Forest Biomass for Biochar Production

Biomass harvest on a fuel treatment in San Juan National Forest.

The Tucker RNG biomass gasification system developed in partnership with USFS.

Chips and biochar produced from biomass harvested on the White River National Forest.

Nate Anderson, Research Forester
U.S. Forest Service, Rocky Mountain Research Station

Photos: Anderson

What's ahead?

- Background
- Useful frameworks
- Biomass challenges
- Biomass solutions
- Conclusions

Forest operations on a BANR project study site in the Colorado State Forest.

Photos: Anderson

U.S. Forest Service Biochar Webinar Series

1.	Biochar: What is it? – Debbie Page-Dumroese	Recorded
2.	Biochar Production Technologies – Tom Miles	Recorded
3.	Biochar from Forest to Farm – Jim Archuleta	Recorded
4.	**Forest Biomass for Biochar Production – Nate Anderson**	**June 25**
5.	**The Economics of Biochar** – Dan McCollum	July 23
6.	**Biochar for Innovative Products** – Kathleen Draper	August 20
7.	**Feasibility Assessments of Biochar Production** – Sahoo Kamalakanta	September 24
8.	**Biochar as Carbon Negative Technology** – Carlos Rodriguez Franco	November 12

USDA

Southern Regional Extension Forestry

http://www.forestrywebinars.net/

USFS-RMRS Biomass Research Partners

Government & University	Industry Partners & Advisors	Funding & In-kind Support
USFS Research and Development	Biochar Solutions, Inc.	U.S. Department of Agriculture
USFS National Forest System	Boulder County Parks	U.S. Department of Energy
USFS Technology and Development Program	Burning Oak Energy, LLC	National Institute of Food and Agriculture
Colorado State Forest Service	Confluence Energy	Biomass Research and Development Initiative
Colorado State University	Cool Planet Energy Systems	U.S. Forest Service
Humboldt State University	Eagle Valley Clean Energy	Bioenergy Alliance Network of the Rockies
Oregon State University	NOVO Biopower	Waste to Wisdom
Northern Arizona University	Pueblo Wood Products	Industry partners
University of Idaho	The Arvos Group	
University of Montana	Tucker Engineering Associates	
	Logging contractors throughout the West	





Photos: Anderson

Conclusions

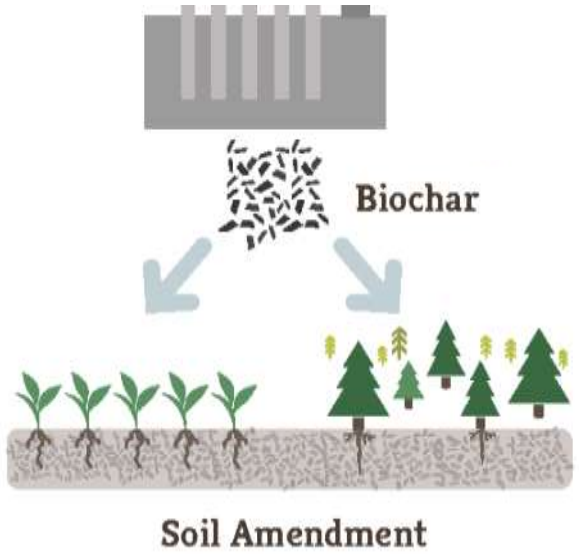
- The big picture is critical
- Challenges are significant
  - Need, access, logistics, and markets
- Solutions are evolving
  - Improving logistics
  - Adding value
- Improvements are possible
  - Decrease costs
  - Increase value
  - Diversify and expand markets
  - Reach appropriate scale

Biomass from beetle salvage in Colorado State Forest (top) and biochar application on Lolo National Forest, Montana.

Photos: Anderson

Frameworks: Biochar Systems

- Biochar for soil



Frameworks: Biochar Systems

- Biochar systems
  - Soil benefits
  - Waste management
  - Renewable energy
  - Carbon sequestration

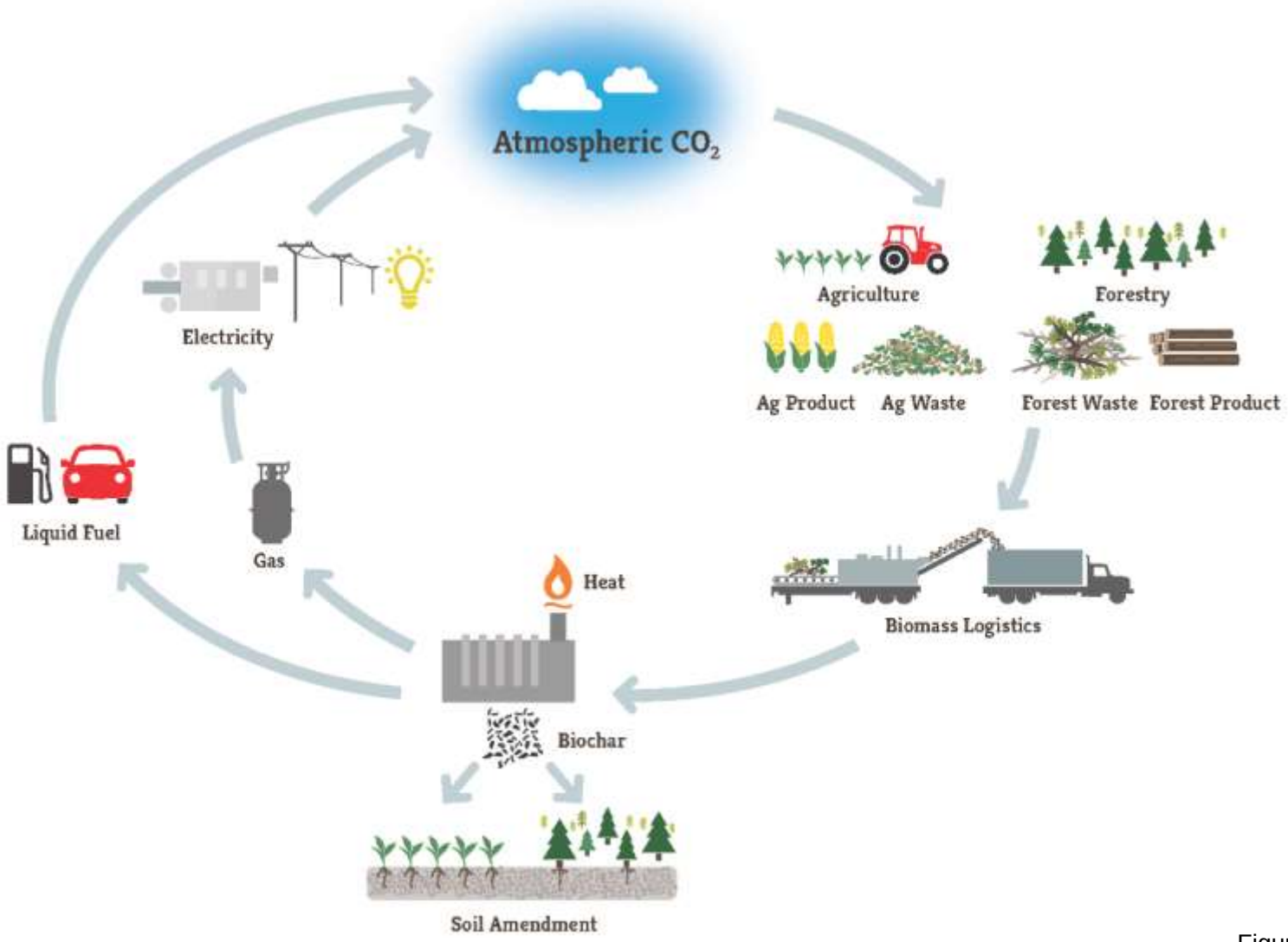
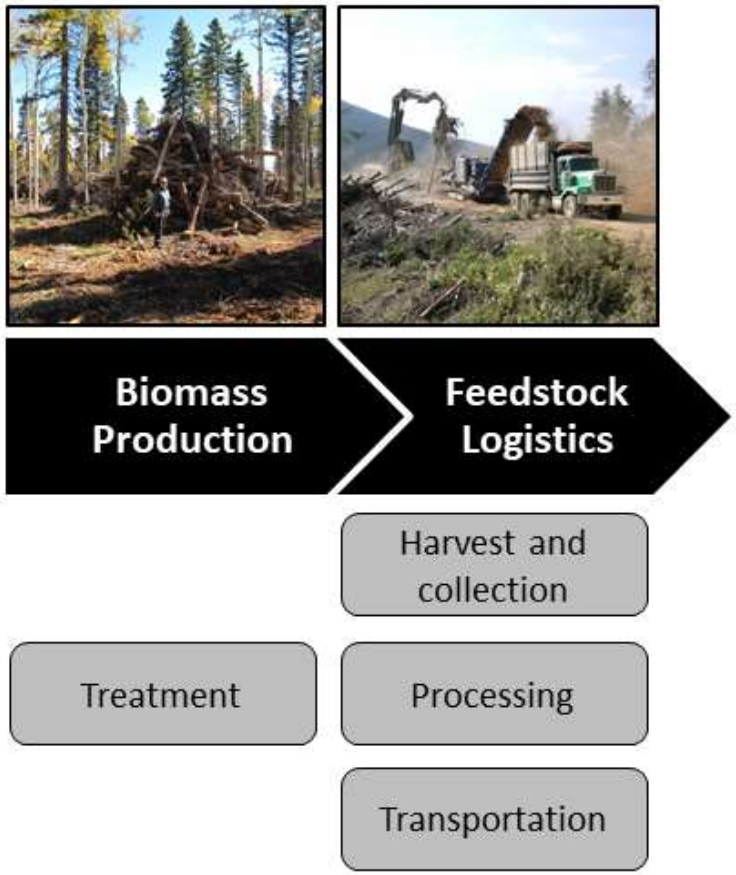


Figure: RMRS 2015

Frameworks: Supply Chain Management

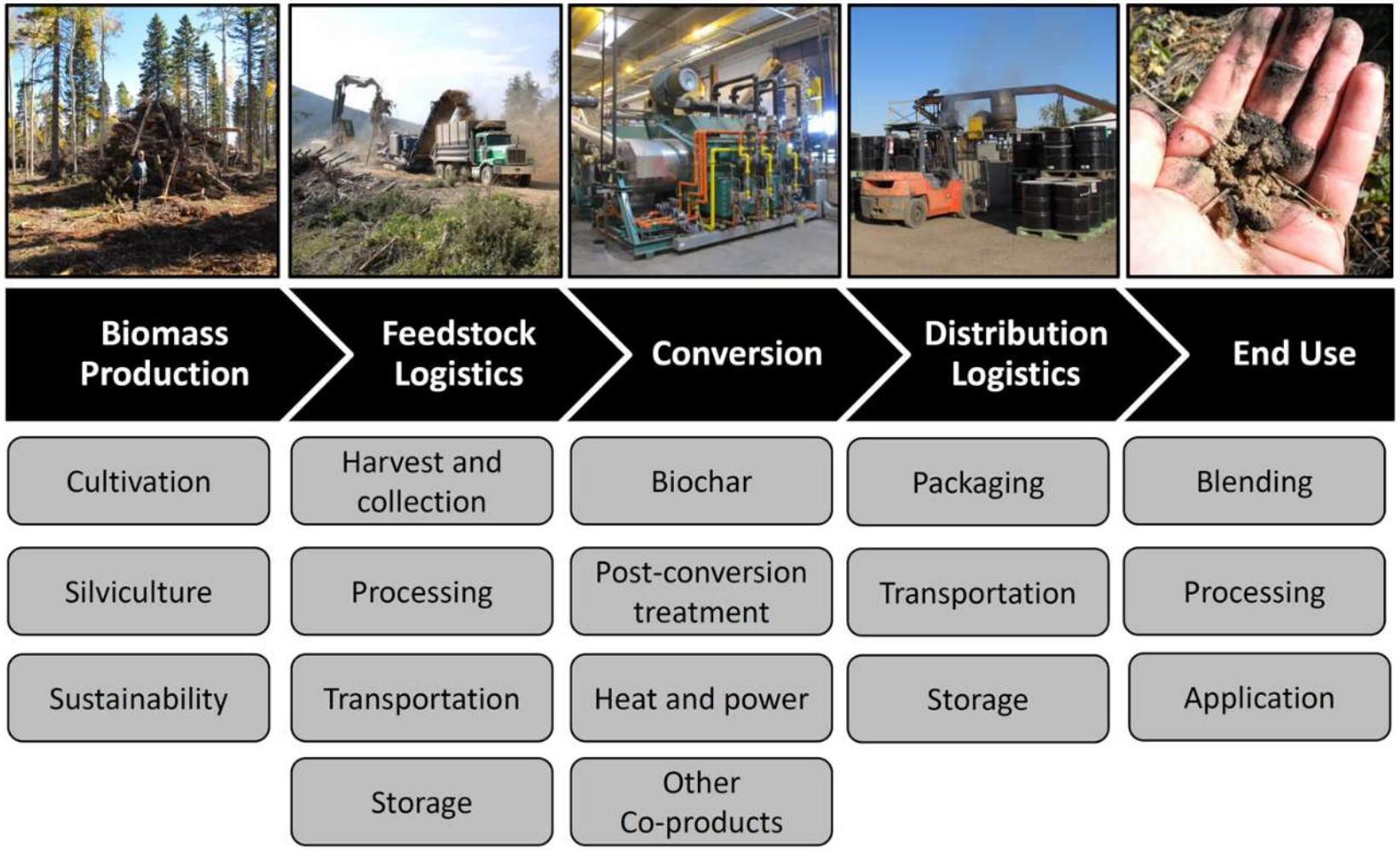
- Biochar systems
- Biomass supply chain



Photos: Anderson

Frameworks: Supply Chain Management

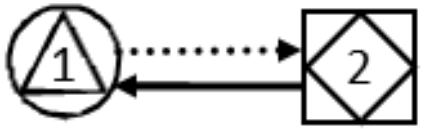
- Biochar systems
- Bioproducts supply chain
  - Production
  - Feedstock logistics
  - Conversion
  - Distribution logistics
  - End use



Anderson et al. 2017. Chapter 2 in *Biochar: A Regional Supply Chain Approach in View of Climate Change Mitigation*, Cambridge University Press. (Photos: Anderson)

Frameworks: Supply Chain Management

- Biochar systems
- Bioproducts supply chain
- A business relationship

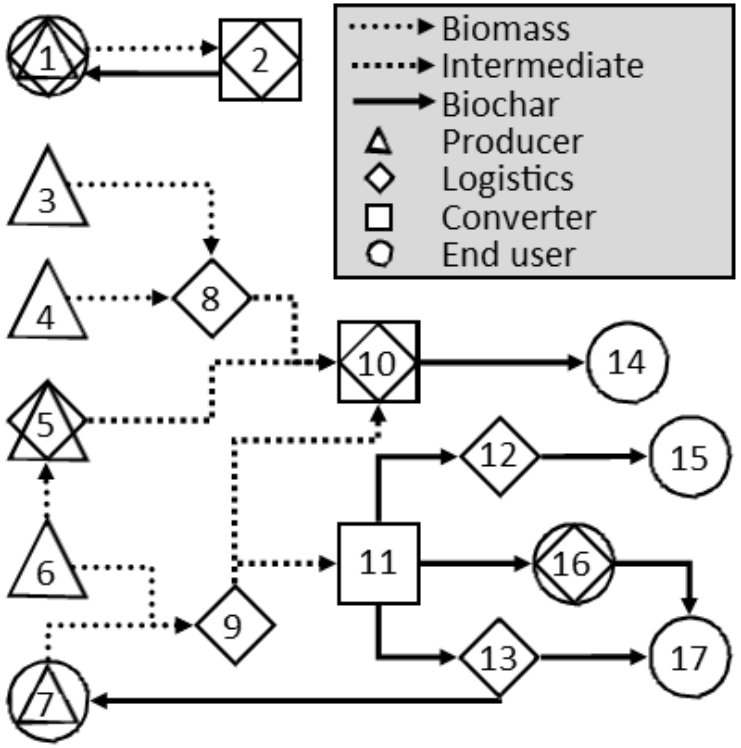


Biomass Production	Feedstock Logistics	Conversion	Distribution Logistics	End Use
Cultivation	Harvest and collection	Biochar	Packaging	Blending
Silviculture	Processing	Post-conversion treatment	Transportation	Processing
Sustainability	Transportation	Heat and power	Storage	Application
	Storage	Other Co-products		

Anderson et al. 2017. Chapter 2 in *Biochar: A Regional Supply Chain Approach in View of Climate Change Mitigation*, Cambridge University Press. (Photos: Anderson)

Frameworks: Supply Chain Management

- Biochar systems
- Bioproducts supply chain
- Industrial ecology



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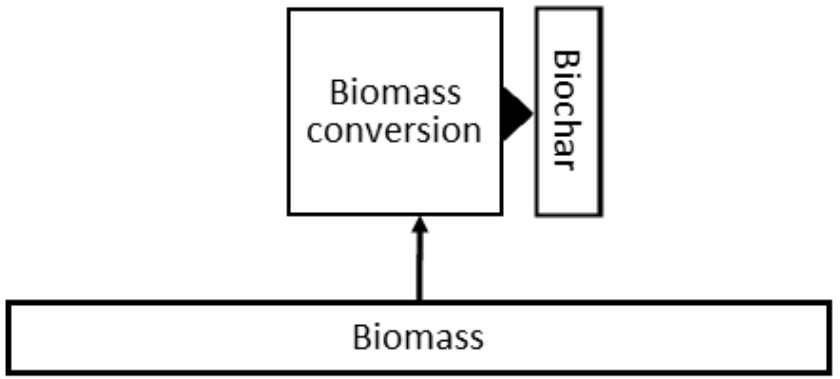
	Storage	Other Co-products		

Anderson et al. 2017. Chapter 2 in *Biochar: A Regional Supply Chain Approach in View of Climate Change Mitigation*, Cambridge University Press. (Photos: Anderson)

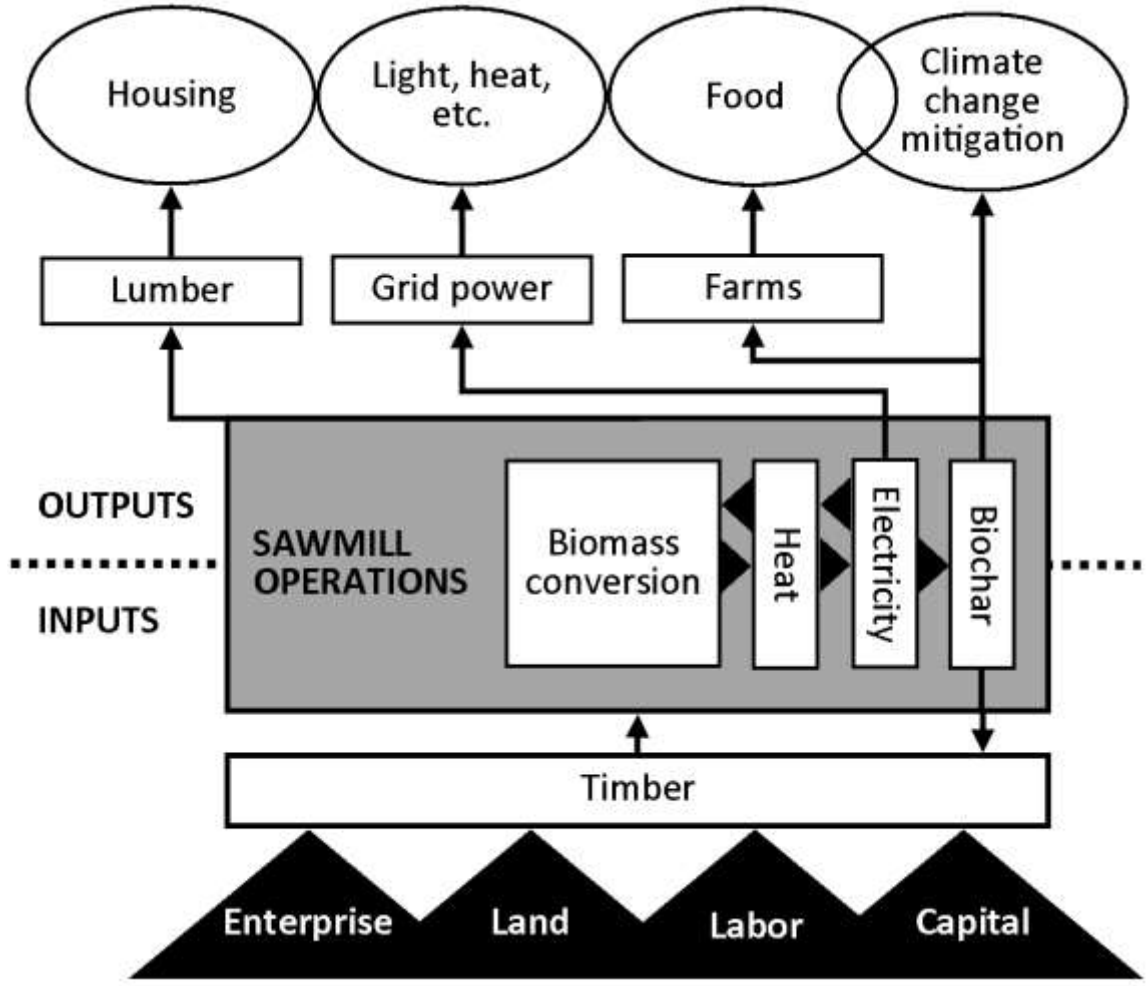
Frameworks: Derived Demand

- Biochar systems
- Bioproducts supply chain
- Industrial ecology
- Demand for intermediates



Frameworks: Derived Demand

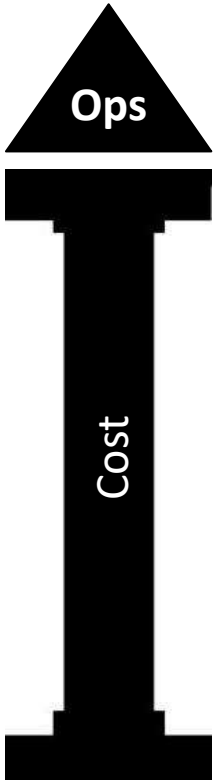
- Biochar systems
- Bioproducts supply chain
- Industrial ecology
- Demand for final products



Anderson et al. 2017. Chapter 2 in *Biochar: A Regional Supply Chain Approach in View of Climate Change Mitigation*, Cambridge University Press.

Frameworks: Sustainable Forest Operations

- Biochar systems
- Bioproducts supply chain
- Industrial ecology
- Demand for final products
- Feedstock cost



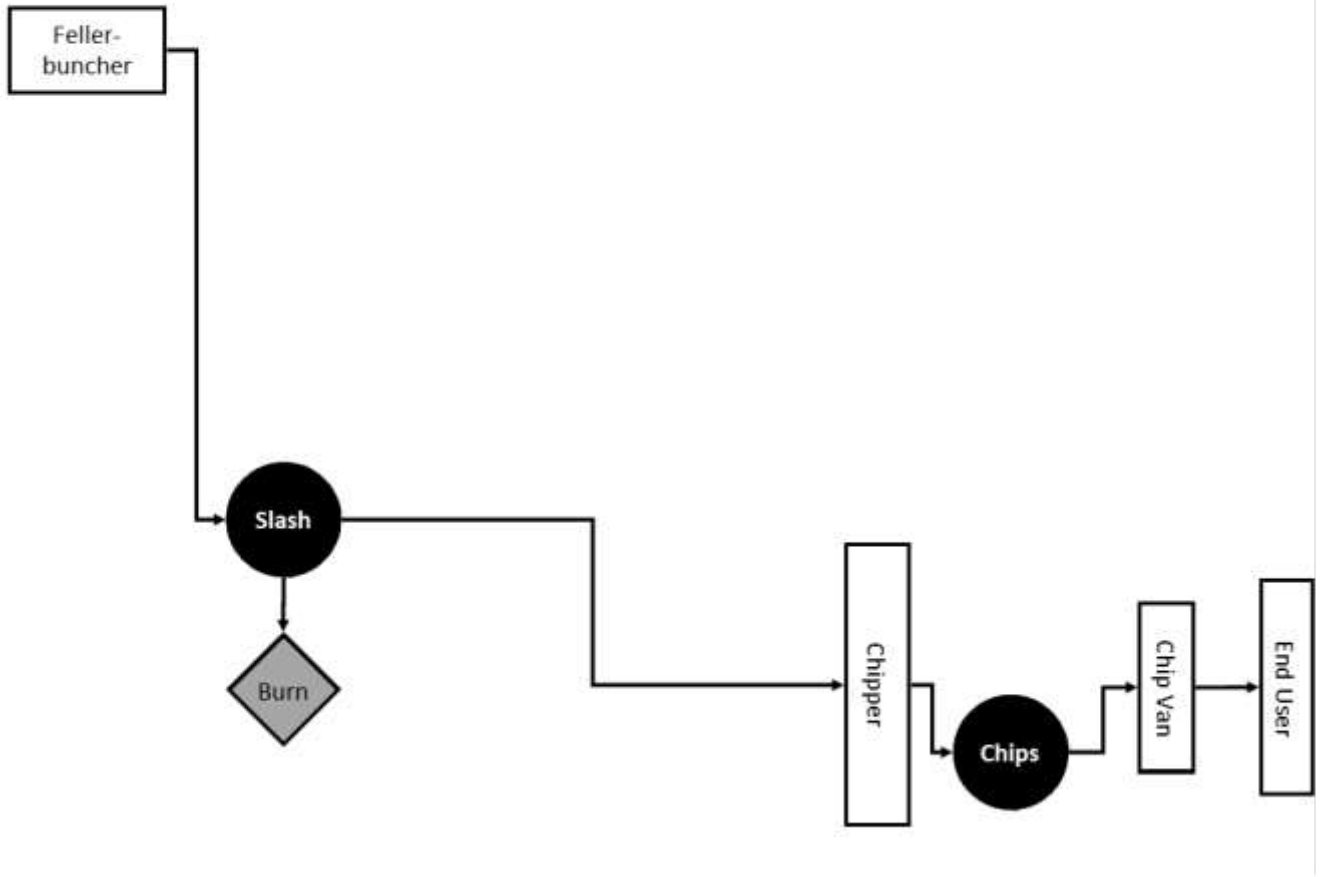
Frameworks: Sustainable Forest Operations

- Biochar systems
- Bioproducts supply chain
- Industrial ecology
- Demand for final products
- Sustainable Forest Operations
  - Efficient, safe and green
  - Focus on the bioeconomy, ecology, human factors and society
  - Across multiple scales, from local to regional to global

Marchi, et al. 2018. Sustainable Forest Operations (SFO): A new paradigm in a changing world and climate. *Science of the Total Environment* 634: 1385-1397.

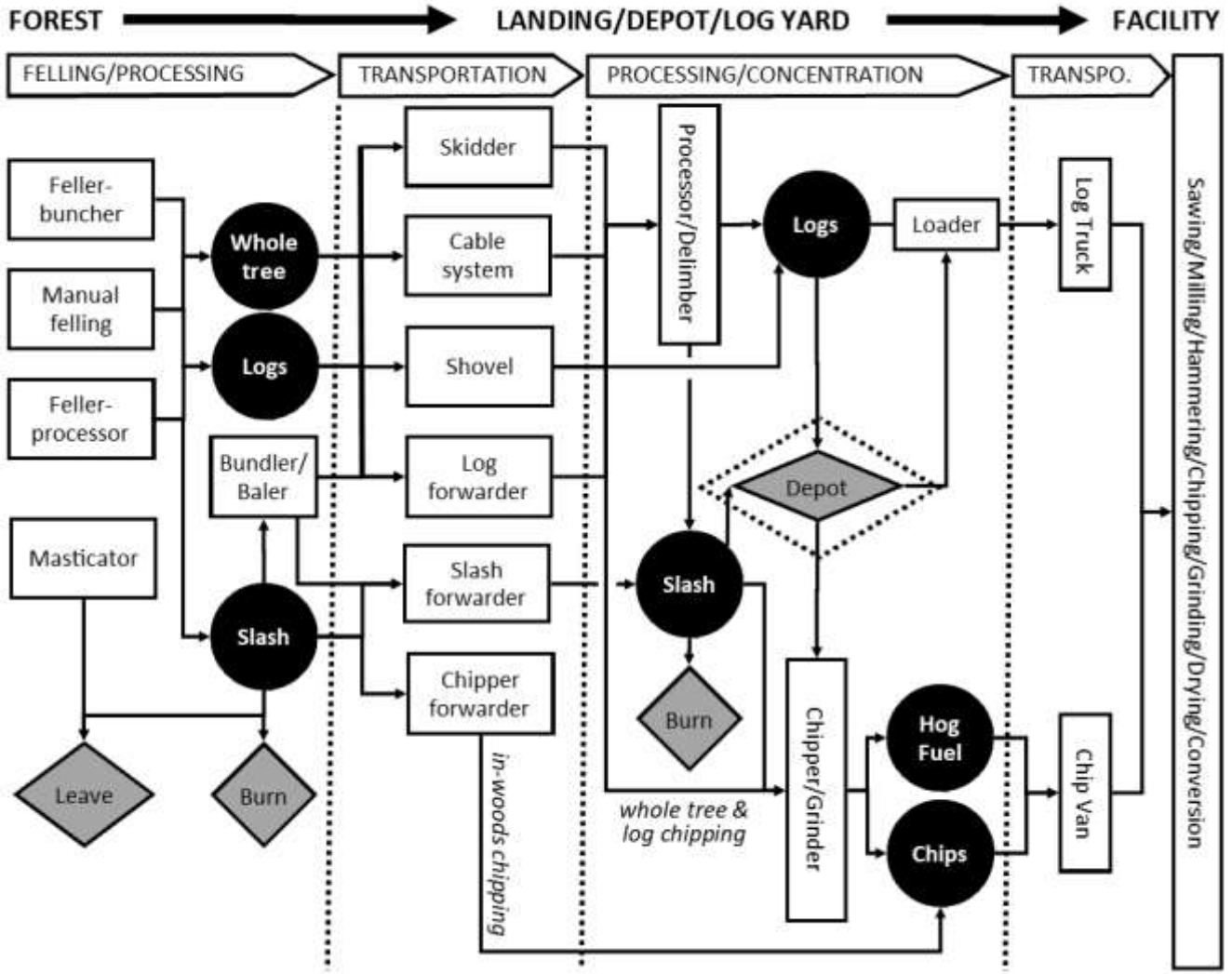
Frameworks: Biomass Production Systems

- Biochar systems
- Bioproducts supply chain
- Industrial ecology
- Demand for final products
- Sustainable Forest Operations
- Biomass removal



Frameworks: Biomass Production Systems

- Biochar systems
- Bioproducts supply chain
- Industrial ecology
- Demand for final products
- Sustainable Forest Operations
- Biomass production systems

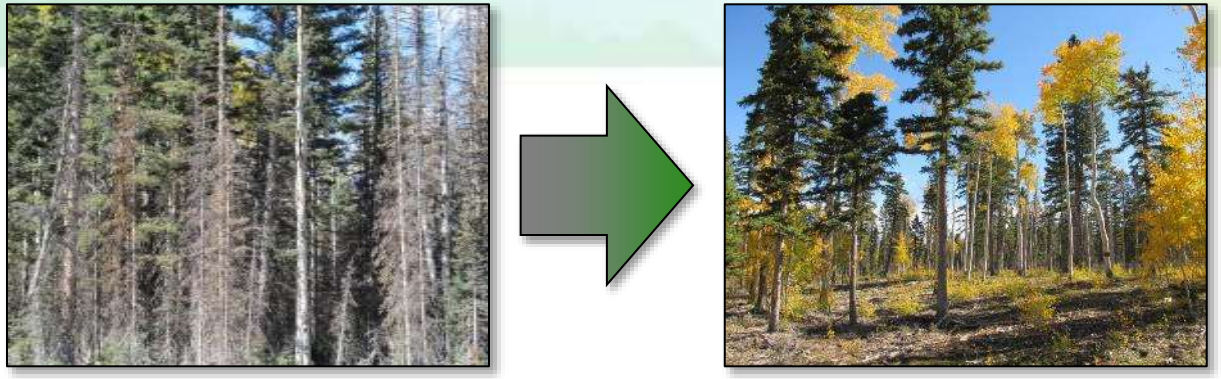


Anderson & Mitchell. 2016. Bioenergy Research 9: 518–533.

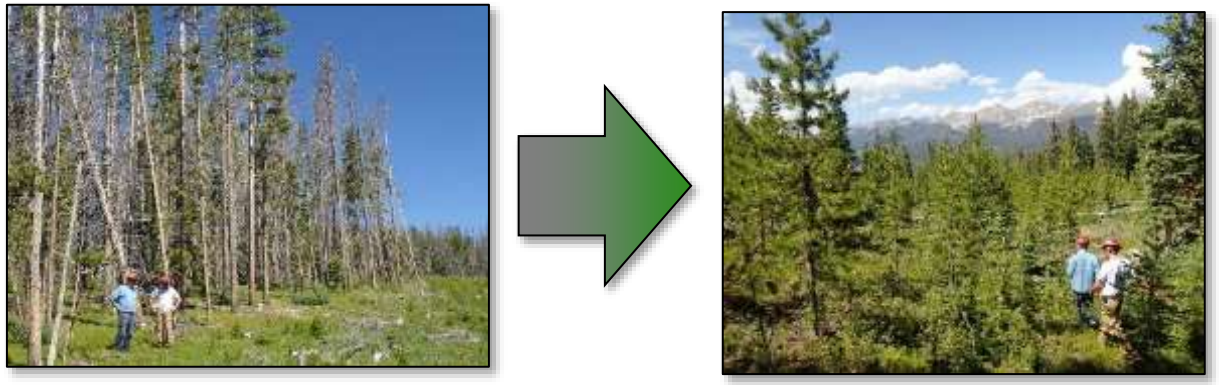
Forest Biomass Challenges

- Widespread need
  - Timber sale
  - Timber salvage
  - Fuel treatment
  - Forest restoration
  - Range encroachment

Mixed conifer, Colorado



Lodgepole pine, Colorado



Ponderosa pine, Arizona

Photos: Anderson

Forest Biomass Challenges

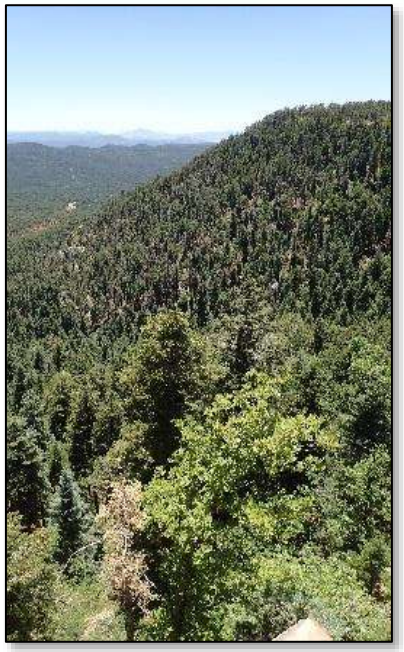
- Widespread need
  - Timber sale
  - Timber salvage
  - Fuel treatment
  - Forest restoration
  - Range encroachment

Forest operations research sites in Arizona, Colorado, and Oregon.

Photos: Anderson, Loeffler (bottom right) and USFS (bottom left)

Forest Biomass Challenges

- Widespread need
- Difficult access
  - Steep train
  - Remote areas
  - Low standard roads


Arizona


Idaho


Oregon


Oregon


Montana


Colorado

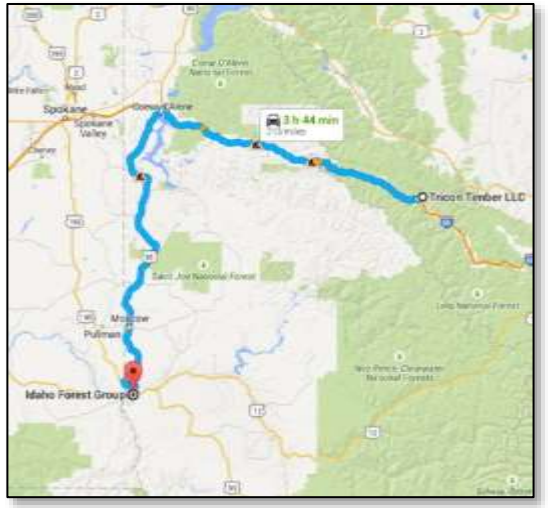

Oregon


Colorado

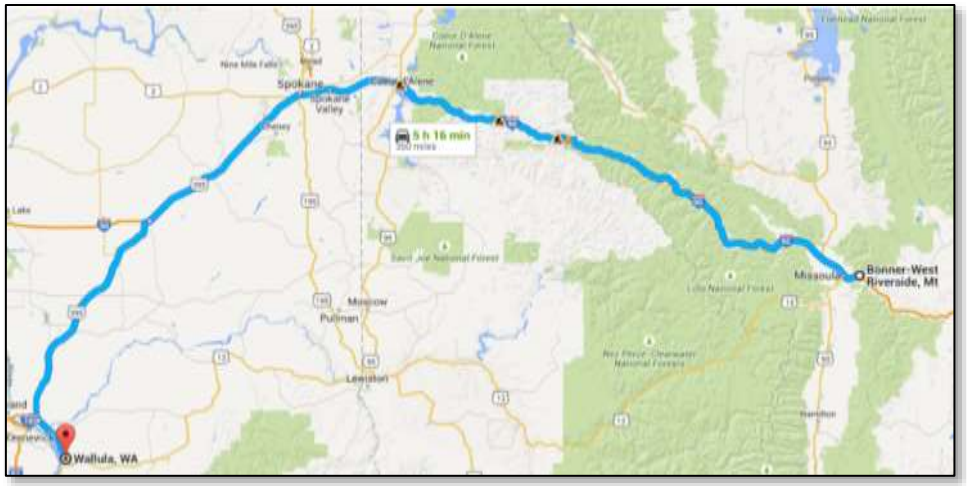
Photos: Anderson

Forest Biomass Challenges

- Widespread need
- Difficult access
- Long distances
  - Big landscapes
  - Dispersed industry
  - Distant markets



St. Regis, MT to
Lewiston, ID
213 mi (343 km)

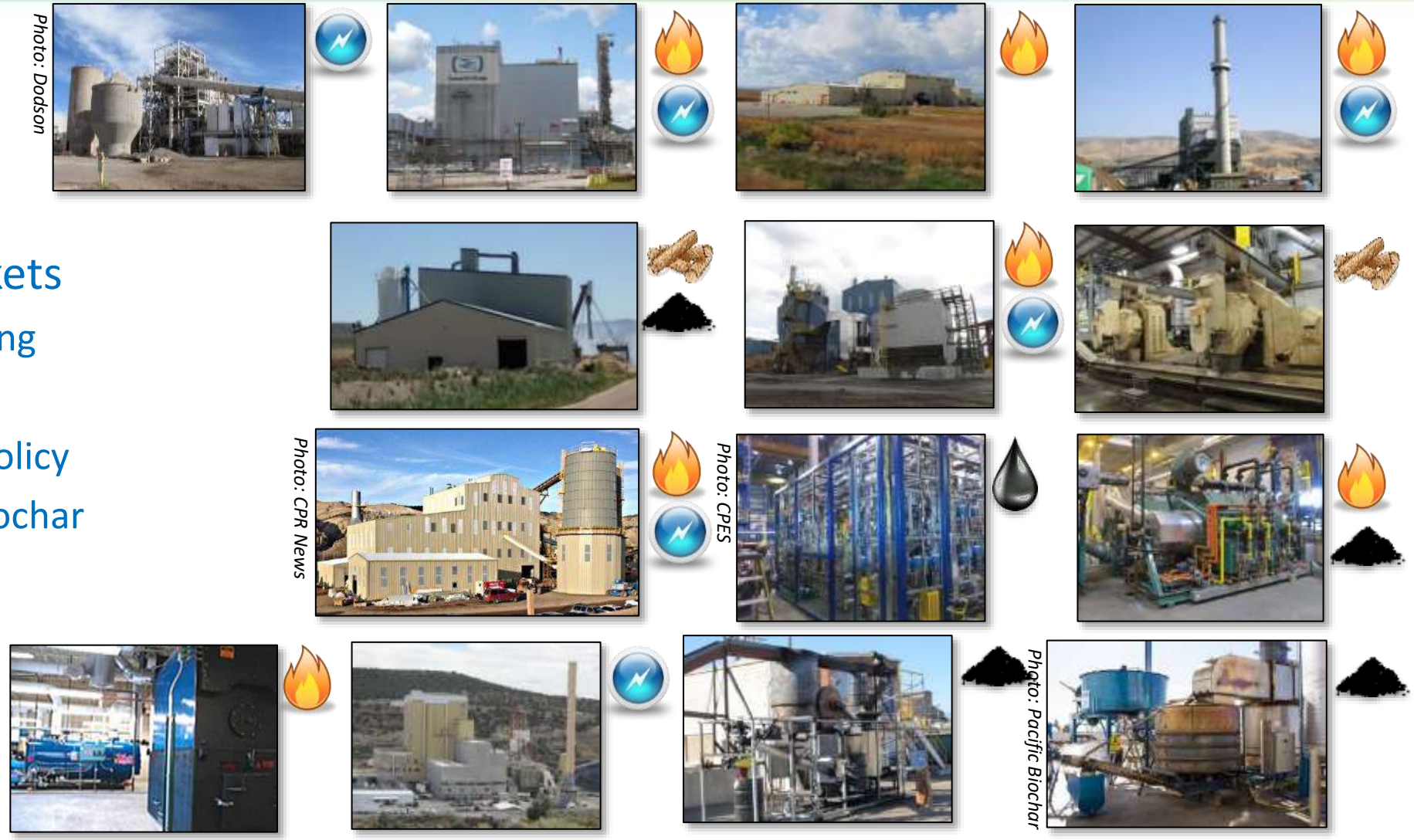


Bonner, MT to
Wallula, WA
350 mi (563 km)

Images: Google Maps

Forest Biomass Challenges

- Widespread need
- Difficult access
- Long distances
- Soft & volatile markets
  - Industry restructuring
  - Low energy prices
  - Uncertain carbon policy
  - Spot markets for biochar



Photos: Anderson except where noted.

Forest Biomass Challenges

- Widespread need
- Difficult access
- Long distances
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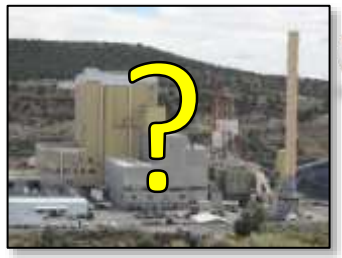


Photos: Anderson except where noted.

Forest Biomass Challenges

- Widespread need
- Difficult access
- Long distances
- Soft & volatile markets
- Diverse byproducts
  - Waste
  - Byproducts
  - Co-products
  - Market dependent


Logging residues


Aspen logs


Mill residues


Fuel Treatment


Beetle kill


Mill residues


Fuel Treatment


Hardwood cull


Hogged slash

Photos: Anderson and Loeffler (bottom left)

Forest Biomass Challenges

- Widespread need
- Difficult access
- Long distances
- Soft & volatile markets
- Diverse byproducts
- Diverse specifications
  - Moisture, ash and size
  - Homogeneity
  - Consistency

Low ash (<0.5%), 0.5 in (1.3 cm) minus, <10% moisture content wood chip for gasification.

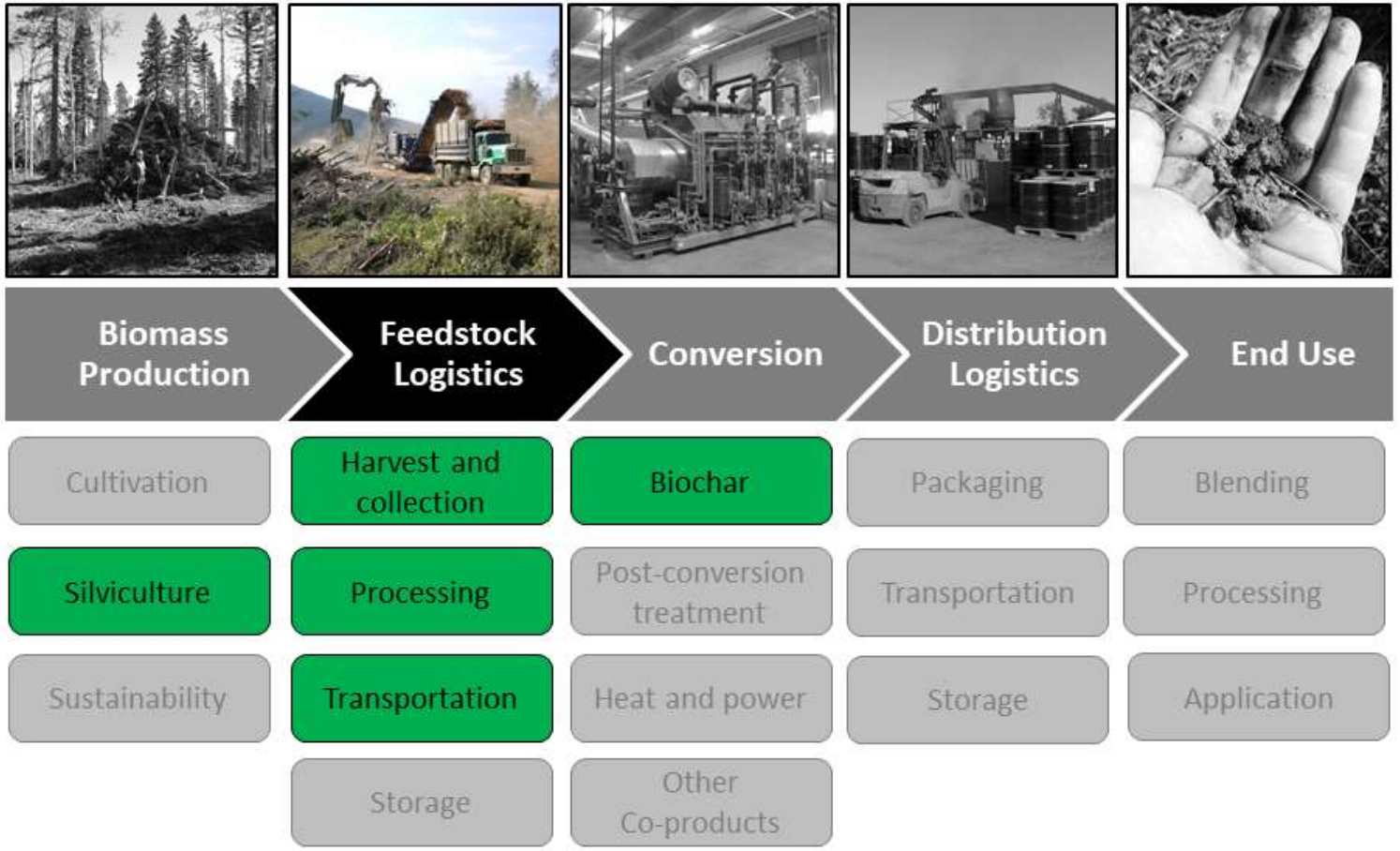
"The Holy Grail: A clean, dry, microchip for $50 per ton" (*€49 per tonne)*

Six biomass products from a single operation in Montana (clockwise from top left): hog fuel, dry microchips, sawdust, pulp chips, bark mulch, and dry shavings.

Photos: Anderson

Solutions

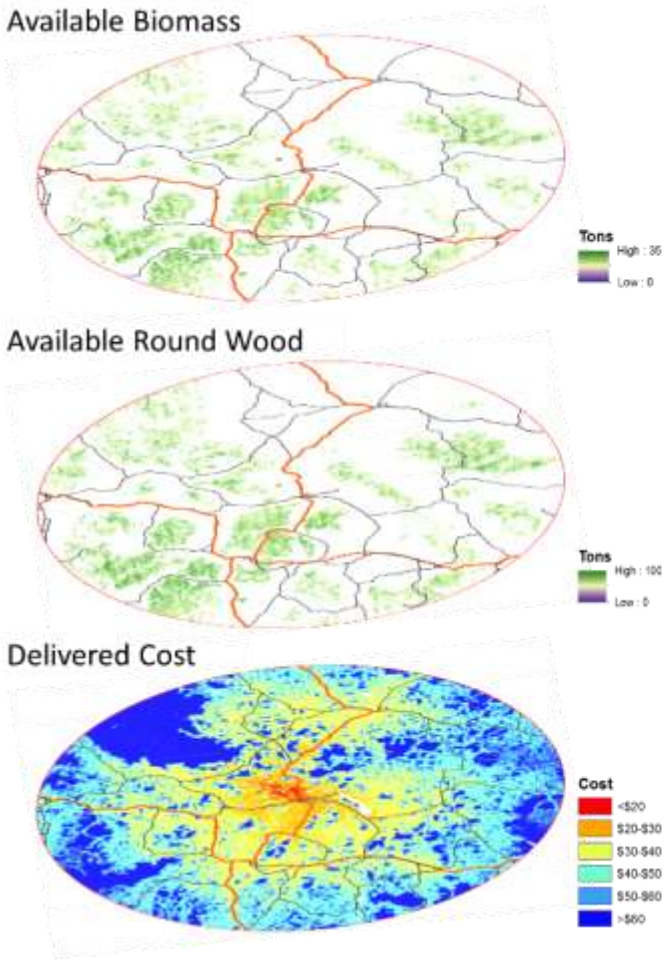
- Planning
- Forest operations
- Transportation logistics
- Designer feedstocks
- Densification
- Non-market values

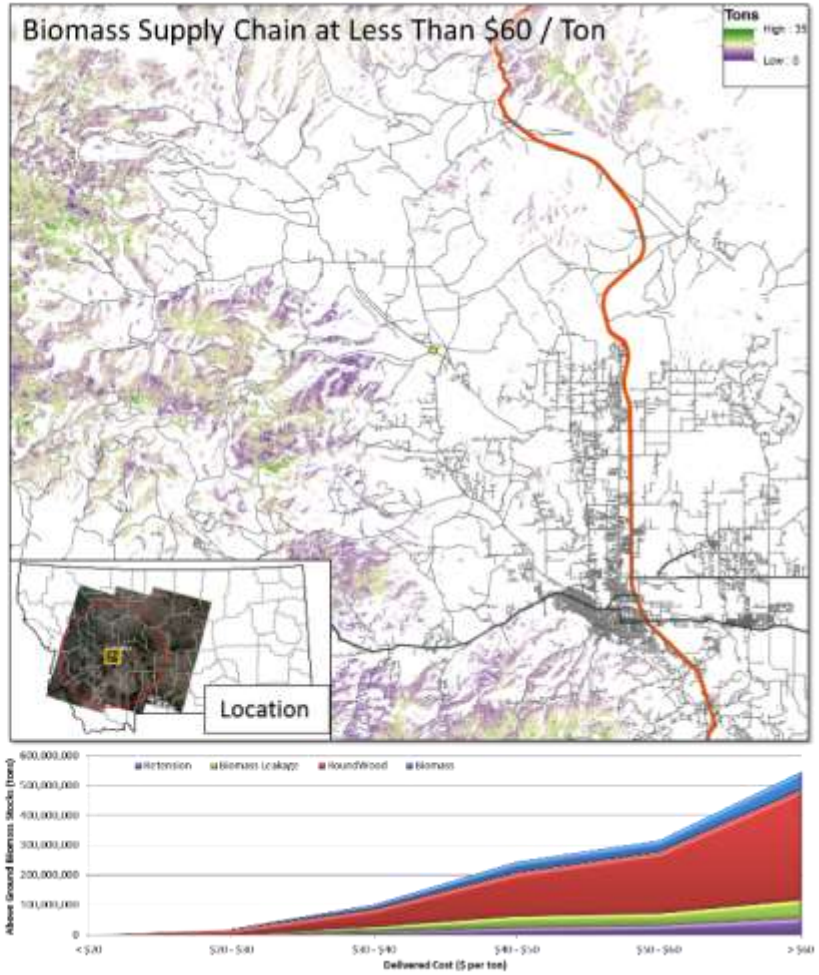


Anderson et al. 2017. Chapter 2 in *Biochar: A Regional Supply Chain Approach in View of Climate Change Mitigation*, Cambridge University Press. (Photos: Anderson)

Solutions

- Planning
  - High resolution
  - Inventory
  - Procurement



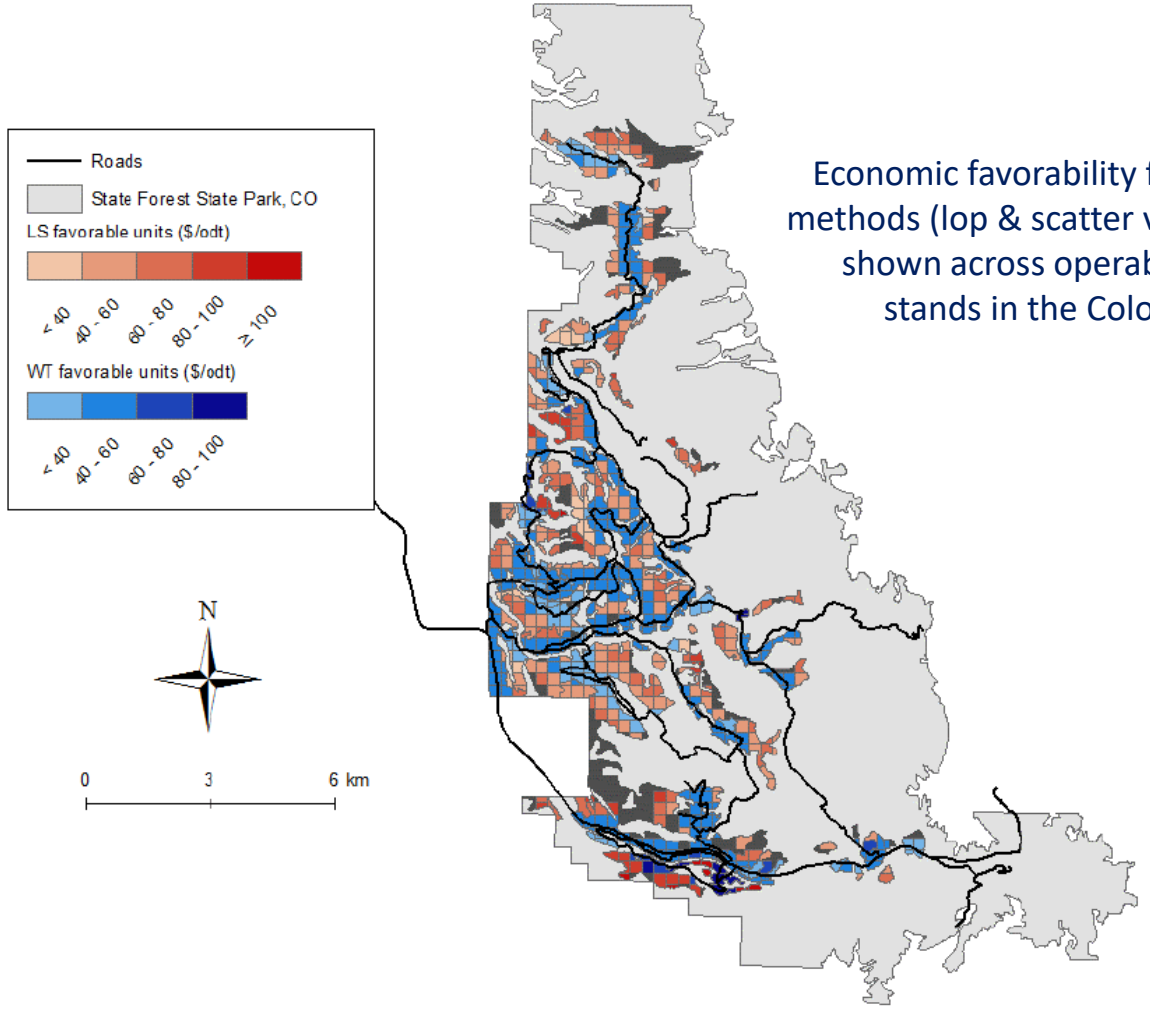


Outputs for biomass logistics and procurement planning using the RMRS Raster Utility: https://www.fs.fed.us/rm/raster-utility/

Hogland, Anderson & Chung. 2018. International Journal of Geo-Information. 7(4): 156.

Solutions

- Planning
  - High resolution
  - Inventory
  - Procurement
  - Forest operations
  - Logistics



Economic favorability for two harvesting methods (lop & scatter versus whole tree) shown across operable lodgepole pine stands in the Colorado State Forest.

Han, et al. 2018. Productivity and costs of two beetle-kill salvage harvesting methods in northern Colorado. Forests. 9: 572.

Solutions

- Planning
- Forest operations
  - Modified equipment
  - Systems for difficult terrain

BANR Project researchers on a site visit in Colorado.

Photo: Han-Sup Han

Slash forwarding

Photo: Bill Quigg

Grapple w/saw

In-woods grinding

Road-legal grinder

Slash forwarding

Photos: Anderson

Roll-off bins

Solutions

- Planning
- Forest operations
  - Modified equipment
  - Systems for difficult terrain
  - Empirical cost models
  - Simulation modeling

Comparing the costs and productivities of different fuel treatment operations in Arizona and New Mexico.

Table 13. Observed and modeled total stump-to-truck costs per tonne by operation in USD. Values may not perfectly sum because of rounding.

	Operation				
Function	1	2	3	4	5
Observed costs ($ per tonne)					
Felling	$4.54	$7.74	$13.17	$3.76	$16.06
Skidding	$8.13	$17.31	$11.37	$4.65	$12.47
Processing	$7.80	$7.38	NA	$5.89	$7.87
Loading	$3.86	$2.54	$9.38	$4.65	$3.42
Grinding	$9.02	$9.24	N/A	N/A	N/A
Round wood cost	$24.34	$34.97	$33.93	$18.94	$39.83
Round wood with biomass cost	$33.36	$44.21	N/A	N/A	N/A
Modeled costs ($ per tonne)					
Felling	$4.33	$4.54	$7.74	$4.84	$15.58
Skidding	$6.72	$9.38	$8.50	$9.59	$11.68
Processing	$7.51	$7.83	NA	$6.51	$7.87
Loading	$3.36	$3.27	$7.29	$4.65	$3.42
Grinding	$9.02	$9.24	N/A	N/A	N/A
Round wood cost	$21.92	$25.02	$23.53	$25.58	$38.55
Round wood with biomass cost	$30.94	$34.26	N/A	N/A	N/A

Townsend, et al. 2019. Harvesting forest biomass in the US southern Rocky Mountains: cost and production rates of five ground-based forest operations. International Journal of Forest Engineering 30(2): 163-172.

Solutions

- Planning
- Forest operations
- Transportation logistics
  - Improved maneuverability
  - Larger payloads
  - Better efficiency

Nested trailer design
(John Jump Trucking)

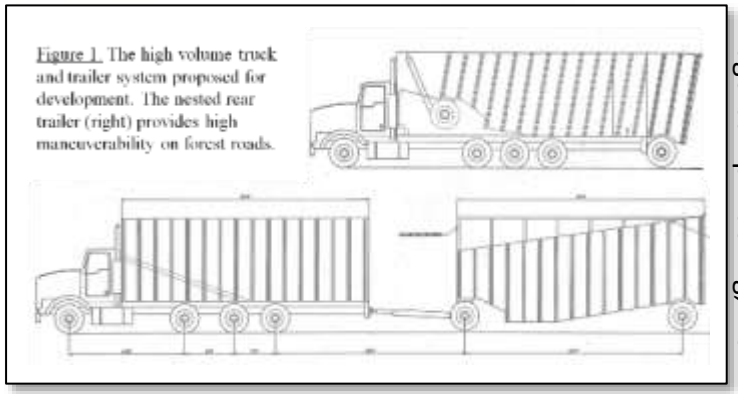


Image: Jump Trucking, Inc.

Photos: Bill Hermann, Hermann Bros. Logging

6x6 drive tractors
Force Steer trailers
Rear axle steering

Images: R. Zamora/J. Sessions (NARA)

Experimental chip flinger to increase load density (NARA)

Solutions

- Planning
- Forest operations
- Transportation logistics
- Designer feedstocks
  - Slash sorting
  - Value handling
  - Precision grinding
  - Production screening

Photos: Han-Sup Han (Waste to Wisdom)

Testing alternative anvil, grate and screen configurations to increase value (W2W).

Solutions

- Planning
- Forest operations
- Transportation logistics
- Designer feedstocks
  - Slash sorting
  - Value handling
  - Precision grinding
  - Production screening
  - New products

Photos: Jim Dooley, Forest Concepts

Forest Concepts “Crumbles”

Photos: Anderson

Production microchips

Solutions

- Planning
- Forest operations
- Transportation logistics
- Designer feedstocks
- Densification
  - Mobile and modular
  - Pellets and briquettes

Photos: David Carter (W2W)

Briquetting red alder.

USFS field trials of mobile pelletization equipment.

Photos: Scott Bell (USFS)

Solutions

- Planning
- Forest operations
- Transportation logistics
- Designer feedstocks
- Densification
  - Mobile and modular
  - Pellets and briquettes
  - Bales

Moblie slash baler (Bighorn Baler®)

Photos: Jim Dooley, Forest Concepts

Solutions

- Planning
- Forest operations
- Transportation logistics
- Designer feedstocks
- Densification
  - Mobile and modular
  - Pellets and briquettes
  - Bales
  - Torrefaction and pyrolysis

Photos: Anderson

Photos: Chuck Norris (W2W)

Tricon microchips
86.5% Volatile
13.1% Fixed C
0.4% Ash

Confluence Energy
8.2% Volatile
88.4% Fixed C
3.4% Ash

Tucker RNG
14.2% Volatile
80.3% Fixed C
5.5% Ash

BSI
16.7% Volatile
71.9% Fixed C
11.4% Ash

ACT
33.6% Volatile C
54.2% Fixed C
12.2% Ash

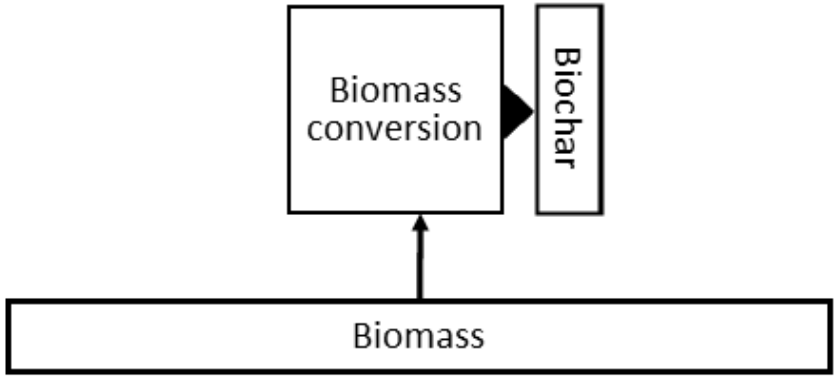
Photos: Anderson

Biochar outputs from various systems.

Solutions

- Planning
- Forest operations
- Transportation logistics
- Designer feedstocks
- Densification
- Non-market values

Who wants to buy my stuff?



Solutions

- Planning
- Forest operations
- Transportation logistics
- Designer feedstocks
- Densification
- Non-market values
  - Fire and smoke risk
  - Ecosystem services
  - Renewable energy
  - Other values

Why are we doing this?

Air Quality

Photo: Montana DEQ

Wildfire Likelihood

Photo: Stephen Lam / Reuters

Public Willingness to Pay

Forest Health

Photo: Anderson

Renewable Energy

Photo: Dodson

Campbell & Anderson. 2019. Comprehensive comparative economic evaluation of woody biomass energy from silvicultural fuel treatments. Journal of Environmental Management. 250: 109422.

Solutions

- Biochar systems
  - Soil benefits
  - Waste management
  - Renewable energy
  - Carbon sequestration

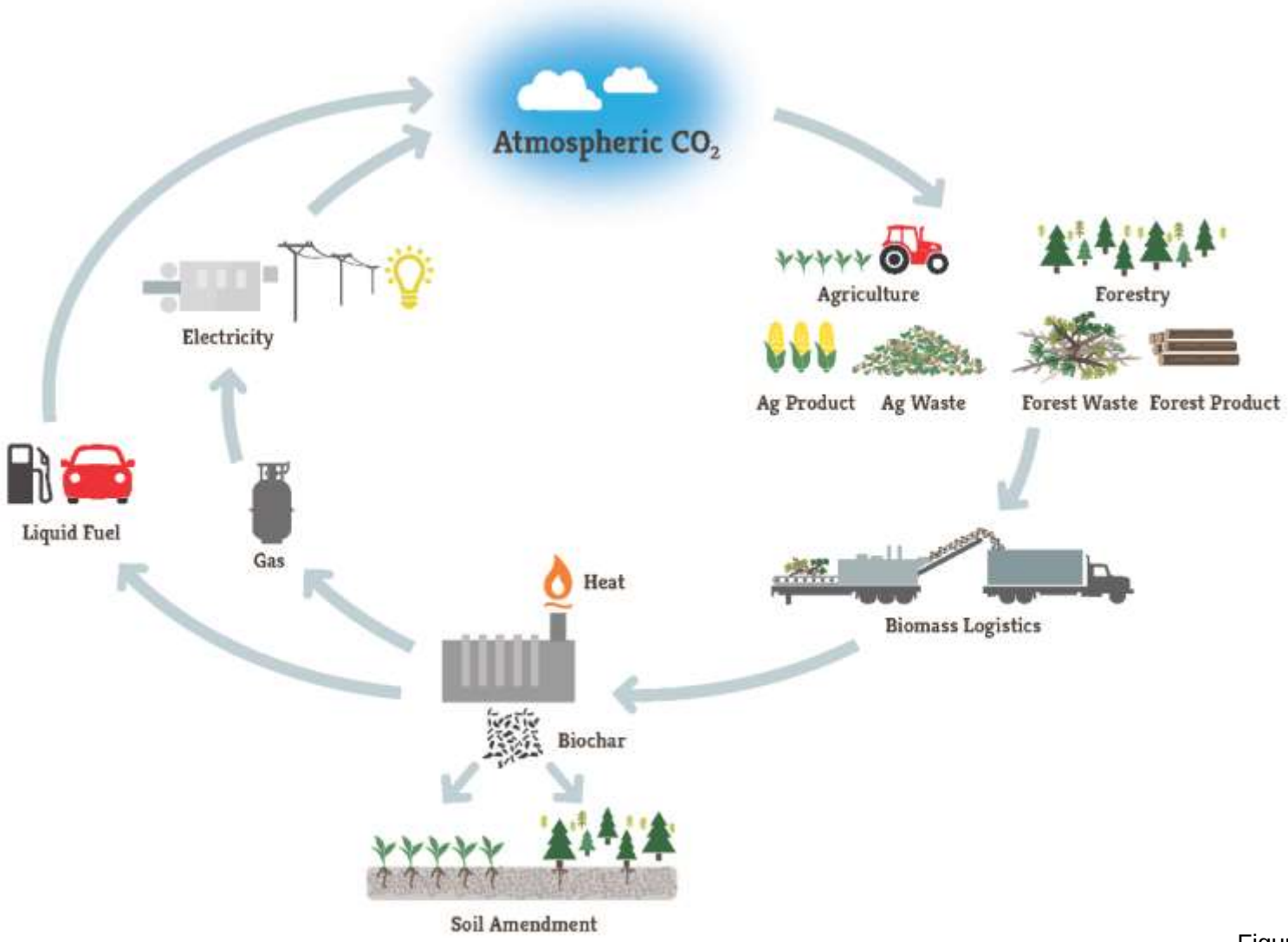


Figure: RMRS 2015

Conclusions

- The big picture is critical
- Challenges are significant
  - Need, access, logistics, and markets
- Solutions are evolving
  - Improving logistics
  - Adding value
- Improvements are possible
  - Decrease costs
  - Increase value
  - Diversify and expand markets
  - Reach appropriate scale

BANR-OSU forest operations research crew, Colorado State Forest

Photo: Anderson

Contact Information

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Rocky Mountain Research Station
800 Beckwith Ave., Missoula, MT 59801
nathaniel.m.anderson@usda.gov

Beetle-kill salvage logs to be used for lumber, Colorado State Forest

THANKS!

Collecting forest operations field data at -15°F (-26°C)

Photos: Anderson (left) and Yaejun Kim (above)