WASTE TO WISDOM

Biofuels and Biobased Product Development Analysis

U.S. DEPARTMENT OF ENERGY

HUMBOLDT STATE UNIVERSITY

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Waste to Wisdom:
Biofuels and Biobased Product Development Analysis

December 7, 2015

9:00 AM – 10:00 AM (PST)

Presenters:

E.M (Ted) Bilek, Ph.D

Economist, USDA Forest Service, Forest Products Laboratory

Rick Bergman, Ph.D

Forest Products Research Technologist, USDA Forest Service,
Forest Products Laboratory

Daisuke Sasatani, Ph.D

Center for International Trade in Forest Products (CINTRAFOR)
University of Washington School of Environmental and Forest Sciences

Deborah Page-Dumroese, Ph.D

Soil Scientist, USDA Forest Service,
Rocky Mountain Research Station

Webinar Outline

1. Background
   - Waste to Wisdom project overview
   - TA-4 organization
2. Webinar preview
   - Economic modeling: Preliminary results
   - Lifecycle analysis: Objectives and preliminary results
   - Economic impact analysis
   - Biochar and forest soils
   - Questions

Waste to Wisdom Project Overview

Forest residuals and slash are an immense, underutilized resource.

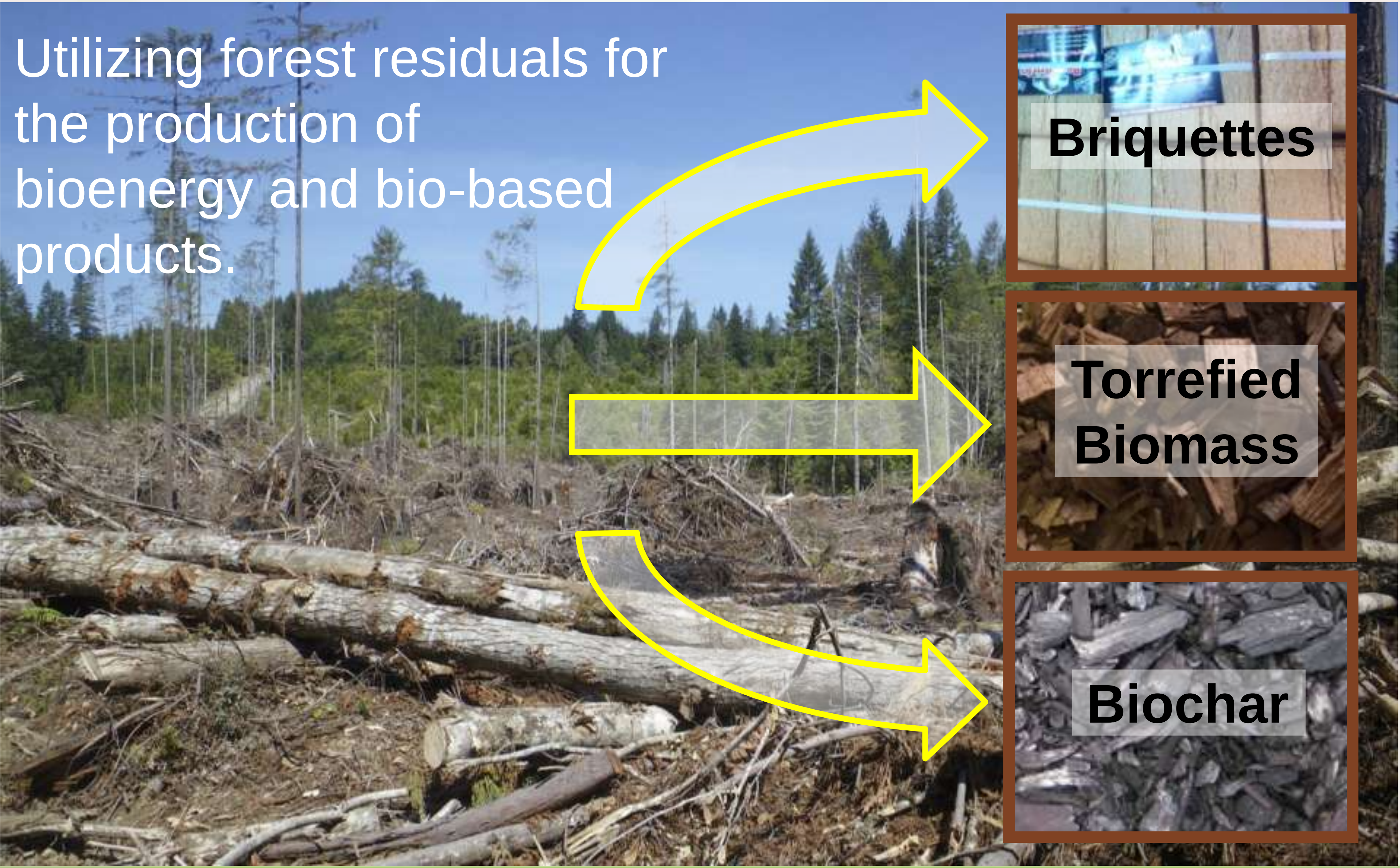
But transportation costs for residuals and slash are prohibitively expensive due to low bulk density and low market value.

These economic barriers can be overcome by

- increasing the transportation efficiency, or
- increasing the value of the residuals before transport.

Waste to Wisdom Project Overview

Utilizing forest residuals for the production of bioenergy and bio-based products.



Waste to Wisdom Project Goals

Research is divided into three major task areas:

•**Feedstock Development**

- Production of high quality feedstocks
- Development of innovative biomass operations logistics

•**Biofuels and Bio-based Products Development**

- Evaluate technical performance of biomass conversion technologies
- Operate the machines at or near forest operations sites

•**Biofuels and Bio-based Products Analysis**

- Evaluate financial feasibility and social impacts
- Analyze the ecological sustainability of each process

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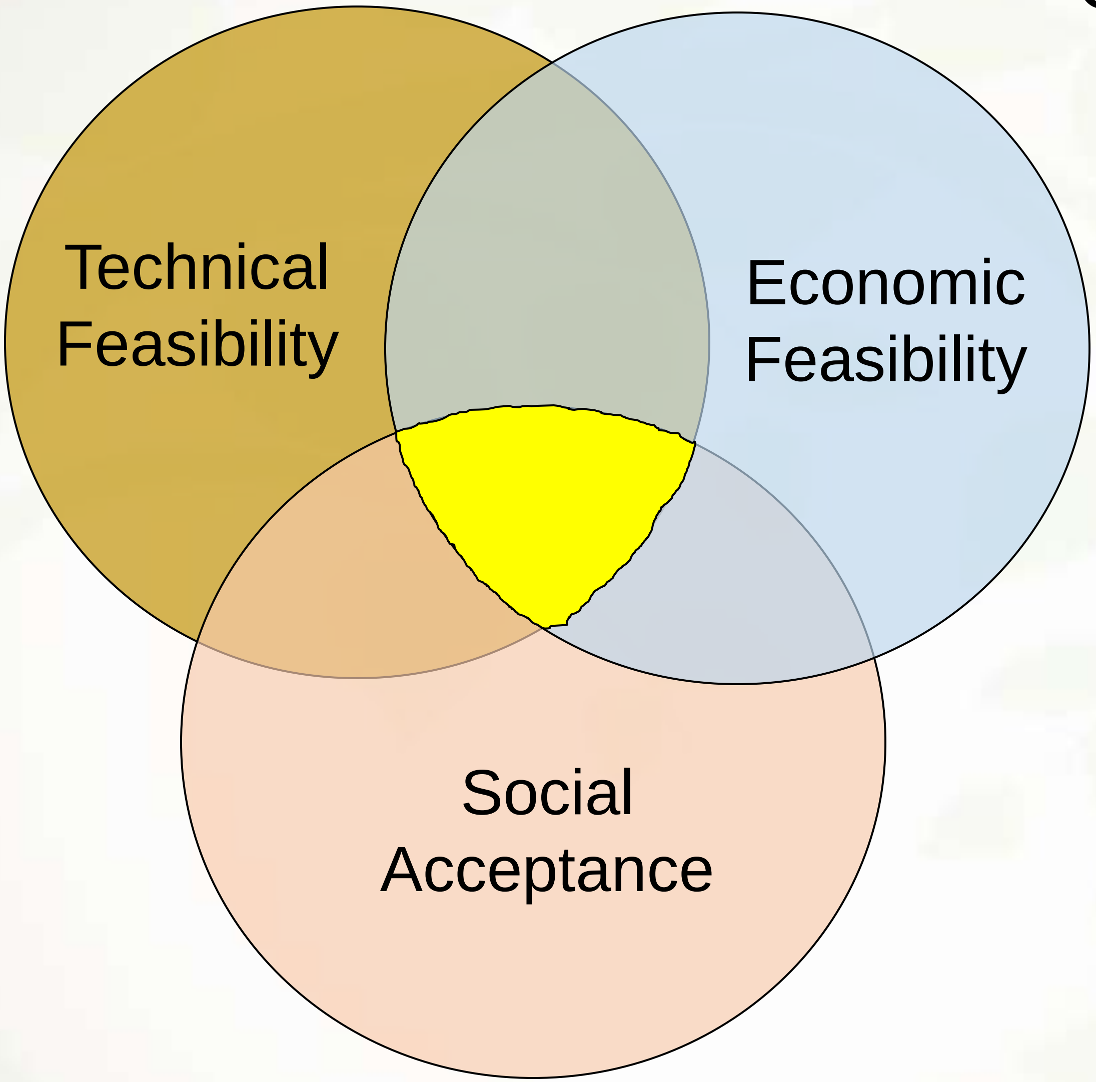
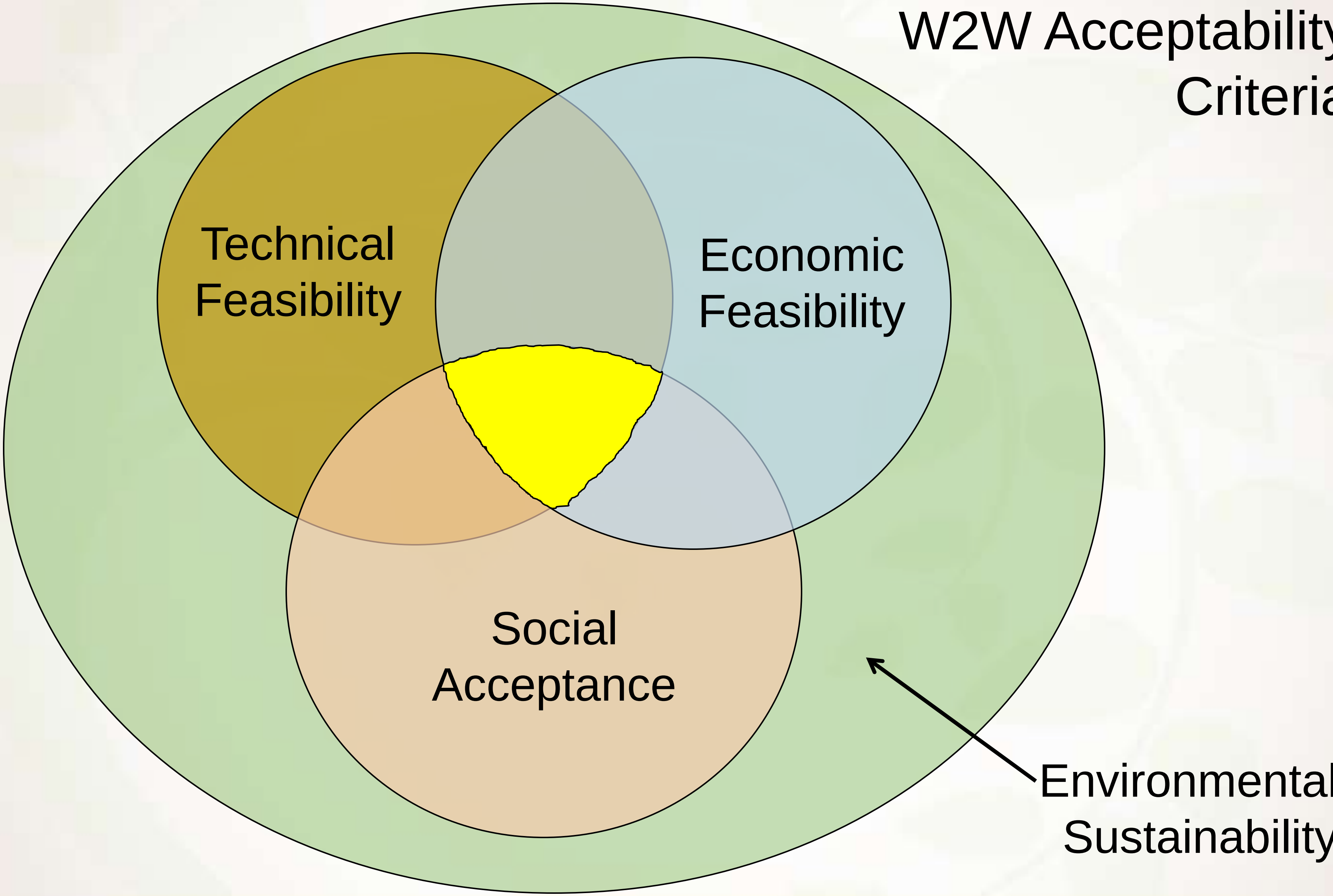
Classic Project Acceptability Criteria



W2W Acceptability Criteria



Economic Modeling of Distributed-Scale Biomass Conversion Technologies (BCTs)

Presented by:

E.M. (Ted) Bilek, Ph.D.

Forest Service
Forest Products Laboratory
Madison, WI

Economic Modeling Goals

Develop a suite of flexible models that will be used to evaluate the economic feasibility of the technologies, and will be customizable by potential adopters of the technologies for individual user's conditions.

- ✓ Produce models for individual machines and technologies
- ✓ Produce models for machine combinations
- ✓ Determine through sensitivity analysis the variables that will be most critical to the economics of the systems

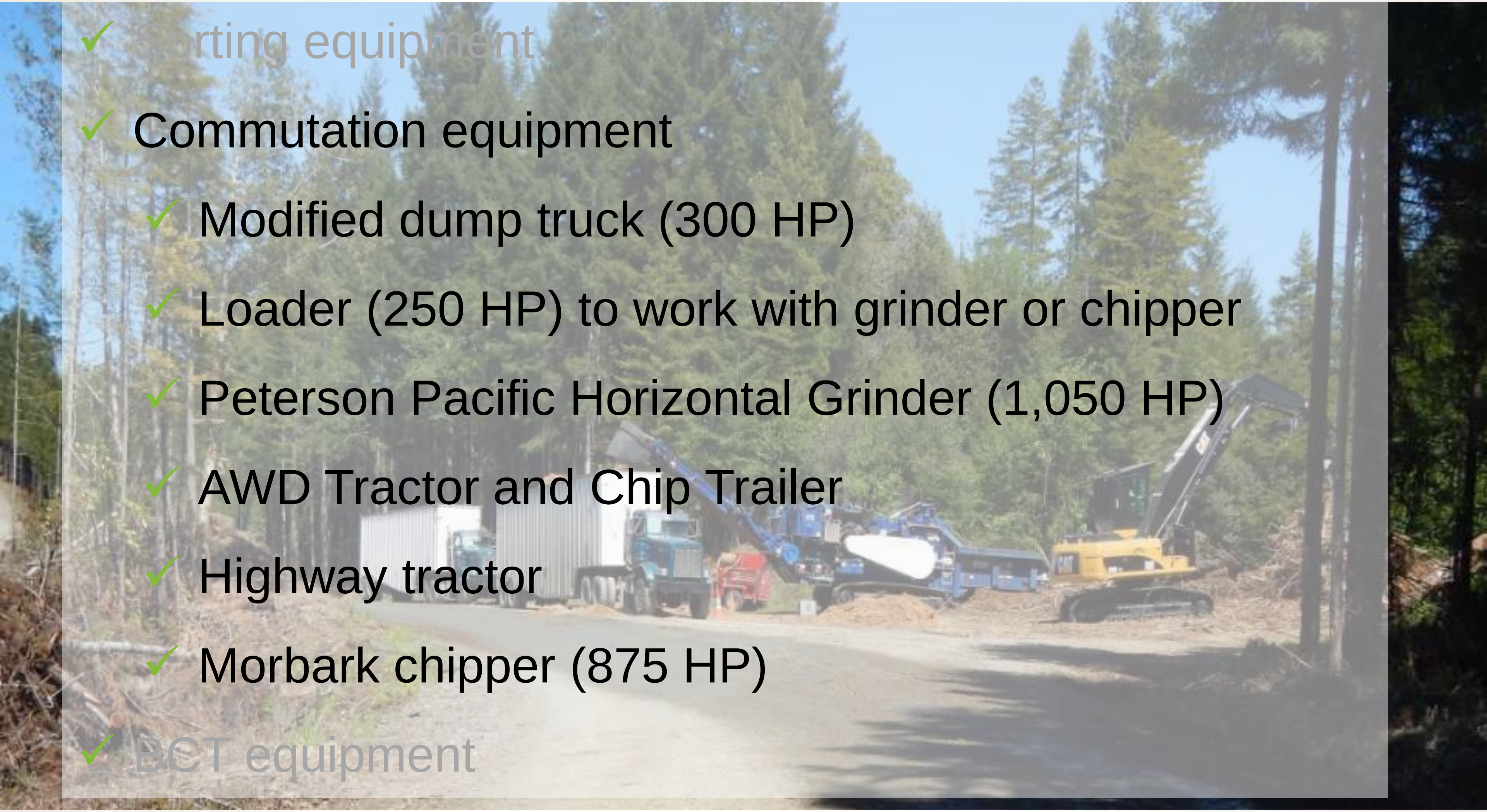
Equipment

- ✓ Sorting equipment
- ✓ Comminution equipment
- ✓ BCT equipment

Equipment

- ✓ Sorting equipment
  - ✓ John Deere 959K fellerbuncher
  - ✓ Caterpillar 568 shovel
  - ✓ John Deere 2954D loader (for sorting and loading)
- ✓ Commutation equipment
- ✓ BCT equipment

Equipment



- ✓ Sorting equipment
- ✓ Commutation equipment
  - ✓ Modified dump truck (300 HP)
  - ✓ Loader (250 HP) to work with grinder or chipper
  - ✓ Peterson Pacific Horizontal Grinder (1,050 HP)
  - ✓ AWD Tractor and Chip Trailer
  - ✓ Highway tractor
  - ✓ Morbark chipper (875 HP)
- ✓ BCT equipment

Equipment

- ✓ Sorting equipment
- ✓ Commutation equipment
- ✓ BCT equipment
  - ✓ Biochar machine (Biochar Solutions)
  - ✓ Briquette press (RUF 200)
  - ✓ Torrefaction machine (Norris Thermal Technologies)
  - ✓ Biomass dryer (Norris Thermal Technologies)
  - ✓ Gasifier genset (All Power Labs)
  - ✓ Woodstraw Baler I (Forest Concepts)
  - ✓ Peterson 4300 Microchipper
  - ✓ Deck Screen and Star Screen (Peterson Pacific)

Preliminary owning and operating costs: Sorting

Cost per Scheduled Machine Hour	Fellerbuncher (John Deere 959K)	Shovel (Caterpillar 568)	Loader for sorting (John Deere 2954D)	Processor (John Deere 2454D)
Fixed or ownership costs	$ 51.76	$ 40.95	$ 34.47	$ 50.46
Variable or operating costs	56.43	59.18	45.74	36.30
Subtotal: Machine costs	$ 108.20	$ 100.13	$ 80.20	$ 86.77
Labor costs	$ 33.25	$ 33.25	$ 33.25	$ 33.25
TOTAL HOURLY COSTS	**$ 141**	**$ 133**	**$ 113**	**$ 120**

TOTAL COST OF OUTPUT	**$/MBF**
No sorting	**$ 13.29**
Moderate	**$ 12.45**
Intensive	**$ 15.37**

Preliminary owning and operating costs: Commutation

Cost per Scheduled Machine Hour	Modified Dump Truck (300 HP)	Loader in unit and with grinder or chipper (250 HP)	Peterson Pacific Horizontal Grinder (1050 HP)	AWD Tractor (HP)	Chip Trailer (trailer only)	Highway tractor	Morbark Chipper (875 HP)
Fixed or ownership costs	$ 19.88	$ 87.73	$ 144.23	$ 14.58	$ 10.93	$ 9.37	$ 132.52
Variable or operating costs	39.33	72.54	199.30	14.87	2.78	50.94	108.44
Subtotal: Machine costs	$ 59.21	$ 160.27	$ 343.54	$ 29.44	$ 13.72	$ 60.31	$ 240.96
Labor costs	$ 42.00	$ 42.00	$ 42.00	$ 28.00	$ -	$ 28.00	$ -
TOTAL HOURLY COSTS	**$ 101**	**$ 202**	**$ 386**	**$ 57**	**$ 14**	**$ 88**	**$ 241**
COST PER BDT OF OUTPUT	**$ 4.30**	**$ 5.91**	**$ 11.92**	**$ 4.34**	**$ 1.48**	**$ 8.72**	**$ 6.44**

Preliminary owning and operating costs: Biomass Conversion Technologies (BCTs)

Cost per Scheduled Machine Hour	Biochar machine (Biochar Solutions)	Briquette Press (RUF 200)	Torrefaction machine (Norris Thermal Technologies)	Biomass dryer (Norris Thermal Technologies)	Gasifier genset (All Power Labs)	Woodstraw Baler I (Forest Concepts)	Woodstraw "New Age" Baler (Forest Concepts)	Peterson 4300 Microchipper	Deck Screen (Peterson Pacific)	Star Screen (Peterson Pacific)
Fixed or ownership costs	$ 22.77	$ 3.26	$ 45.55	$ 8.20	$ 0.55	$ 20.30	$ 52.64	$ 81.99	$ 61.95	$ 80.17
Variable or operating costs	12.00	11.00	30.00	5.40	0.27	19.82	69.95	138.00	52.48	38.81
Subtotal: Machine costs	$ 34.77	$ 14.25	$ 75.55	$ 13.60	$ 0.82	$ 40.12	$ 122.58	$ 219.99	$ 114.43	$ 118.98
Labor costs	$ 33.25	$ -	$ 33.25	$ -	$ 33.25	$ 33.25	$ 33.25	$ -	$ -	$ -
Feedstock costs	$ -	$ -	$ -	$ -	$ 16.00	$ -	$ -	$ -	$ -	$ -
TOTAL HOURLY COSTS	**$ 68**	**$ 14**	**$ 109**	**$ 14**	**$ 50**	**$ 73**	**$ 156**	**$ 220**	**$ 114**	**$ 119**
COST PER UNIT OF OUTPUT	**$ 883/BDT**	**$ 76/BDT**	**$ 412/BDT**	**$ 20/BDT**	**$ 4.17/kWh**	**$ 62/BDT**	**$ 26/BDT**	**$ 5/BDT**	**$ 10/BDT**	**$ 5/BDT**

Future work:

- ✓ Refine machine costs with data from TA-2 and TA-3
- ✓ Incorporate costs into integrated models
- ✓ Advise TA-2 and TA-3 researchers where the economic bottlenecks appear to be so that we can move from waste to wisdom

Next up: Rick Bergman

Life Cycle Analysis of Distributed-Scale Biomass Conversion Technologies (BCTs)

Presented by:

Richard Bergman, Ph.D.

Forest Service
Forest Products Laboratory
Madison, WI

Sub-task Collaborators

- Elaine Oneil, Ph.D., University of Washington

- Maureen Puettmann, Ph.D., WoodLife Environmental Consultants, LLC

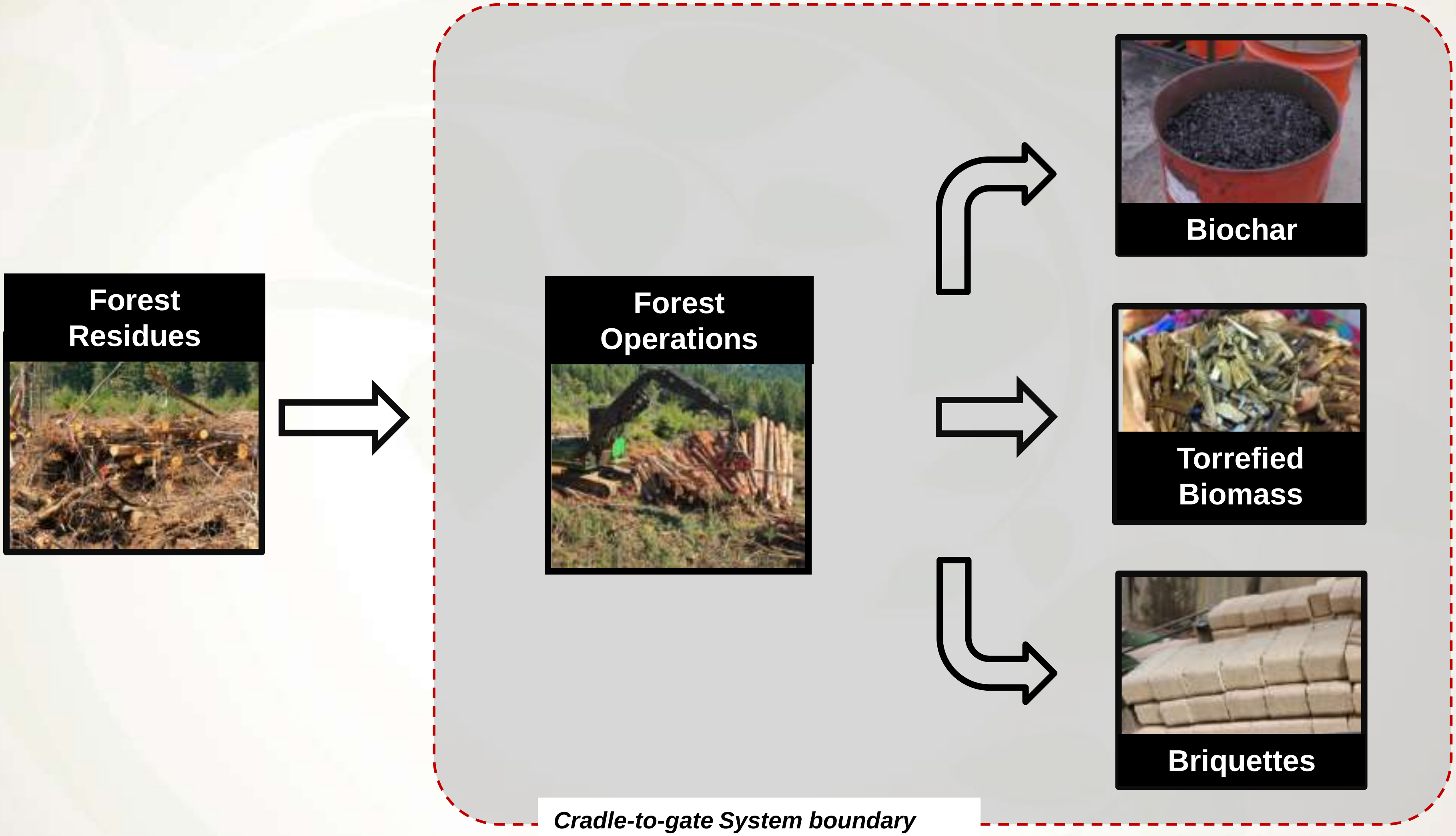
- Sevda Alanya-Rosenbaum, Ph.D., USFS-FPL

Goals of Conducting Life Cycle Assessment (LCA)

Determining environmental success of utilizing forest residues for production of bioenergy and biobased products (an attributional process-based approach)

- ✓ Develop a cradle-to-gate life cycle inventory (LCI) for the in-woods biomass operations
- ✓ Quantify the life cycle environmental impacts of forest operations
- ✓ Develop a cradle-to-gate LCI for biomass conversion technologies (BCTs): biochar, torrefaction, and briquetter
- ✓ Quantify the life cycle environmental impacts of the individual BCTs

Life Cycle System Boundary



LCA Method

Study to conform to ISO14040 and ISO14044

Scope Definition

- Cradle-to-gate LCA; including feedstock procurement and processing stages
- To include or not include use phase

Data Inventory

- Quantitative data on mass and energy flows of the forest operations and BCTs will be based on the operational data and field work
- US LCI database will be used for background processes

Impact Assessment

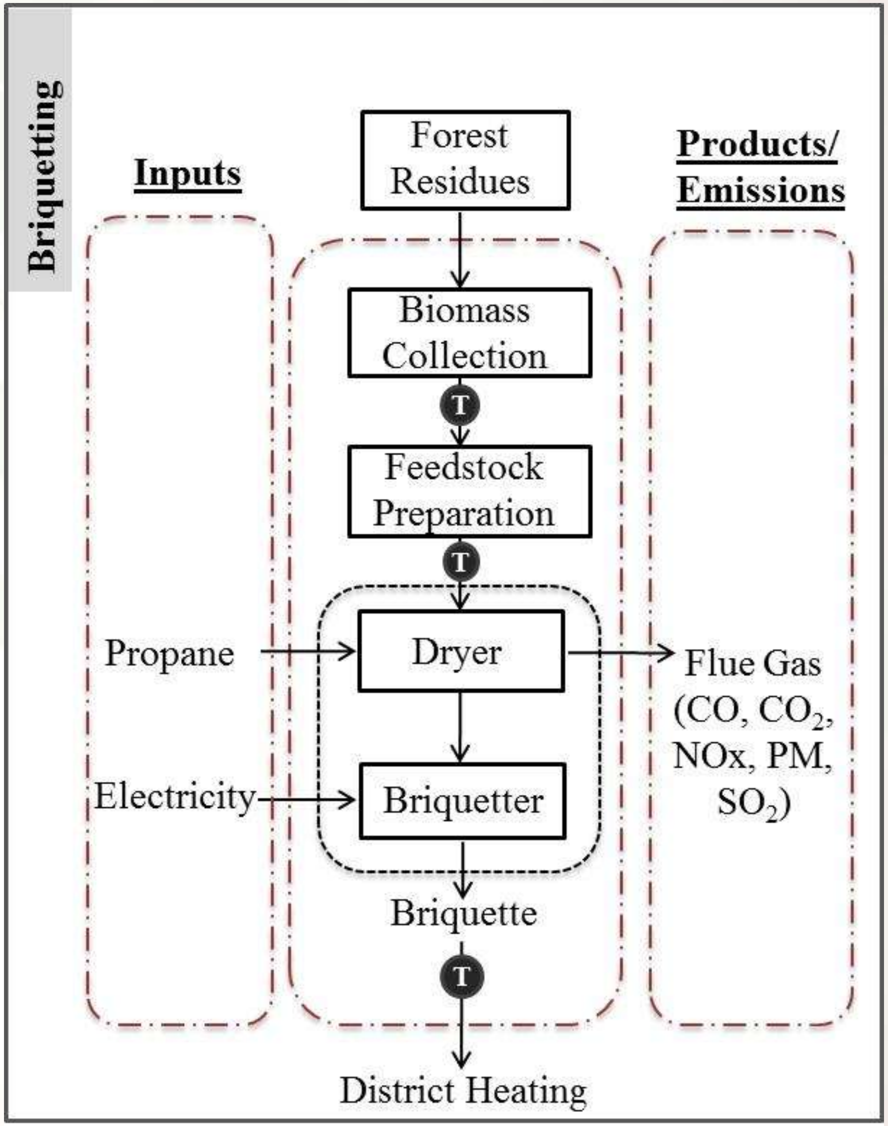
- The Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI) impact assessment method is used
- Systems will be modeled using SimaPro software

Interpretation

- Identification of significant issues based on the results of the LCI and LCIA phases;
- Evaluation of the study considering completeness, sensitivity and consistency checks; and
- Conclusions, limitations and recommendations.

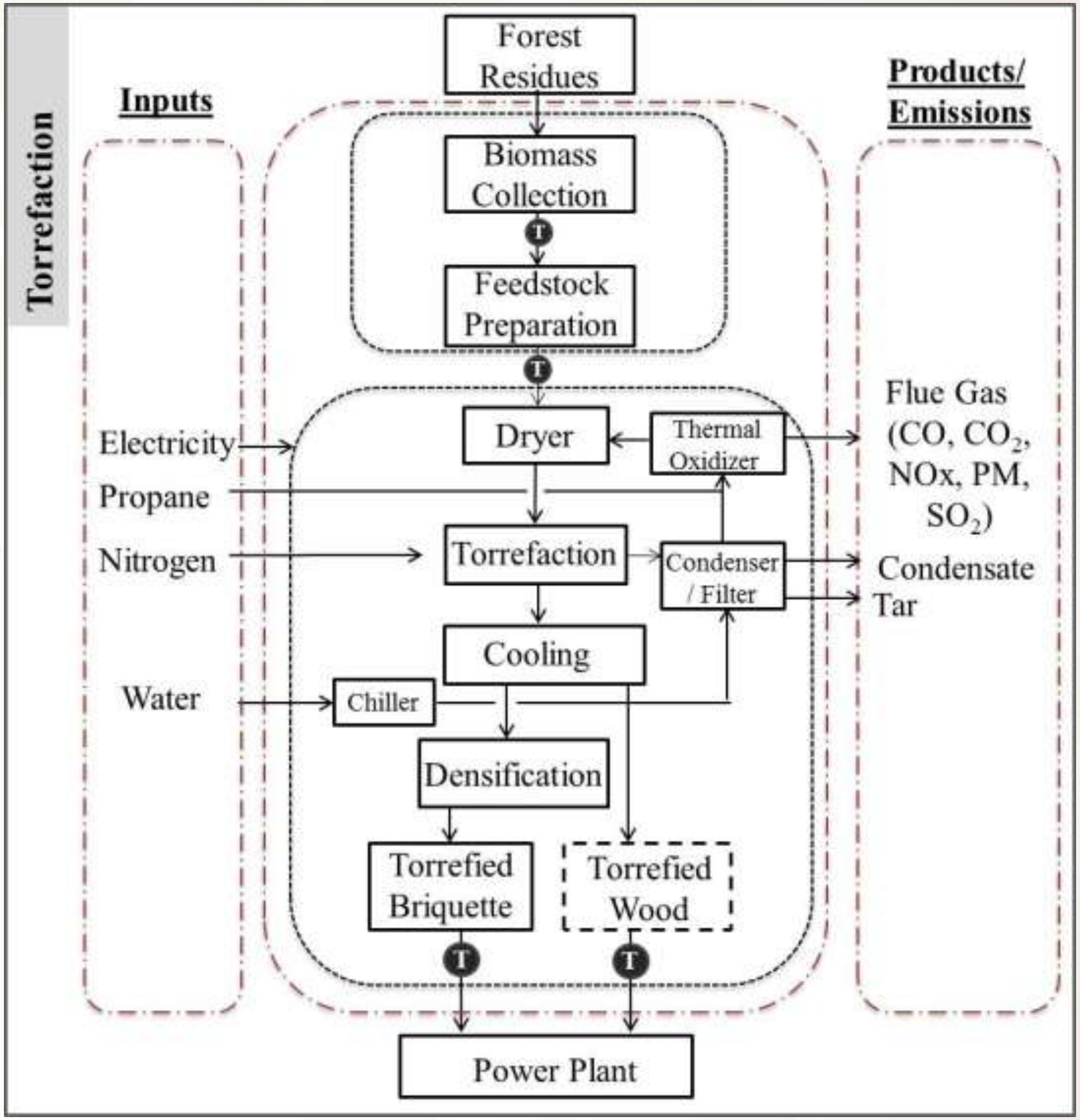
System Boundaries of Briquetting

- RUF200 model briquetter (RUF Briquetting Systems)
- Capacity of 200 kg feedstock per hour
- No plans to scale-up



System Boundaries of Torrefaction

- ✓ A screw-type distributed-scale torrefaction system (Norris Thermal Technologies)
- ✓ Capacity of 6 kg feedstock per hour
- ✓ To be scaled-up



BioChar Production Machine

- ✓ A gasification-based, auto-thermal biochar production machine (Biochar Solutions, Inc.)
- ✓ Input: Feedstock 400 kg/hr at 18% MC wet basis
- ✓ Output: Biochar 45 kg/hr biochar
- ✓ Manufacturer is currently doubling the throughput

BioChar Production Results

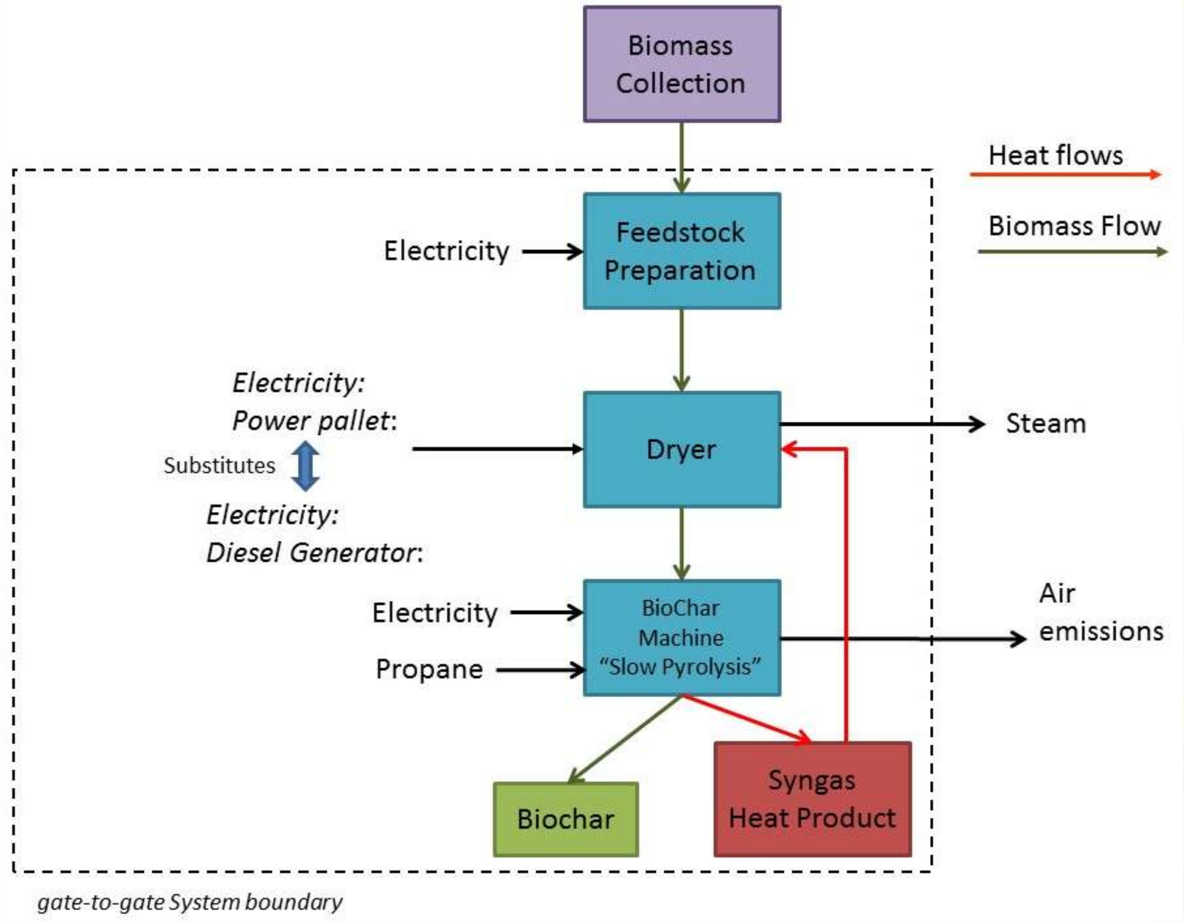
- ✓ Biochar machine tested August 2014 in Pueblo, CO.
- ✓ 7 combinations of feedstock, comminution methods, and contaminant level were tested.

Species	Contaminant	Comminution method	Biochar Ash Content	Biochar Fixed Carbon
Hardwood	none	ground	6%	72%
Conifer	2/3 bole, 1/3 tops	ground	15%	65%
Conifer	9 % soil	ground	23%	58%
Conifer, chip, small	none	chips, small	13%	60%
Conifer, chip, medium	none	chips, med	4%	63%
Conifer, ground	none	ground	6%	79%
Pinyon & Juniper	as received	ground	65%	24%

Data credit: Mark Severy and David Carter, Humboldt State U.

BioChar LCA Flow

- ✓ Input and Outputs from BioChar production will be primary data for LCA
- ✓ Comparisons of all 7 combinations of feedstock species will be modeled.



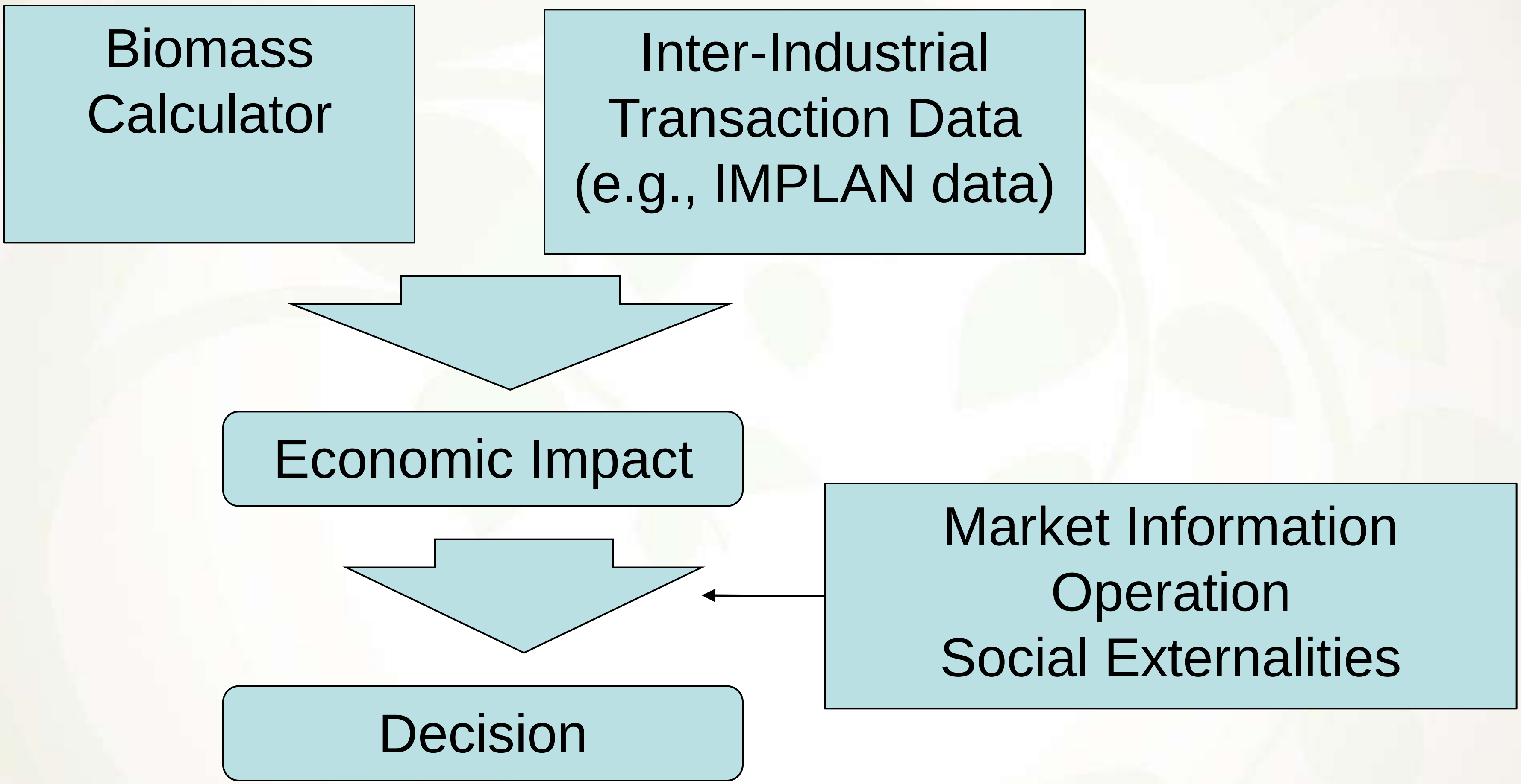
Waste to Wisdom: Preliminary potential regional economic impacts

An input-output analysis of the potential regional economic impacts of using currently-unused harvested forest biomass was set up for Washington using 2011 data. Preliminary results are presented.

Daisuke Sasatani
Research Associate
CINTRAFOR
http://www.cintrafor.org/

Special thanks to:
Benjamin Barenboim (RA) and Ivan Eastin (PI)

Boundary of the task



Input-output (I-O) model

Industrial sectors are inter-related in the region (i.e., sectors purchase from other sectors). Each region has the structured economic system. Analyzing economic impacts through the whole economic system.

When new demand is generated in the region…

→ Direct Economic Effects

→ Indirect Economic Effects

→ Induced Economic Effects by households

→ Induced Economic Effects by local governments

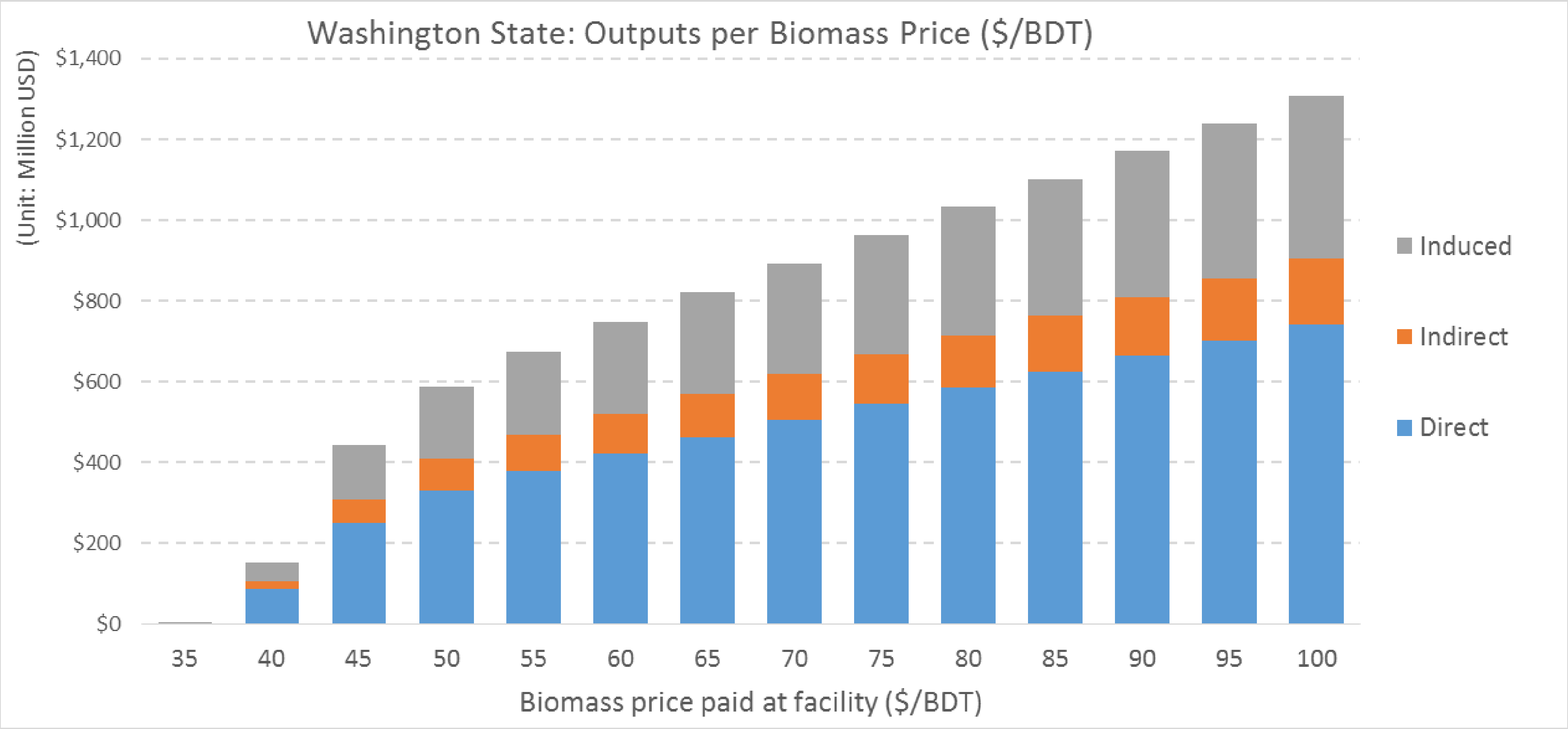
Sensitivity Analysis based on Biomass Calculator

Variable: **Biomass Price paid at facility** ($35-100/BDT)

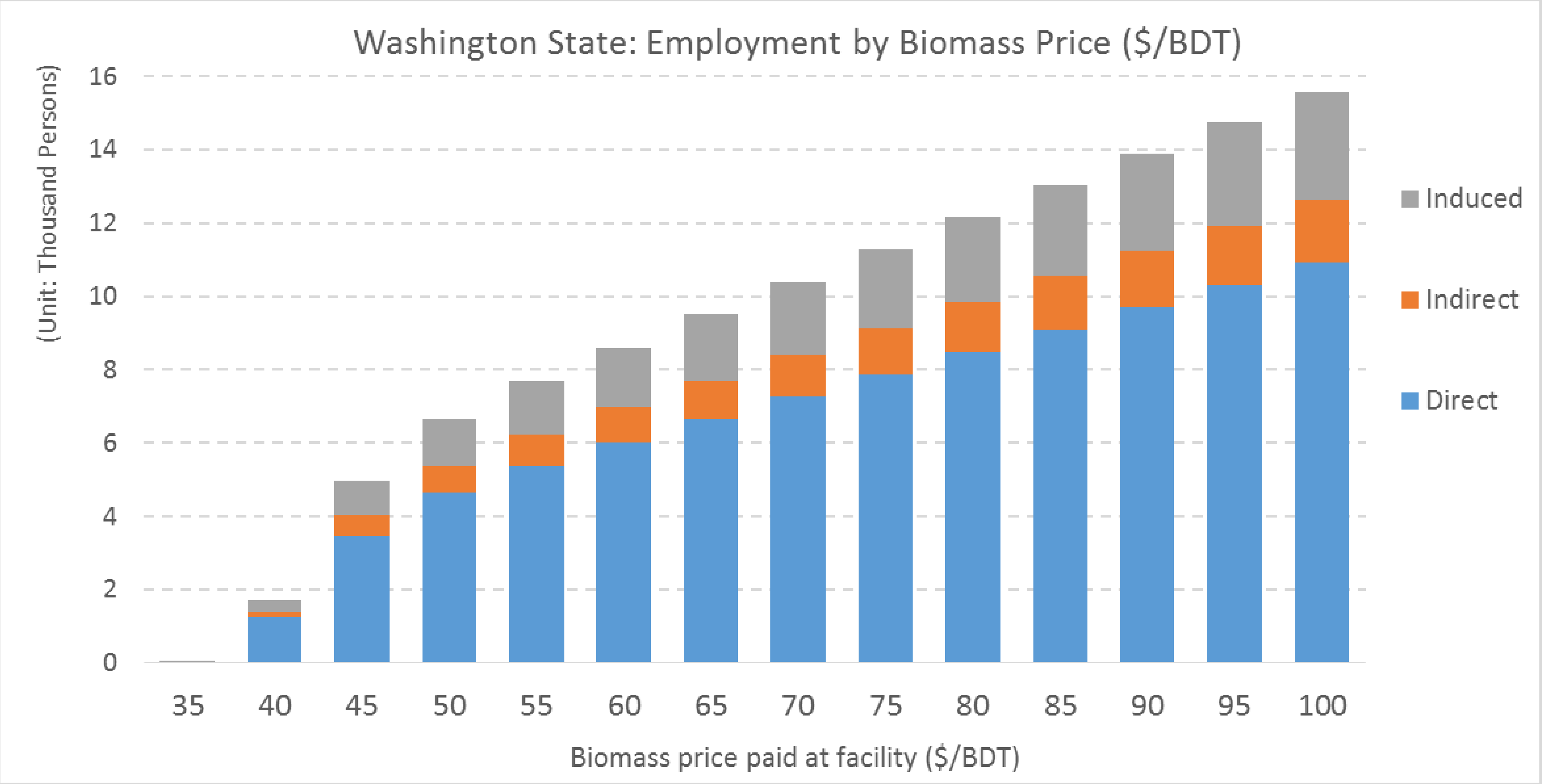
Assumption:

- Average statewide harvest with existing facilities
- Medium harvest costs ($45/BDT forest health cost; $26/BDT load/unload cost; $120/hr mobilization cost; $95/hr haul cost)
- Market biomass (BDT) is calculated by Biomass Calculator http://wabiomass.sefs.uw.edu/
- Sectors to absorb the revenue in the region
  - "transportation by truck" ← haul cost
  - "commercial logging" ← 50% of the remainders
  - "forestry & forest products production" ← 25% of the remainders
  - "support activities for forestry" ← 25% of the remainders

Results: Outputs in WA



Results: Job Creation in WA



Case Study: If biomass was $50/BDT in WA

Direct Effects		
	Outputs	Jobs
Forestry & forest products	20.9%	3.7%
Commercial logging	41.8%	38.0%
Support activities for forestry	20.9%	49.7%
Transport by Truck	16.3%	8.6%

Indirect Effects			
Outputs		Jobs	
Petroleum refineries	18.8%	Support forestry	50.6%
Support forestry	14.0%	Commercial logging	13.2%
Commercial logging	9.6%	Wholesale trade	3.9%
Wholesale trade	6.7%	Transport by truck	3.8%
Transport by truck	4.8%	Employment services	2.7%
Architect. & engineering	2.7%	Architect. & engineering	2.6%
Couriers & messengers	2.7%	Couriers & messengers	2.4%
Forestry machinery	2.5%	Automotive repair	1.5%
Credit intermediation	2.4%	Real estate	1.2%
Extraction of oil & gas	2.2%	Services to buildings	1.2%
Others	33.5%	Accounting	1.2%
		US Postal Service	1.2%
		Animal production	1.2%
		Others	13.2%

Induced Effects			
Outputs		Jobs	
Rental of dwelling	12.9%	Food services	12.0%
Offices of clinic	5.6%	Offices of clinic	6.6%
Wholesale trade	5.5%	Real estate	5.1%
Food services	5.1%	Private hospitals	4.7%
Real estate	5.0%	Wholesale trade	4.3%
Private hospitals	4.8%	Nursing & care	3.7%
Petroleum refineries	3.9%	Retail – General	3.6%
Credit interned.	3.2%	Retail – Food	3.5%
Insurance carriers	3.1%	Family services	2.7%
Retail – General	1.7%	Retail – Car	2.4%
Retail – Food	1.7%	Retail – Misc	2.1%
Retail – Car	1.6%	Social org	2.0%
Investments	1.6%	Private HH	1.7%
Nursing & care	1.6%	Investments	1.6%
Medical labs	1.6%	Retail - Clothing	1.6%

Conclusion

The W2W project can significantly impact state economy and jobs.

As the sales price of the biomass increases, the total outputs and jobs created increase statewide.

Economic impacts are different for sector by sector in the region.

Future direction to complete the project

Conduct the similar analysis for OR and CA

Data needed to move forward:

- Biomass Calculation estimates for WA, OR and CA
- 2014 Inter-Industrial transaction data

Using Biochar to Improve Forest, Range, or Mine Soils

Biochar can be applied to numerous western USA sites. Soil physical property changes and vegetation responses on **Forest** and **Mine** Sites will be discussed.

Deborah S. Page-Dumroese
Research Soil Scientist
USDA Forest Service
Rocky Mountain Research Station

Hazardous Fuel Reduction is not Profitable

What to do with "waste" slash piles?

- Biomass is largely unmarketable
- Drop and leave is still a fire hazard
- Piling and burning is costly
    - Releases pollutants
    - Wastes energy

Sustainable Bioenergy

Alternatives to pile burning

- Slash pile burning can cause long-term soil damage
- Use 'waste' wood to create biochar
- Soil application of biochar

Pellets, Bulk Biochar or 'Natural Charcoal'?

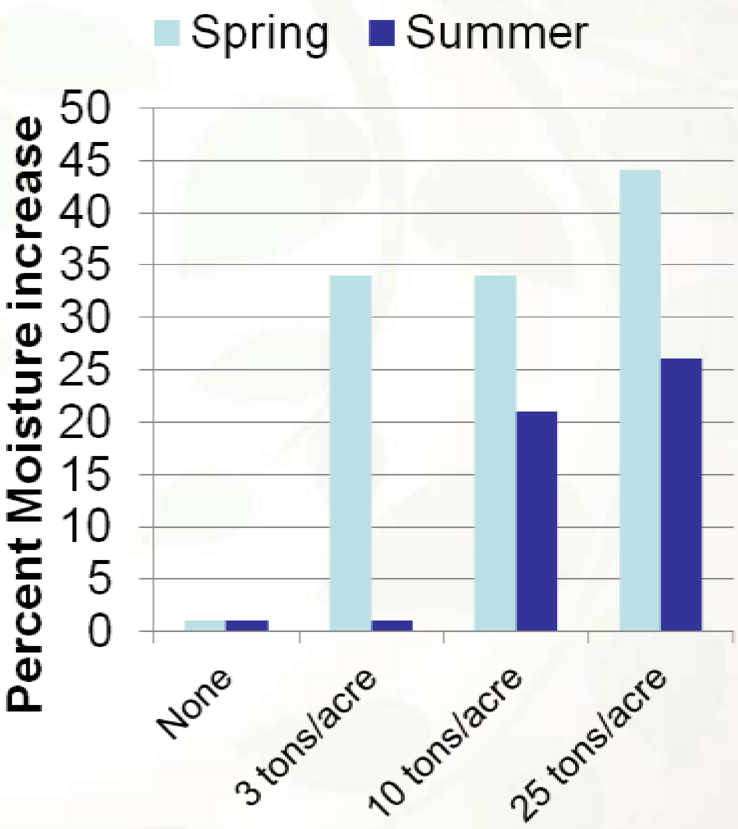
- Biochar in many forms
- Adds site carbon
- With a 1% increase in soil organic matter, water holding increases.

Soil Texture	Increase in water
Silt loam	3.4%
Sand	2.2%
Silty clay loam	2.8%

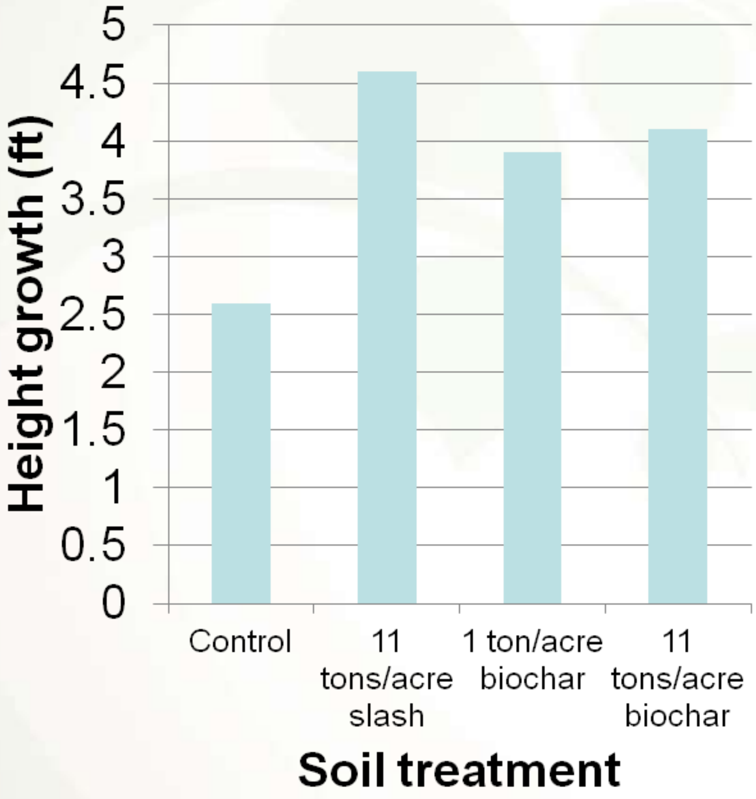
Forest Soils: Increased Water Holding

Decommissioned Roads in Montana

- Spring and Summer: increased water in the mineral soil
- Spring: 30-40% increase
- Summer: 20-25% increase



Forest Soil: Long-Term Forest Response (5 year growth)

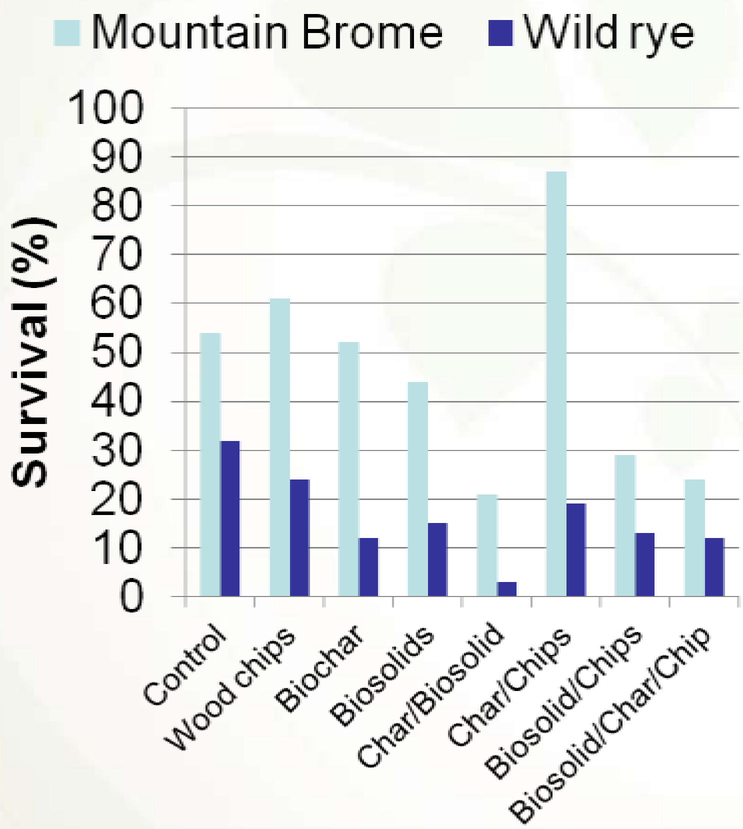


- Neutral to positive responses to biochar additions
- Similar to leaving slash
- Long-term C sequestration
- After 5 years 15-40% increase in tree height
- The C sequestration gains aboveground (increased tree growth) PLUS belowground can be significant as the stand ages

Mine Site Rehabilitation

- Add organic matter to subsoil or degraded top soil
- Top dressed (not incorporated)
- May improve water holding capacity
- Planting seedlings is preferred to seed applications

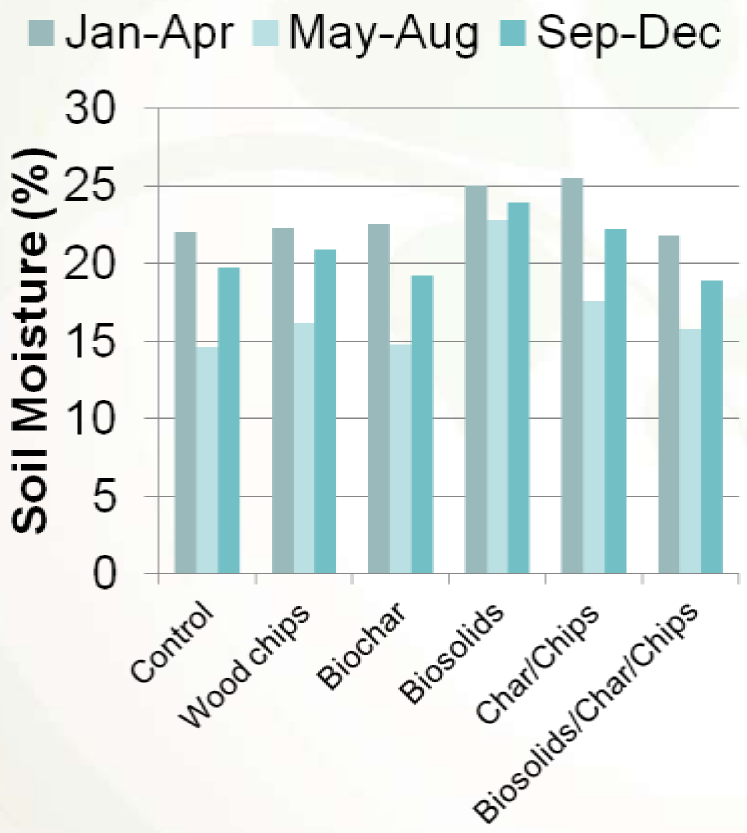
Mine Site Rehabilitation – Planted Seedling Survival



Seedling Survival

- Combinations of amendments may be targeted for individual sites
- Planted species selection is critical
- Plots were ½ planted and ½ seeded
  - Minimal (<2%) seed germination and survival
- Wood chips are short-term
- Char is long-term

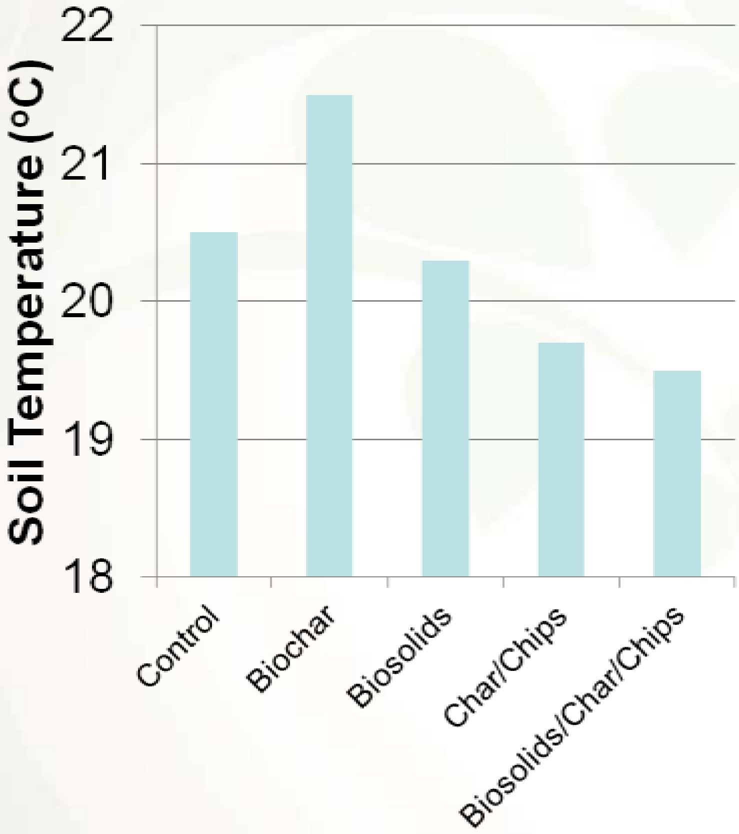
Mine Site Rehabilitation – Changes in Available Water



Yearly Soil Moisture

- Most soil amendment treatments have higher soil moisture than the control
- Increased water during the summer drought
- Soil recharge is higher in most plots in the fall

Mine Site Rehabilitation – Changes in Soil Temperature (Summer)



Soil Temperature in Summer

- Except for biochar (alone) soil temperature was moderated by soil amendments
- Biochar should be incorporated into the mineral soil (where possible)

Using Biochar as a Soil Amendment

- On forest sites, keep the forest floor intact
- Using a biochar spreader (left) facilitates bulk or pellet biochar application on log landings and skid trails without impacting the mineral soil
- Understand soil properties and biochar quality before application

Summary – Biochar as a Soil Amendment

Benefits

- Increased water holding capacity
- Less acid soils (alters pH)
- Potential to improve habitat for microorganisms
- Long-term (>100 years) carbon sequestration
- Removal of forest residues
- Reduce need for slash pile burning
  - Fewer particulate and green house gas emissions
  - No soil damage from severe fire
- Responses are soil (and maybe) site specific

Best Application Sites

- Damaged or contaminated areas
  - Inactive mine sites
  - Road salt damage
- Decommissioned roads
- Skid trails
- Log landings

Questions and Discussion

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