USDA Forest Service
U.S. DEPARTMENT OF AGRICULTURE

Forest Products Laboratory
Madison, WI

Life-Cycle Assessment of Harvested Wood Products

Harvest

Transport

Manufacture

Transport

Co-products

End-use

End of life

Transport

Landfills

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Minnesota Forest Resources Council

MN Forest Resources Council Meeting
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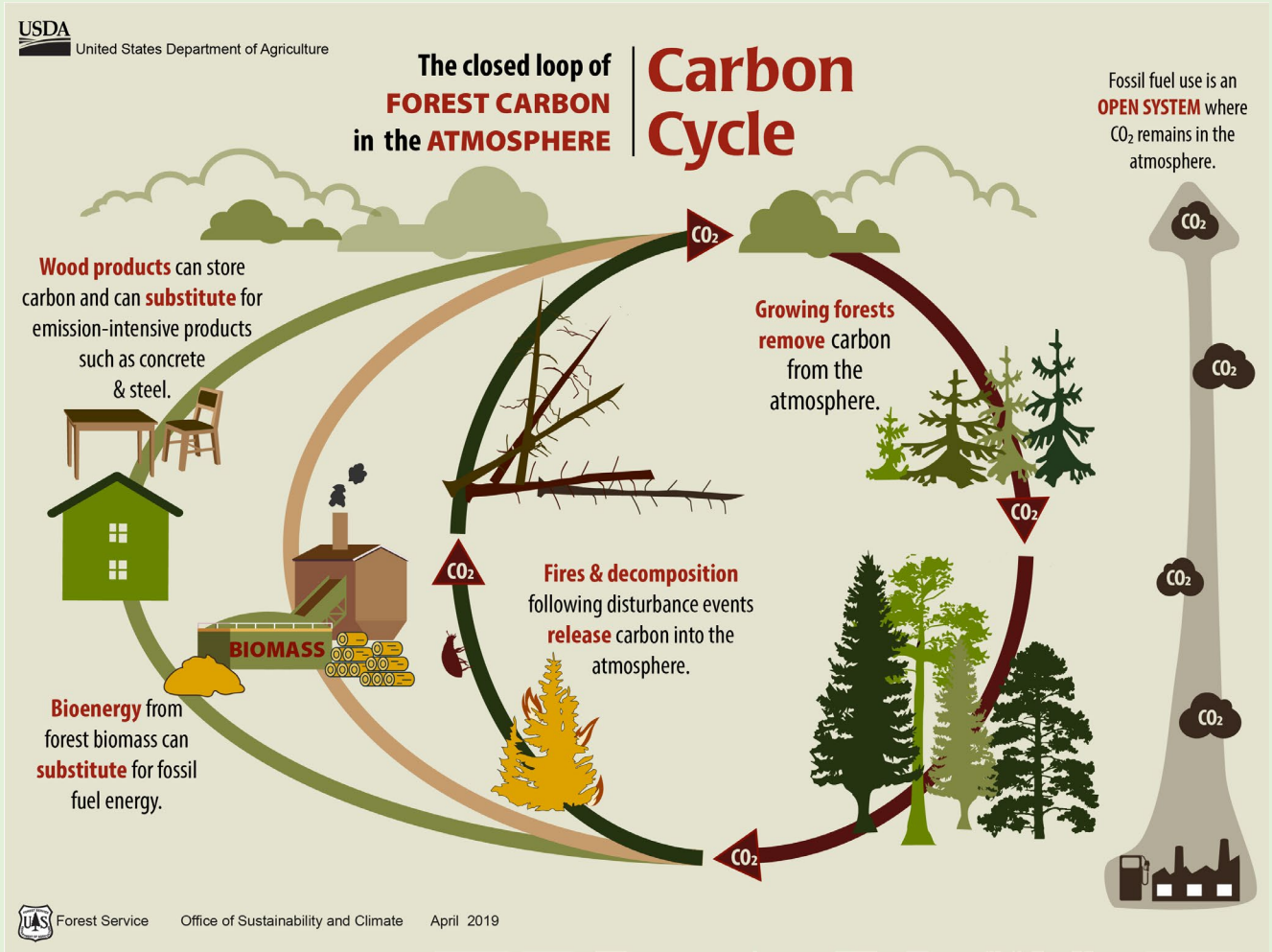
Presentation Outline

- Carbon cycle
- Life-cycle assessment (LCA)
- Harvested wood product carbon flow
- FPL's previous & ongoing LCA studies
- GHG mitigation
  - Long-term products
  - Short-term products
- Key factors affecting the GHG impacts of wood products (product and energy substitution)
- Conclusions

Carbon Cycle

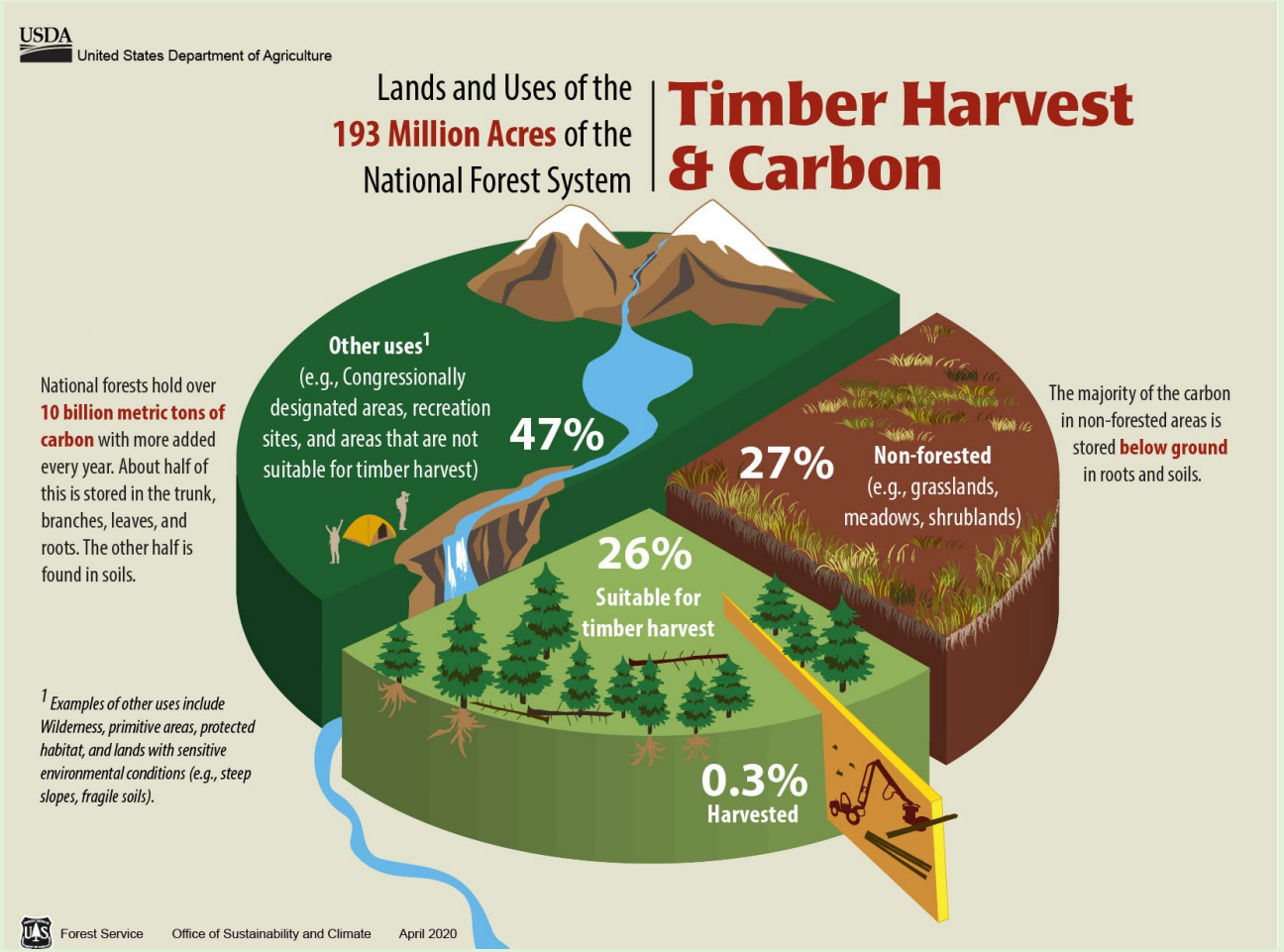
- Types
  - Fossil (anthropogenic)
    - Locked in ground
    - Fossil fuels (i.e., coal, natural gas, crude oil)
    - One-way flow
- Biomass (biogenic)
  - Natural carbon cycle
  - Plants (i.e., trees)
  - Two-way flow (renewable)



Source: https://usdagcc.sharepoint.com/sites/fs-nfs-osc/Carbon%20Resources/Carbon%20Graphis%20June%202020.pdf

Why Carbon?

- CO_2 constitutes the largest share of the greenhouse gas (GHG) emissions
- GHGs keep the Earth warm
- Too much GHGs cause a global problem (<1.5ºC)
- Natural climate solutions exist
- Forest and forest products offset ~15% of domestic CO_2 emissions annually
- Life-cycle assessment is a tool for understanding carbon footprint of a product or a process



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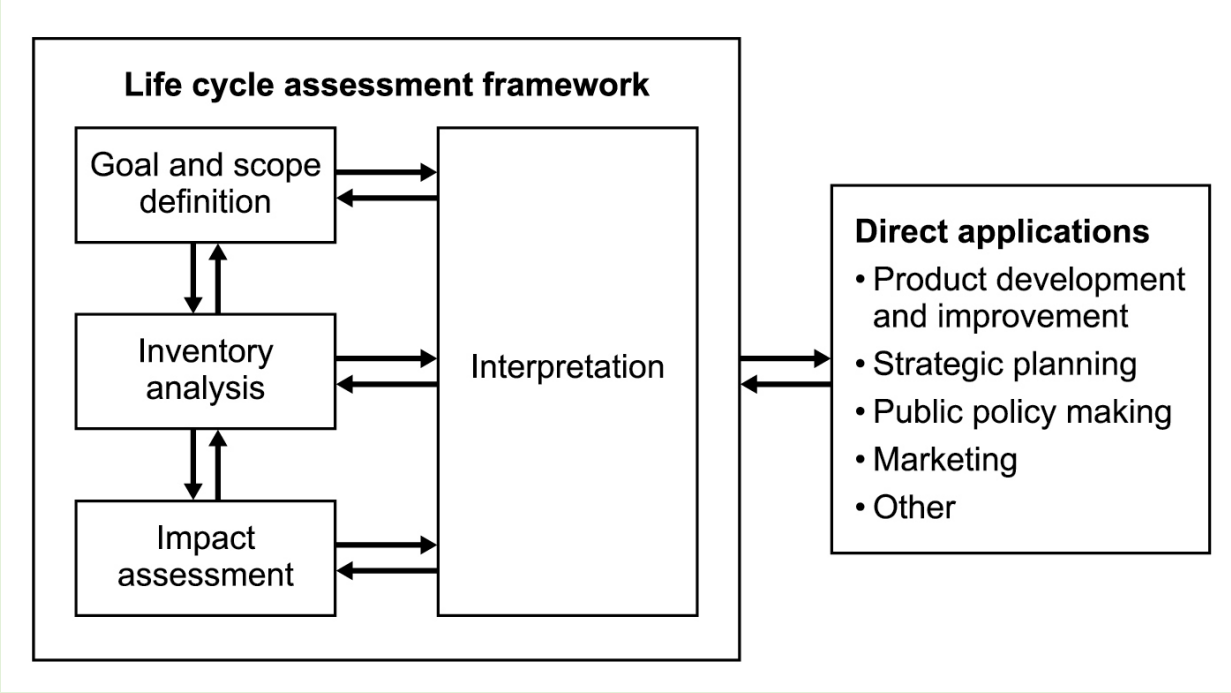
What is a Life-cycle Assessment (LCA)?

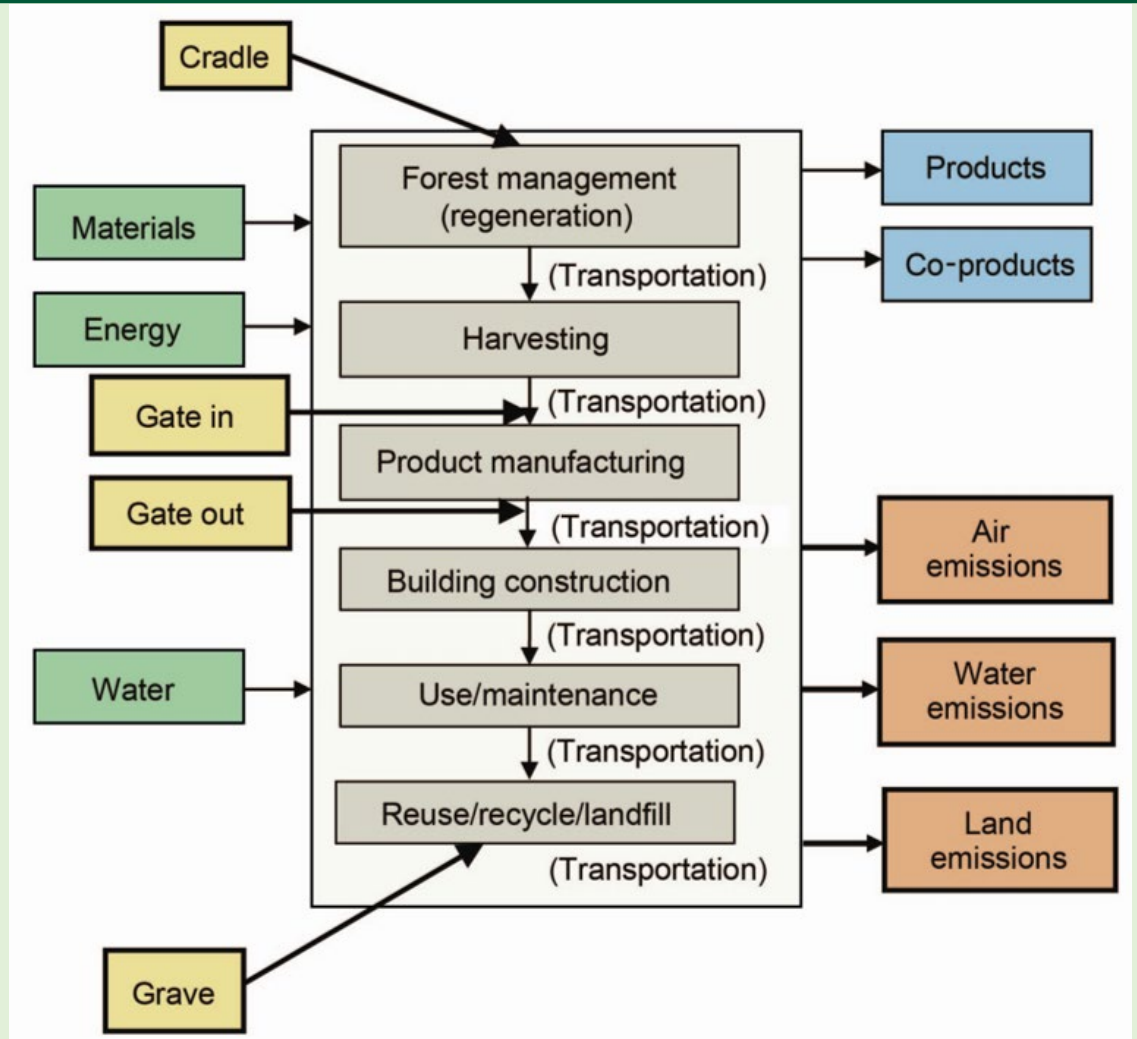
- Goal and scope
  - Define product life-cycle to be assessed
  - To what end will assessment be serving
- LCI (life-cycle inventory) measures all inputs and outputs from a single process
  - E.g., harvesting and product production
  - Part of an LCA
  - Data- and time-consuming phase ($$$)
- LCA (life-cycle assessment) analyzes these outputs from all processes for their impact on risk to human health such as from water or air pollution (GHGs)



Stages of an LCA according to ISO 14040

What is a Life-cycle Assessment (LCA)?

- Can cover parts or all of the life-cycle from cradle-to-grave (nature-to-nature)
  - Selecting system boundaries
  - Define functional or declared unit (e.g., m^3, kg, MJ, acre harvested)
  - Gate-to-gate product manufacturing for traditional wood products are data intensive
  - Gate-to-grave analyses tend to more uncertain
- >>>LCA tracks GHG (carbon) emissions along the supply chain
  - Direct (Scope 1)
  - Indirect (Scopes 2 and 3)
- Identify environmental 'hotspots'

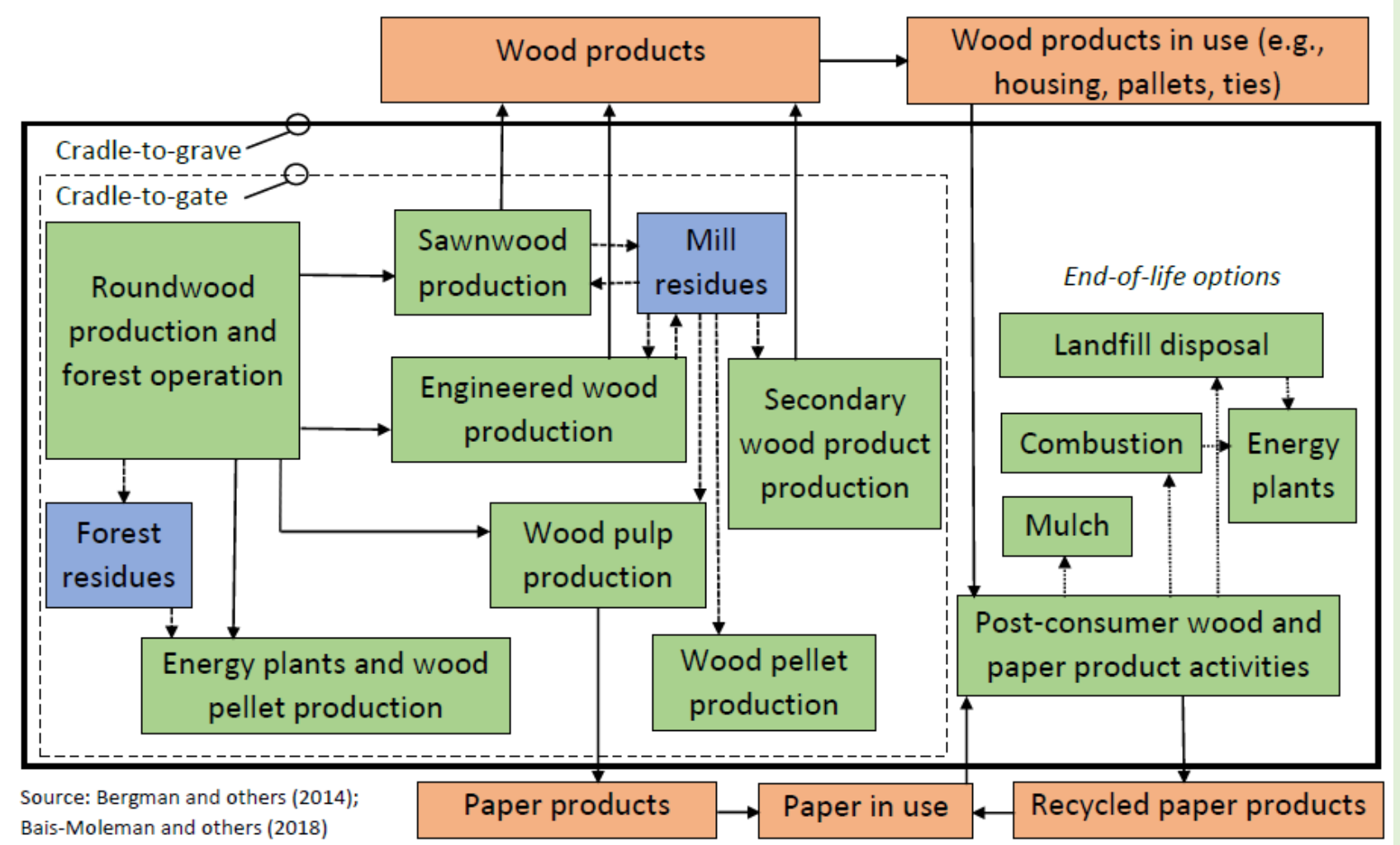


Source: Bergman et al. 2014. https://www.fs.usda.gov/treesearch/pubs/46328

Purpose of an LCA

- ❑ Environmental performance metrics
  - Estimate product carbon footprints (kg CO_2e/unit)
- ❑ Support for strategic choices
  - Show green products (procurement)
  - Compare to similar products (comparative assertion)
  - Better informed policy makers, industry, and consumers
- ❑ Benchmarking – baseline data (CORRIM: www.corrim.org)
- ❑ Life-cycle data for LCI databases
  - Publicly available datasets (US LCI and LCA Commons)
  - LCA practitioners and modeling tools

Harvested Wood Products Carbon Flow



Forest Products Lab's Climate Change (CC) Focus

Primary Research Approach (#2)

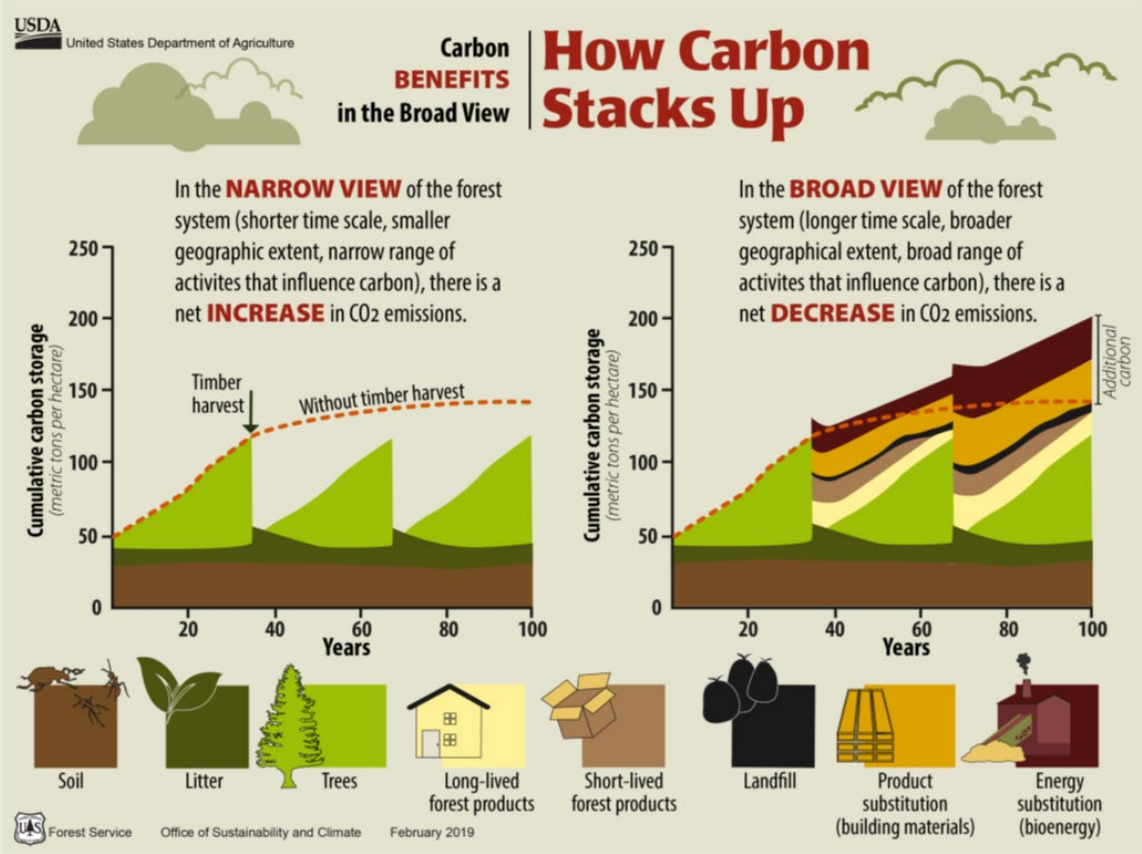
- ❑ *Mitigation -- transferring woody biomass out of forests and into wood products* (increase C sequestration and storage)

Part of FPL's Research Goals

- *Inventing new wood products from currently unused forest growth,*
- *Developing new processes to generate fuels from cellulose more efficiently*
- *Creating new equipment to minimize transportation and associated fuel costs while processing small diameter woody biomass and other residues*

Forest/Wood Products-based GHG Mitigation

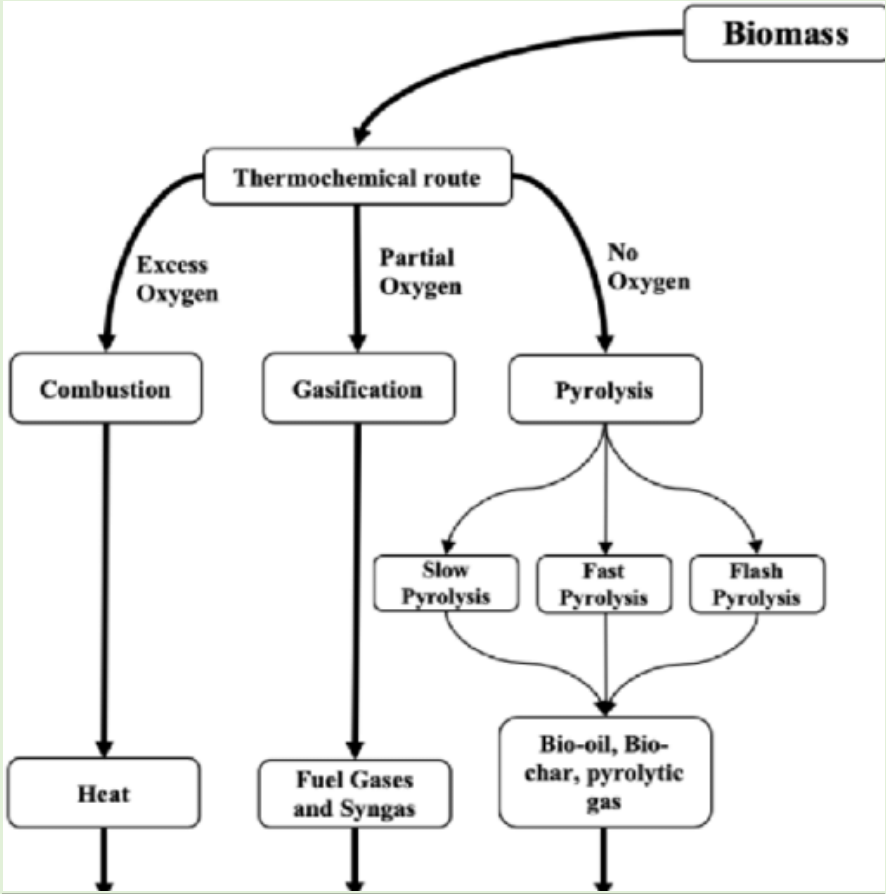
- Growing trees actively pull CO_2 from air (sequester carbon)
- Paper/pulp and durable wood products store carbon in use
  - Long-term products
    - Wood building products (large market)
    - Bioproducts [i.e., biochar] (small market)
  - Short-term products
    - Pulp and paper products (large markets)
    - Wood pellets (large markets)
    - Briquettes (small markets)
- Substitute for fossil-fuel intensive products
- Post-recovery activities (cascading/recycling)
- Life-cycle assessment can cover all stages



Forest Products Lab's CC Projects

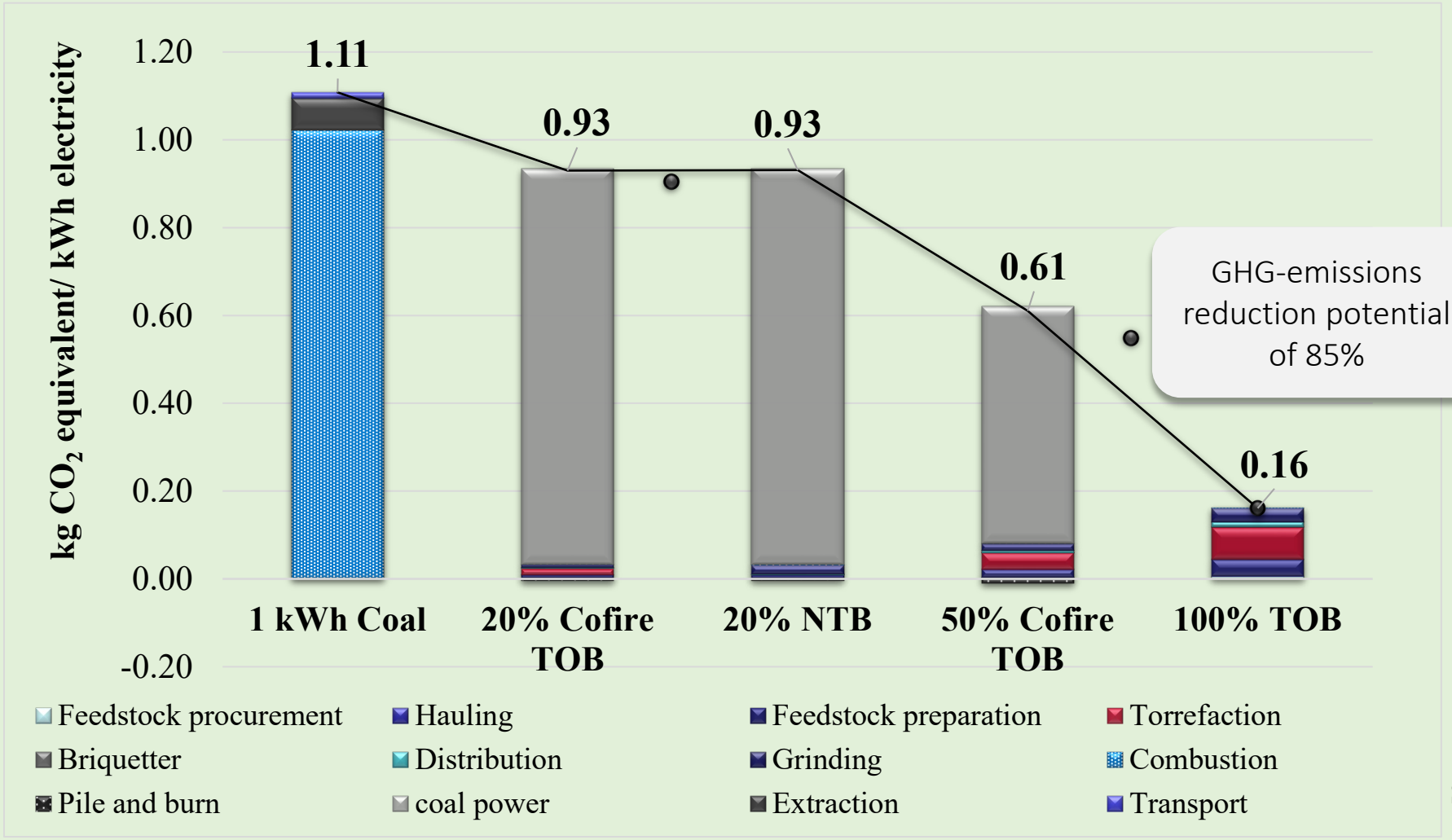
Evaluate GHG benefits from woody biomass use from forests including ones in the West (via various products and bioenergy technologies)

- Reason: Need to indicate GHG benefits of biomass removal to reduce fire hazard
- Partners: other FS research stations, universities, industry
- Projects
  - LCA of new modular thermochemical technology (electricity, biochar, and activated carbon)
    - USDA BDRI Rocky Mountain Research Station (2010-2016)
  - LCA of new thermochemical technology (high-octane gasoline)
    - USDA AFRI CAP Bioenergy Alliance Network of the Rockies (2014-2020)
  - LCAs of three mobile biomass conversion technologies (biochar, briquettes, and torrefied briquettes)
    - USDOE BRDI Humboldt State University (2012-2018)
    - Bergman et al. 2018 (Waste-to-Wisdom Final Report)
  - LCAs of multiple products from forest residues/energy crops (MASBio (2020-2025))



Source: Hamilton et al. 2020

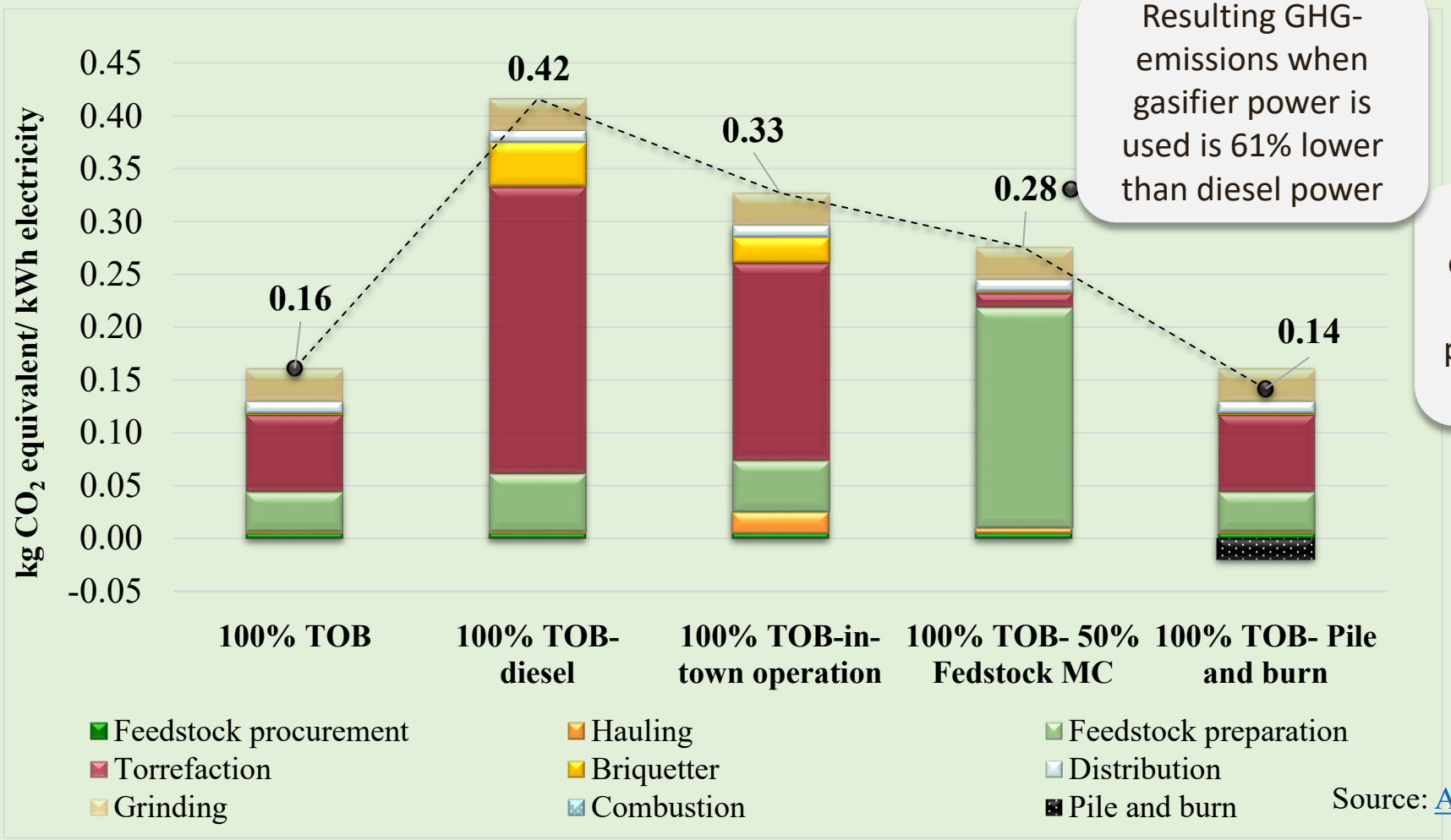
GHG impacts of Torrefied Briquette (TOB)



Comparison of global warming impact per 1kWh electricity generated from 100% coal, cofire with NTB (20%) and TOB (20%, 50%, and 100%) at coal-fired power plant.

Source: Alanya-Rosenbaum et al. 2019

GHG impacts of Torrefied Briquette (TOB)

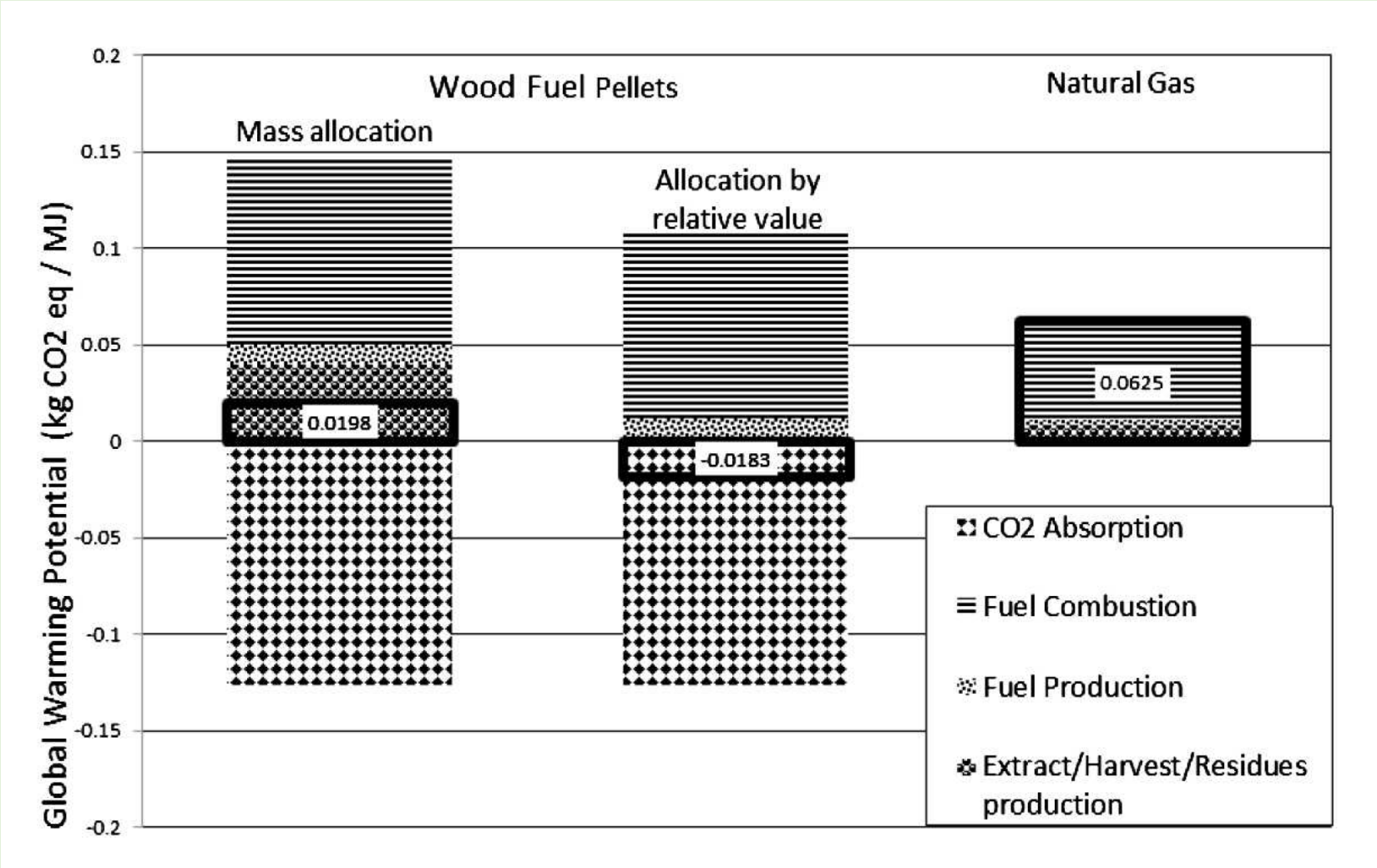


Resulting GHG-emissions when gasifier power is used is 61% lower than diesel power

51% lower GHG emission compared to in-town processing with grid electricity

Source: Alanya-Rosenbaum et al. 2019

GHG Impacts of Wood Pellets Vs. Nat. Gas



Source: Reed et al. 2012

Carbon Impacts of Wood Use for Energy

Products	Replaced fossil energy	GHG benefit (tonnes of CO_2e avoided per tonne of HWP used)
Mill Residue	Fossil-based electricity	0.270
Logging residue		0.267
Pulpwood (softwood)		0.261
Wood fuel (All types)	Coal	0.68
	Oil	0.57
	Natural gas	0.45

Source: USDA GHG Entity Report (forthcoming) – updating Hoover et al. 2014

Carbon Impacts of Wood Products

Objectives:

State how wood products can mitigate carbon emissions through biogenic carbon emissions, carbon storage, and avoiding emissions

The Wood Product Carbon Impact Equation

A-B-C-D = E

Source: Bergman et al. 2014

A = Gross carbon emissions during wood production = [fossil CO_2 + biogenic CO_2]

B = Carbon emissions from burning wood residues = [biogenic CO_2]

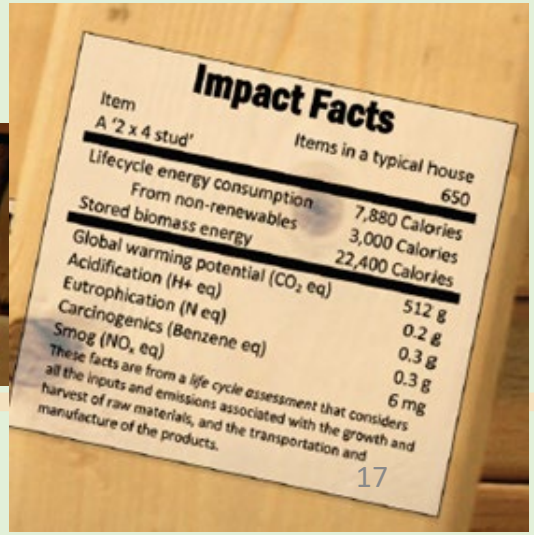
C = Carbon stored in the wood product

D = Alternate product emissions avoided = [Alternative product **fossil CO_2**]

E = Net Carbon Savings = [A - B - C - D]

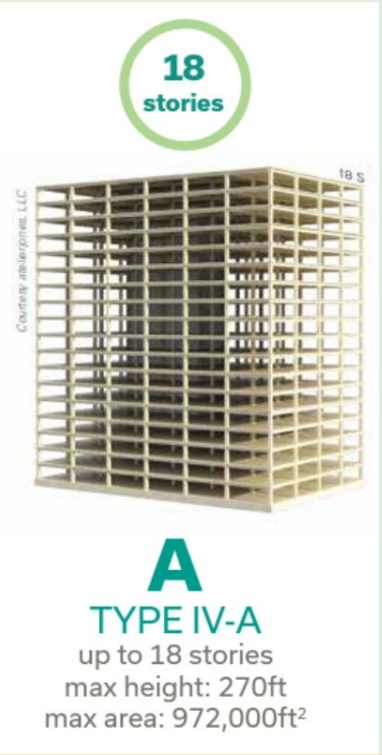
Forest Products Lab's CC Projects

1. Develop LCAs for wood building products that include GHG and other emissions
   - Reason: Needed for use in EPDs (market access) and whole and green building designs (Athena Impact Estimator for Buildings)
   - Partners: CORRIM, US Endowment, Athena Sustainable Materials Institute, Federal LCA Commons, wood industry, wood product associations
2. Develop environmental product declarations (EPDs) for wood products
   - Reason: Green building certification systems and structure designers generally can use EPDs to choose materials with low environmental burdens (No. 1 industry objective)
   - Partners: CORRIM, American Wood Council, Canadian Wood Council



Forest Products Lab's CC Projects (cont..)

3. The potential for tall wood buildings to sequester carbon, support forest communities and create new options for forest management (2018-2021)
   - Reason : Evaluate environmental and economic feasibility of using mass timber for non-residential construction
   - Partners: NCSU, LEVER Architecture, US Endowment, Dovetail Partner Inc.
   - Outcome: Project results will incorporate a multi-attribute decision support tool to allow for the analysis of trade-offs and used to focus the public discussion on the benefits and costs of the wide-scale deployment of cross-laminated timber (CLT) manufacturing and building systems
   - Similar project with The Nature Conservancy on a global scale

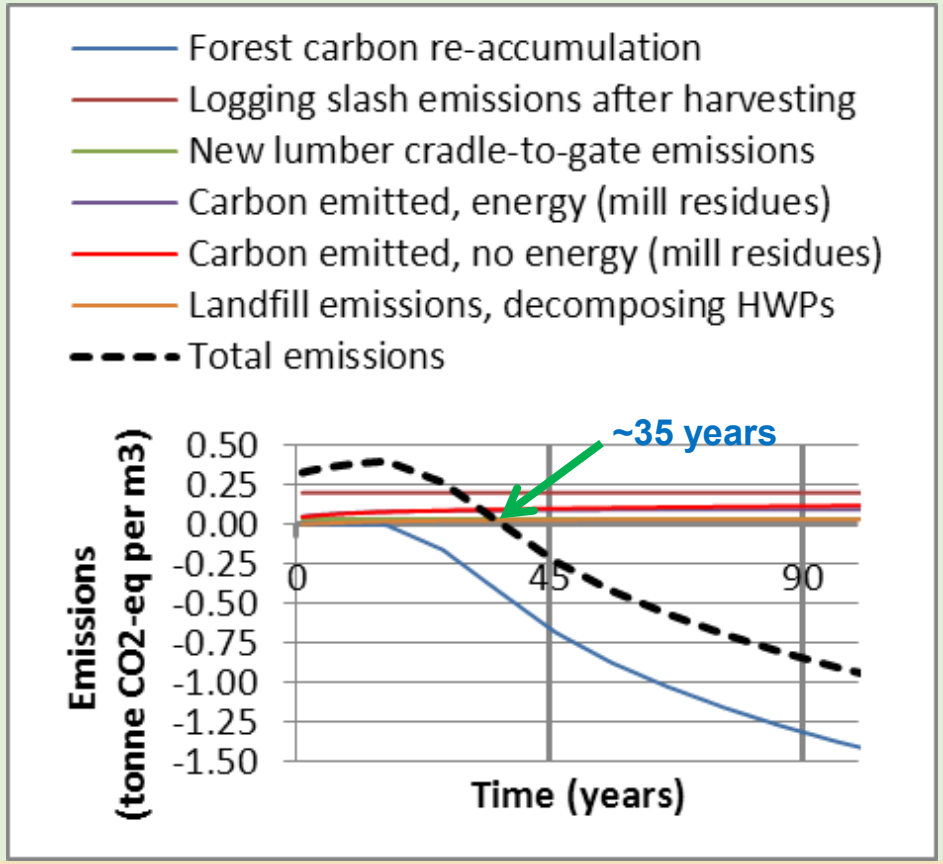


Carbon Impacts of Wood Use in Construction

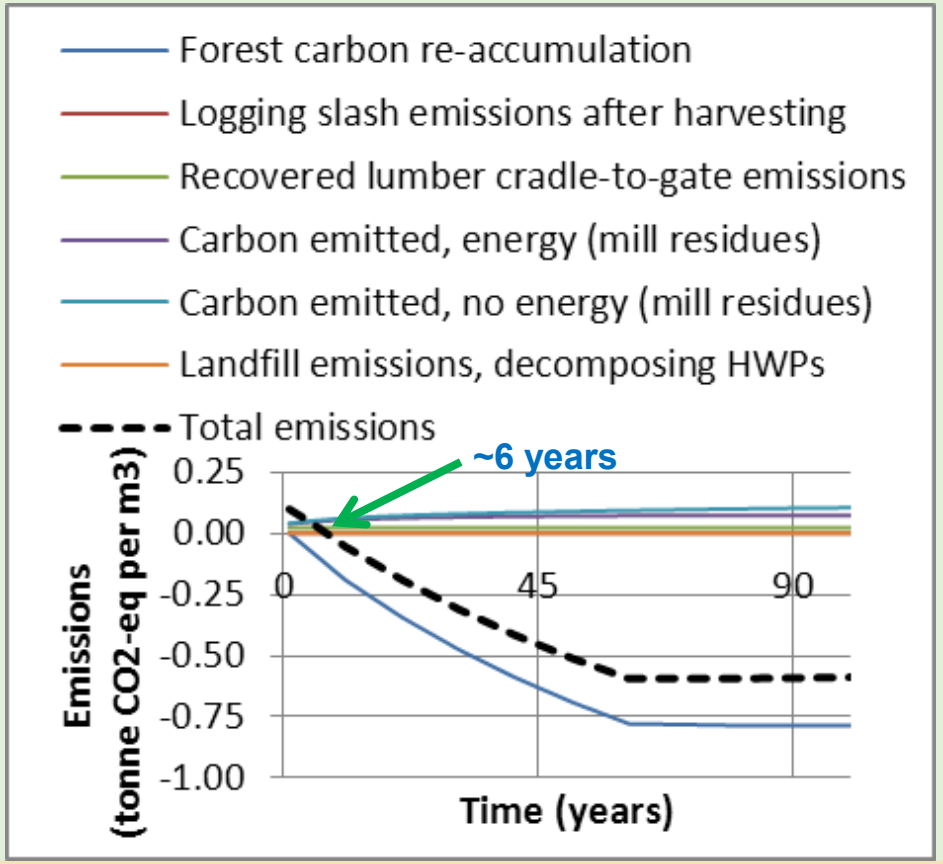
Products	Replaced non-wood products	GHG benefit (tonnes of CO_2e avoided per tonne of HWP used)	Source
Softwood lumber	Steel Studs	0.99	Bergman et al. (2014)
SW lumber, Plywood, OSB combined	Structural material in non-residential construction	2.03	Nepal et al. (2016)
Hardwood lumber	Doors	2.29	Bergman et al. (2014)
Non-structural panels	Non-structural construction materials	1.6	Leskinen et al. (2018)
Cross-laminated timber (CLT)	Steel/Concrete in tall wood buildings	0.69	Avg. estimated values from various US mass timber projects

Dynamic GHG emission profile (1 of 2)

GHG emissions for the new wood scenario for the Pacific Northwest stand



GHG emissions for the recovered wood scenario for the Pacific Northwest stand



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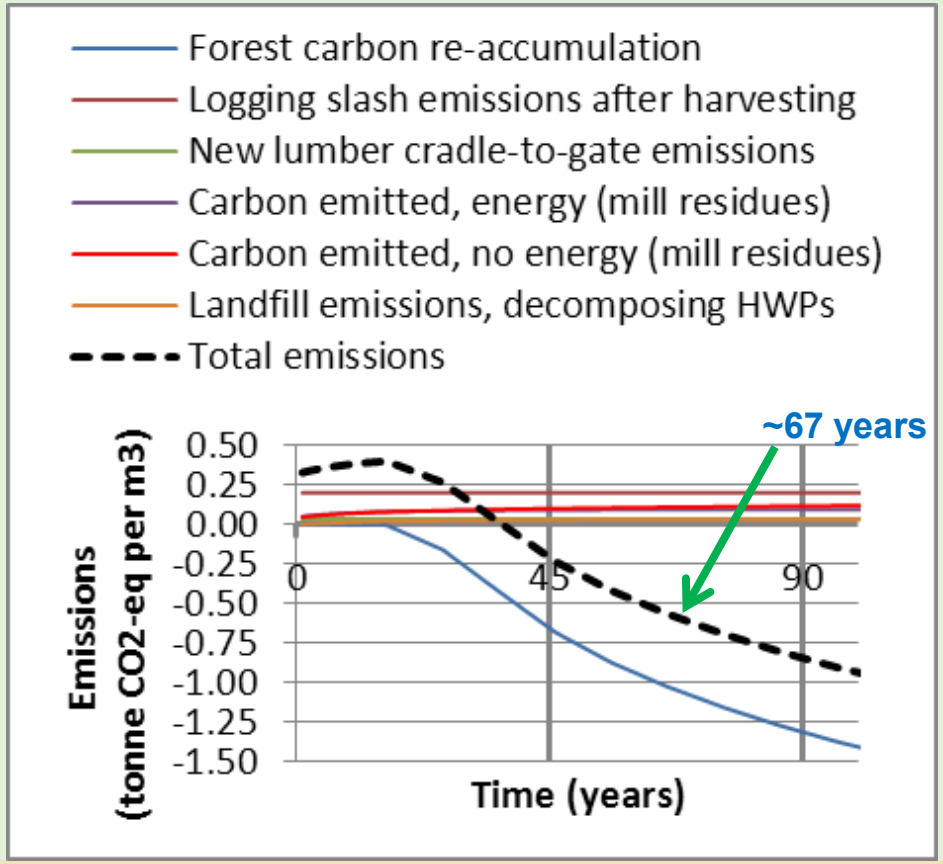
Time for total GHG emissions *to go below zero*

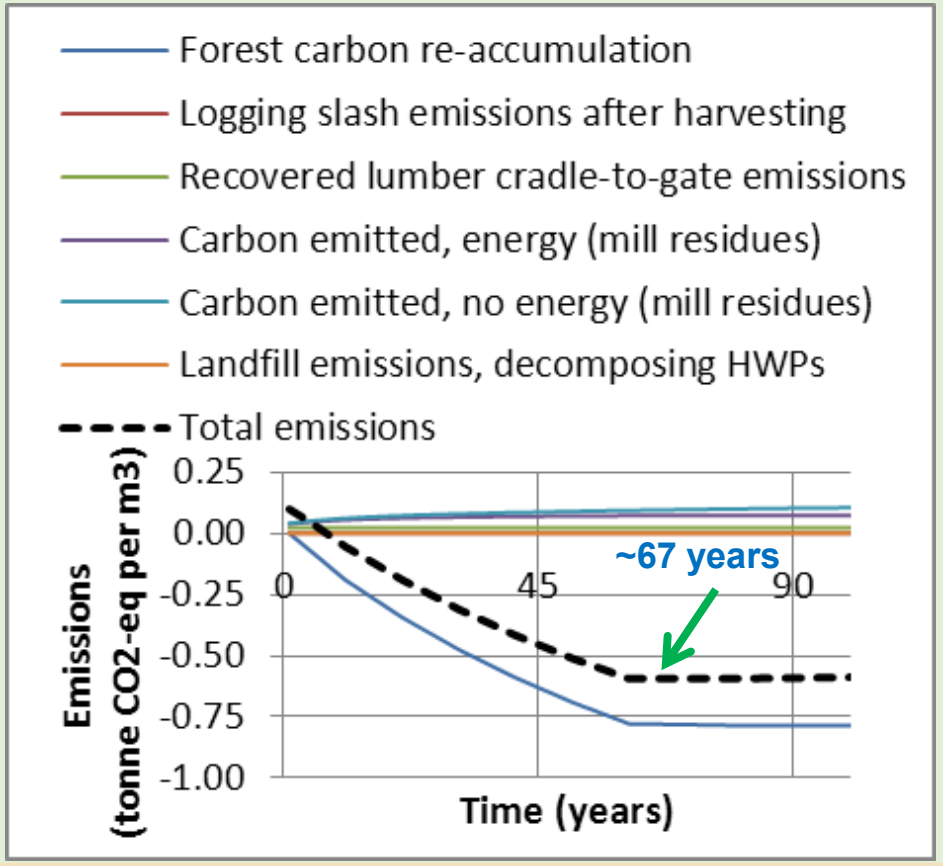
Bergman et al. 2012 https://www.fs.usda.gov/treesearch/pubs/42089

Dynamic GHG emission profile (2 of 2)

GHG emissions for the new wood scenario for the Pacific Northwest stand



GHG emissions for the recovered wood scenario for the Pacific Northwest stand



Time when two scenarios *are equal*

Bergman et al. 2012 https://www.fs.usda.gov/treesearch/pubs/42089

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Forest Products Lab's CC Projects

- Resource Planning Act (RPA) Assessment (2025 Update)
  - Forest sector GHG mitigation
  - Consequential LCA – What if scenarios
- Pacific Northwest Research Station Carbon Initiative (2021-?)
  - Projecting state-wide harvested wood products and substitution impacts
  - West Coast states (CA, OR, and WA)
- Integrate LCA and techno-economic analysis (TEA)
  - USDA/USDOE projects
  - P3Nano (nanocellulose)
- Integrate LCA and life-cycle cost analysis of buildings
- Urban forests and forest products
- Wood building deconstruction (end of life)

Key factors affecting GHG benefits of wood products

- System boundary (broad (forest system) vs narrow (plot level))
- Reference vs alternate products/cases baseline (counterfactual)
- Time frame considered
  - Short-term impacts vs. long-term impacts
  - Time for forest to regrow
- Types and sources of feedstock
  - Plantation vs. natural forests
  - Mill residues vs logging residue vs roundwood use
- Materials/fuels being replaced (avoided)
  - Materials (e.g., concrete, steel, plastic); type of products (buildings, pallets, waste treatment)
  - Fossil fuels (e.g., coal, oil, natural gas); type of energy (heat vs electricity)
- Market impacts
  - Market competition for wood among different uses
    - E.g., biomass for energy use vs. traditional (pulp and paper)
    - E.g., lumber production for use in wood-framed construction vs. CLT production
  - Land-use/land-use change (deforestation)
  - Tree planting policy initiatives (intensifying, resilient, faster-growing, afforestation, etc.)
- Dynamic vs static LCA

Summary and Conclusions

LCA

- LCA is globally accepted tool to evaluate environmental impact of a product or a service through its entire life
- LCA helps making informed policy choice

FPL

- FPL is engaged in various studies to better understand GHG impacts of a range of wood products
- Collaboration with various partners

GHG impacts of wood products

- GHG impacts of wood products vary depending on system boundary, dynamic vs static LCA, reference vs. alternate case, time horizon, non-wood materials/fossil-energy being replaced

Thank You !

Questions?

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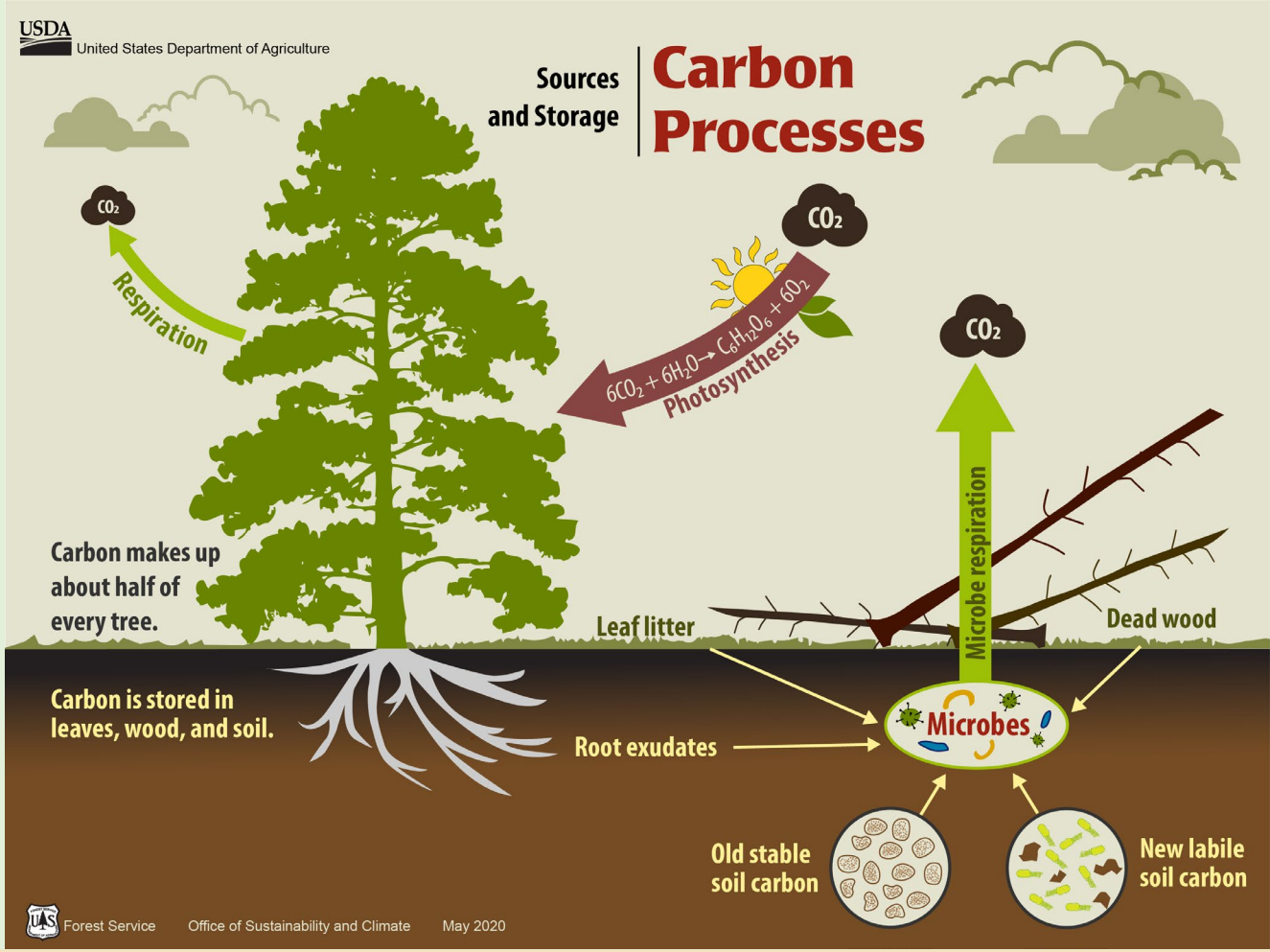
Acknowledge: Dr. Prakash Nepal

What is Carbon?

- Carbon (C-12)
  - 4th most common element
  - Trees are ~50% C (oven dry weight)
  - Forest products are the same
  - Trees consume ~1.83 kg CO_2 to produce 1 kg of wood or 0.5 kg C



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