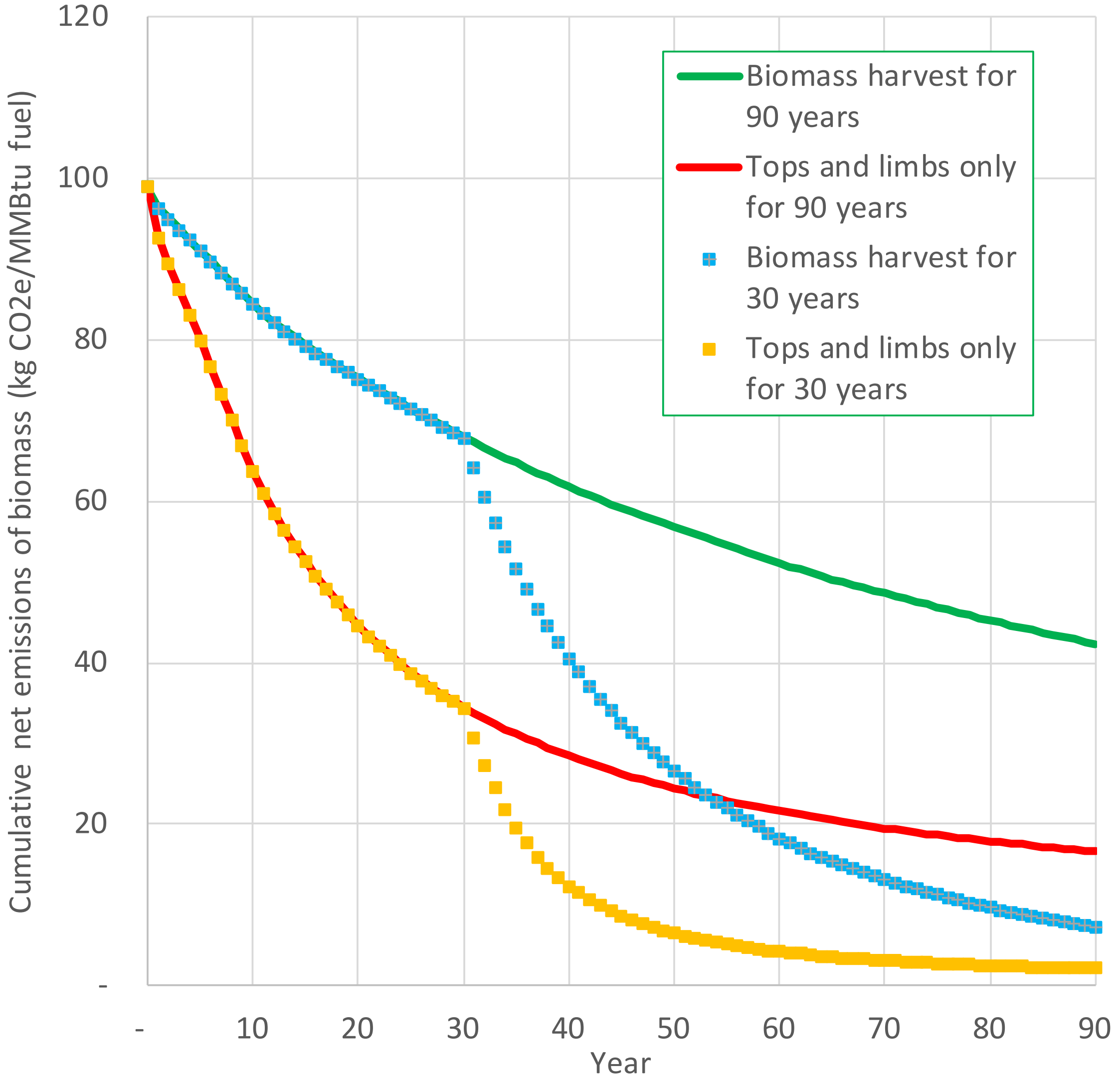
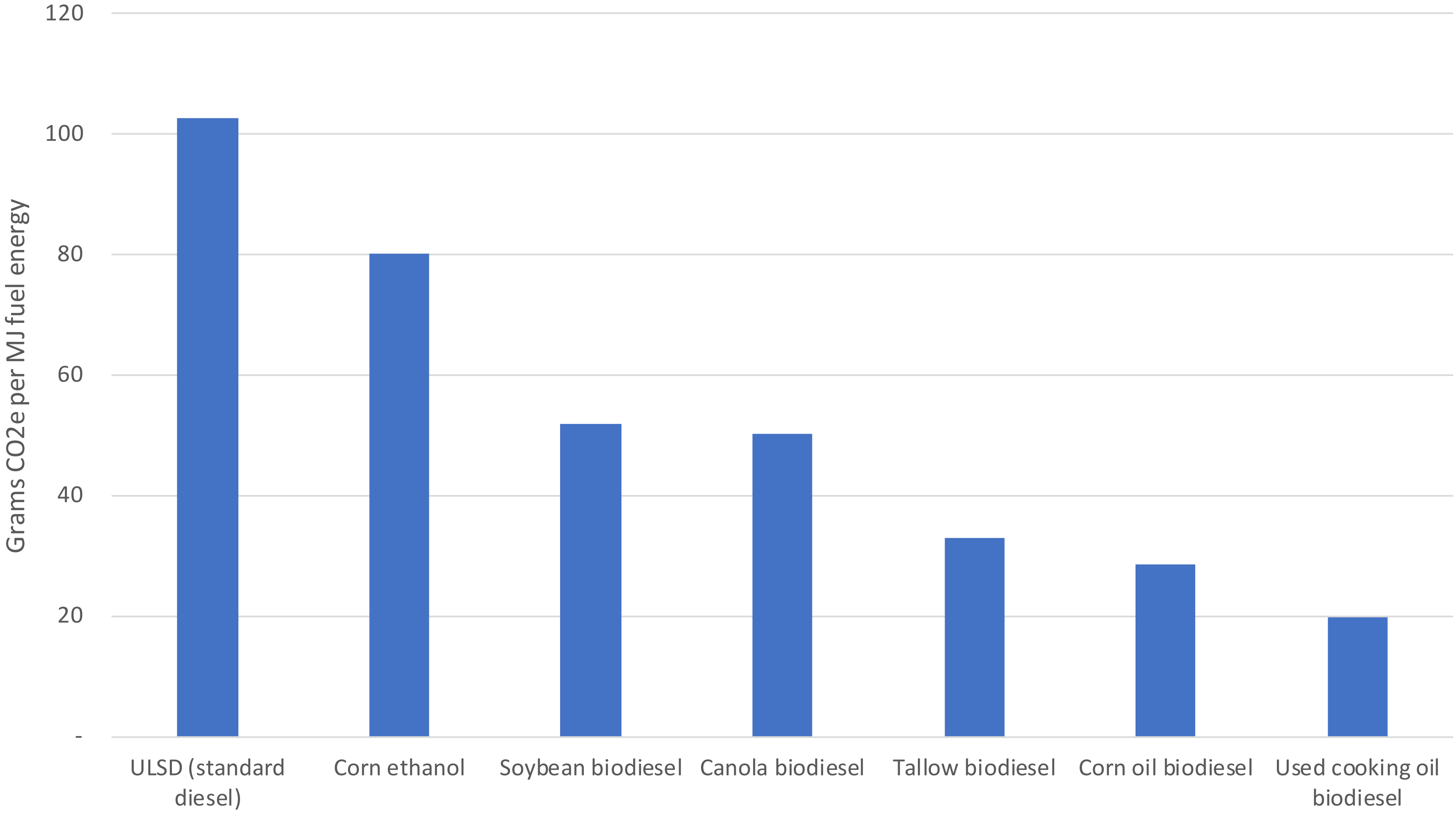
Net emissions of woody biomass per unit of fuel burned



Liquid biofuels



Source: Biofuels International, Sept. 28, 2015 http://biofuels-news.com/display_news/9701/californias_air_resource_board_lists_biodiesel_as_lowestcarbon_fuel/

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Biogas

- Emissions highly dependent on feedstocks and process technology

		Default GHG emission values (g CO2e/MJ LHV)					
		Cultivation	Processing	Upgrading	Transport	Credits	Net Total
Wet manure	no off-gas combustion	-	4.4	27.3	0.9	(111.9)	(79.3)
	with off-gas combustion	-	4.4	6.3	0.9	(111.9)	(100.3)
Corn silage	no off-gas combustion	17.6	6.0	27.3			50.9
	with off-gas combustion	17.6	6.0	6.3			29.9
Biowaste	no off-gas combustion	-	7.2	27.3	0.5		35.0
	with off-gas combustion	-	7.2	6.3	0.5		14.0

Notes:

With closed digestate tank.

Does not include land use impacts.

Does not include non-CO2 combustion emissions.

European Commission considers CO2 emissions from combustion to be zero.

Source: Solid and gaseous bioenergy pathways: input values and GHG emissions, calculated according to the methodology set in COM(2016) 767, Version 2, Giuntoli, et al, 2017

These values are used in Annex 5 of the Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources.

These values are being used as interim default values in Canada's Clean Fuel Standard - Proposed Regulatory Approach, Environment and Climate Change Canada, June 2019

Conclusions

- GHG emissions of biofuels can be credibly estimated
- Biofuels can make a contribution to GHG reduction
- GHG assessment is complicated
- Liquid biofuels have been well analyzed
- There are tools for case-specific GHG calculations
  - California Air Resources Board Tier 1 Simplified CI Calculator for Biomethane from Anaerobic Digestion of Food, Green and Other Organic Wastes (https://www.arb.ca.gov › fuels › lcfs › ca-greet › tier1-fgw-calculator)
  - GREET (Greenhouse gases, Regulated Emissions, and Energy use in Transportation) life-cycle model, Argonne National Laboratory (http://greet.es.anl.gov/)
  - U.S. Forest Service Vegetation Simulator (http://www.fs.fed.us/fmsc/fvs/)

Thanks for your attention!

Questions?

Information resources

"Energy infrastructure design for low carbon, reliability and resiliency"
Winter 2019 District Energy Magazine

"Carbon emissions from biomass: A roadmap through the maze"
Winter 2020 District Energy Magazine

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