WASTE TO WISDOM

Lifecycle Assessment and Economics of Biochar from Forest Residues

Debbie Page-Dumroese
Rocky Mountain Res. Station

Ted Bilek
Forest Products Lab

Maureen Puettmann
WoodLife Environmental Consultants

August 23, 2017

U.S. DEPARTMENT OF ENERGY

HUMBOLDT STATE UNIVERSITY

For more information please visit WasteToWisdom.com

Waste to Wisdom Project Overview

Forest residuals and slash are an immense, underutilized resource.

Creating biochar is one by-product that can be created from these residues using small-scale near-woods production.

Our presentation will include information on

- Biochar applications
- Lifecycle analyses
- Biochar economics

Waste to Wisdom Project Overview

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

Project Focus areas:
- Feedstock development
- Biomass conversion technologies
- Economic and environmental assessment

Webinar Outline

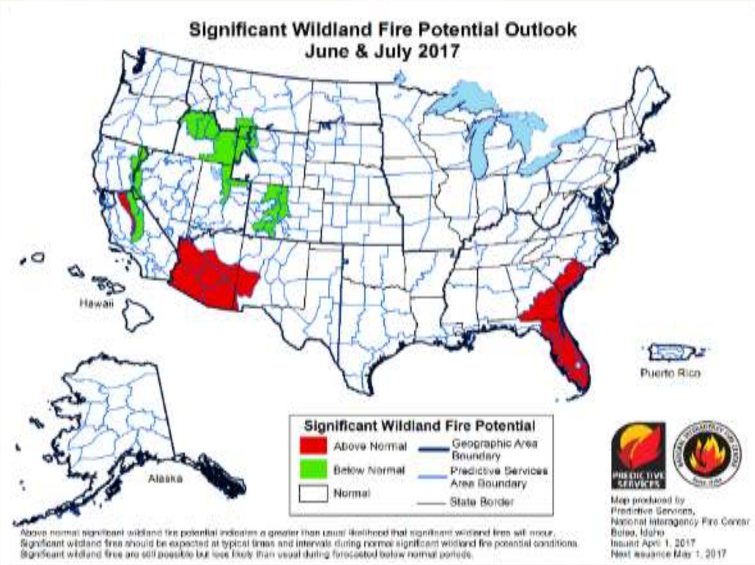
1. Environmental impacts of biochar application (Deb Page-Dumroese)
   a) Why biochar?
   b) Ecosystem responses

2. Lifecycle assessment of biochar (Maureen Puettmann)
   a) Methods
   b) Results - Global Warming Impact

3. Economics of torrefied biomass production (Ted Bilek)
   a) Analysis methodology
   b) Economic results

4. Question and answer period (moderated by Ted Bilek)

What is happening?



Insect and disease risk map

- Millions of acres of overstocked forests in the western US
- Millions of acres of beetle-killed forests in Canada and western US
- Longer fire season and increasing fire severity
- Smaller burn windows

What to do with the non-merchantable wood?

Current land management

- Forest restoration: thinning and salvage logging
- Pile and burn excess woody biomass
  - Cheap, easy, reduces fire risk
- Pile burning can alter soil properties
  - Long-term impacts

Other concerns

- Bioenergy harvesting could degrade long-term productivity
- HOWEVER
  - Biochar applications can replace C removed during harvesting
  - Improve soil conditions to lessen drought or nutrient stress

Reducing Risks and Increasing Benefits

- **Increase soil water**
  - Decreased wildfire
  - Decrease insect risk
  - Decrease disease risk
- **Increase soil carbon**
  - Climate change
  - Carbon credits
  - Decrease GHG emissions

The Role of Biochar

Residual biomass converted to biochar can:

- Provide value to unmerchantable material
- Increase tree growth
  - ~5-20% (or more)
- Restore
  - skid trails, log landings, road beds
  - water relations
  - carbon sequestration
- Improve soil resiliency
  - less erosion and leaching; improved infiltration; more resilient to floods and droughts

LCA of Biochar

Presented by:

Maureen Puettmann
WoodLife Environmental Consultants
Corvallis, OR

Collaborators
Elaine Oneil
Consortium for Research on Renewable Industrial Materials (CORRIM)

Mark Severy and David Carter
Schatz Energy Research Center
Humboldt State University

CORRIM
Consortium for Research on Renewable Industrial Materials

SCHATZ ENERGY RESEARCH CENTER

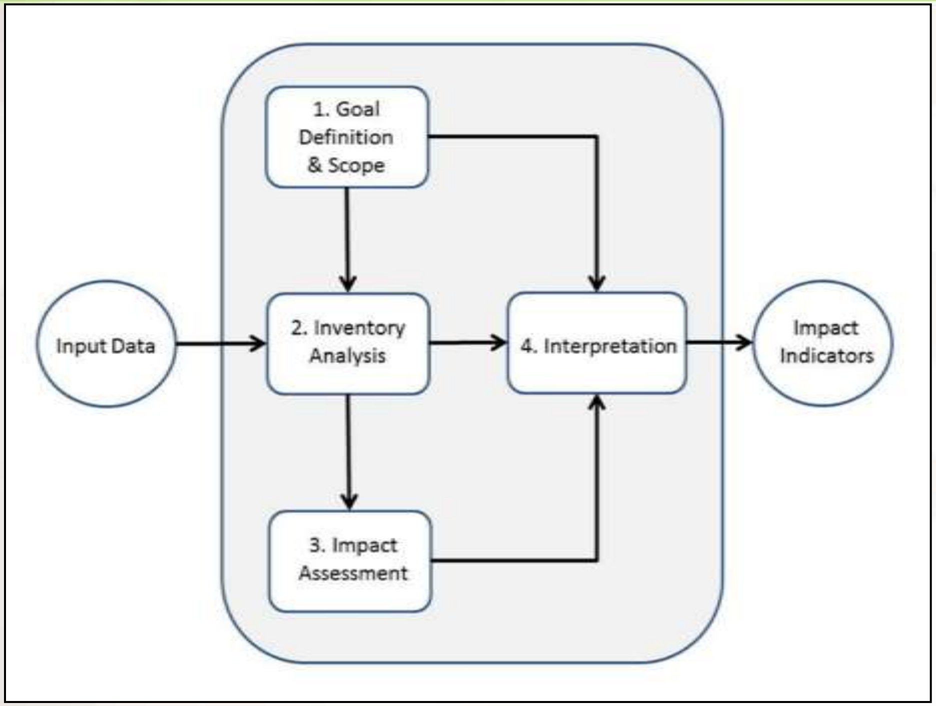
LCA of Biochar

- Task:
  - What are the environmental impacts of producing biochar?
  - Is there a relationship between biochar quality and environmental impacts?
  - Is there a relationship between feedstock quality and environmental impacts?
  - Comparison of different biochar production systems
    - **BSI system**
    - Oregon Kiln
    - Air burners

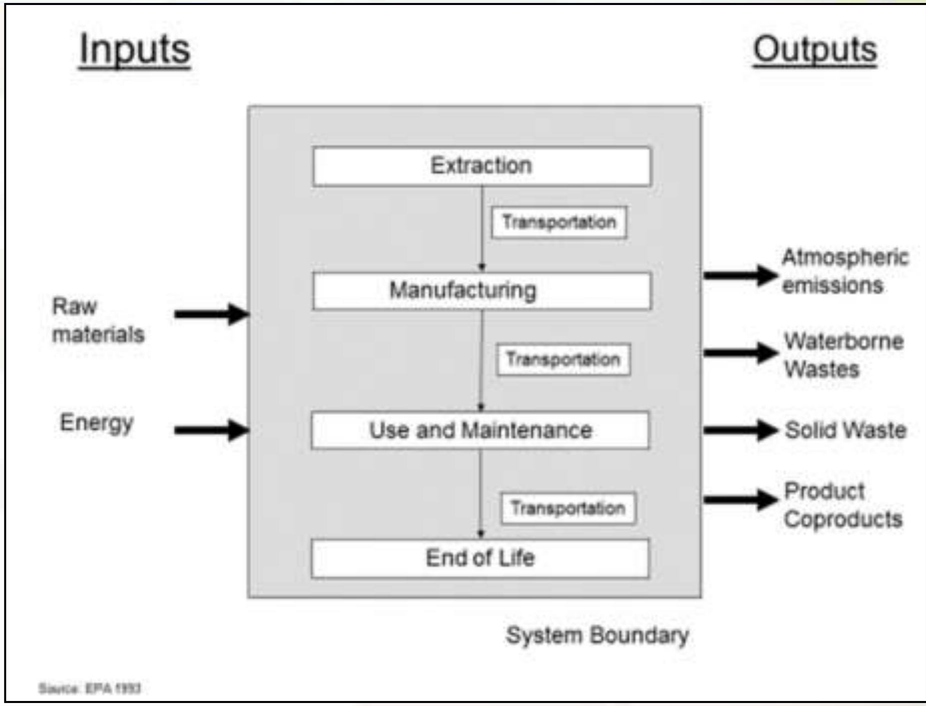
LCA of Biochar

- What environmental impacts are we looking at?
  - Energy consumption
  - Emissions generated? (eg. CO, CO_2, particulates, NOx, CH_4, SO_2)
  - Impact categories such as:
    - **Global Warming Potential (GWP),**
    - Ozone Depletion Potential
    - Smog Potential

LCA Method



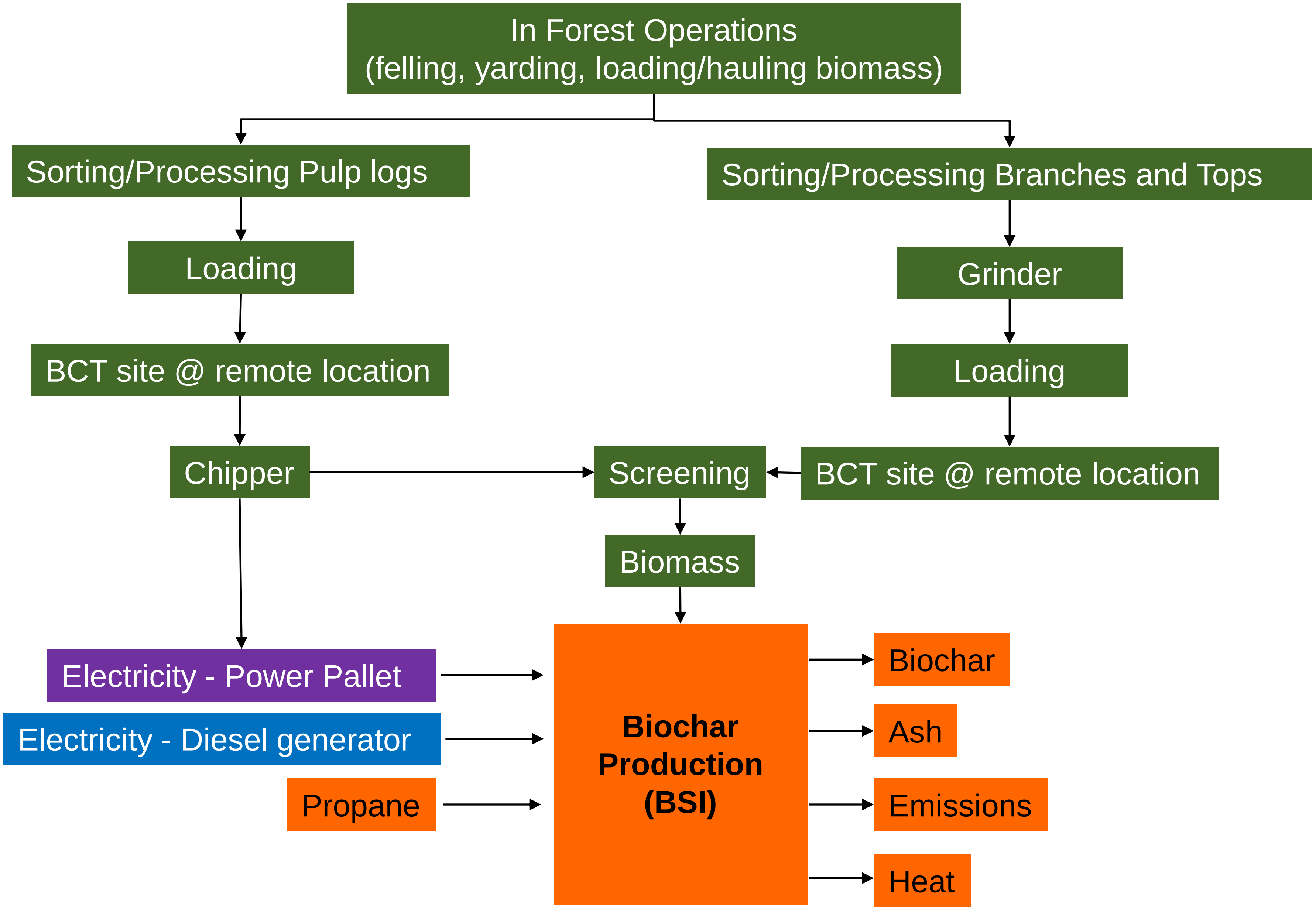
Life cycle inventory



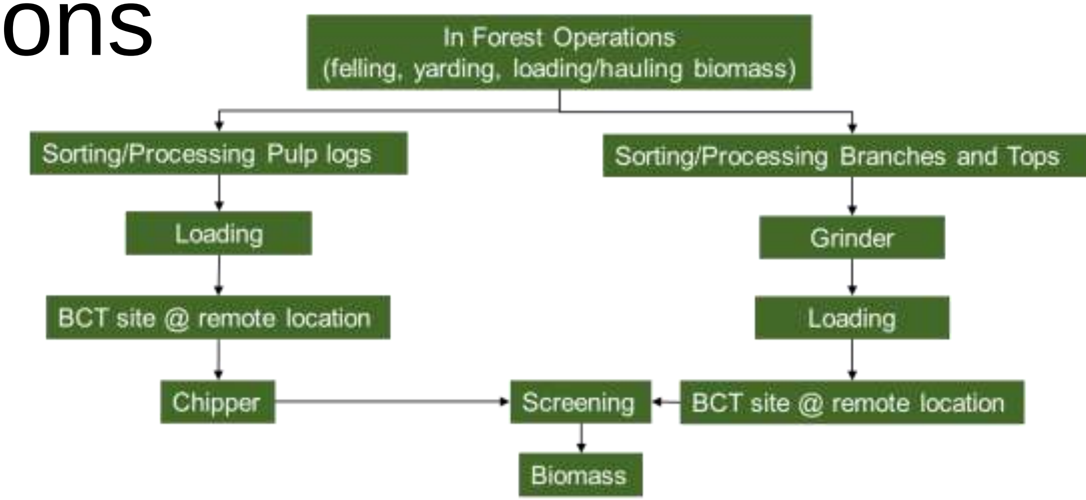
LCA of Biochar

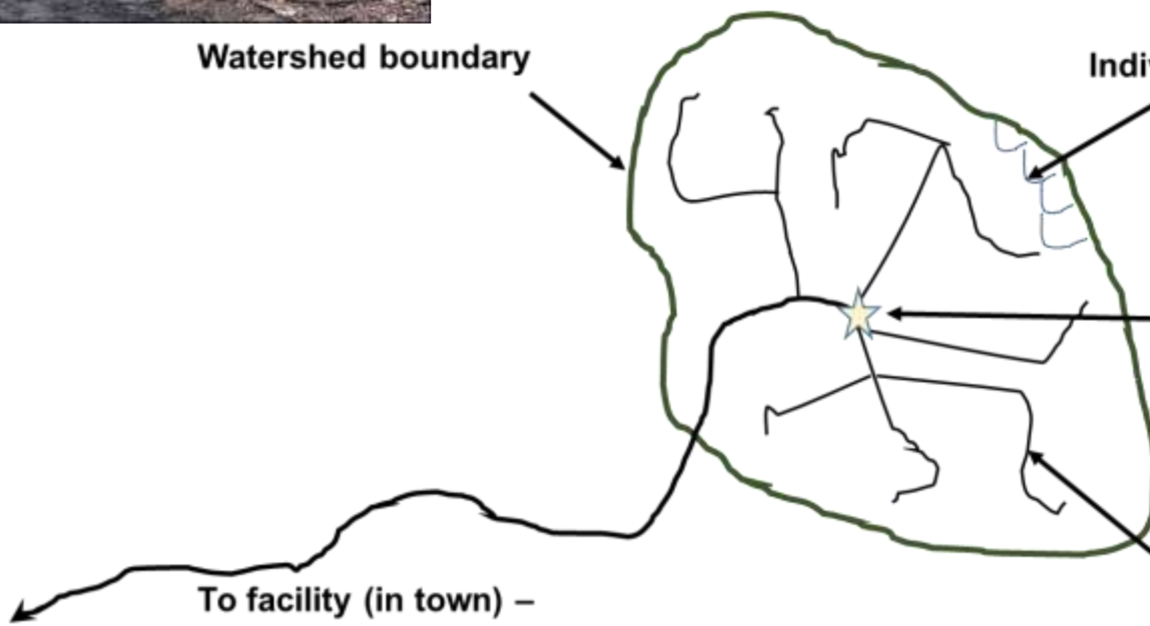
- **Functional Unit**
  - 1 mt of Biochar
- **Cradle to gate (collection through production)**
- **Life cycle data**
  - Forestry operations, feedstock collection, feedstock processing, and transportation *(from Oneil, Waste to Wisdom PI)*
  - Biochar production runs were performed by engineers at the Schatz Energy Center *(Humboldt State U.)*
  - US LCI database
  - Calculations

LCA System Boundary



Forestry Operations





Biochar Production - BSI System

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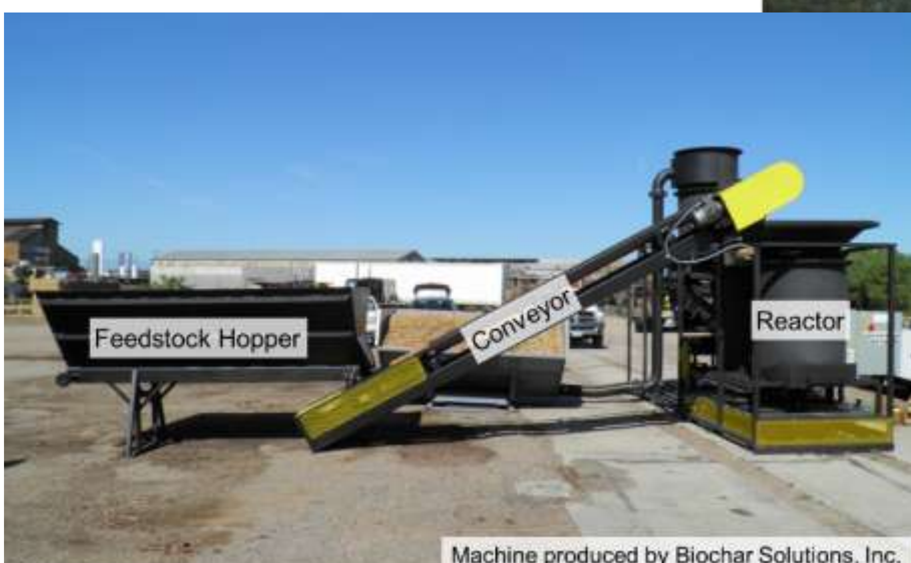
- Testing Goals
  - Develop feedstock quality specifications
  - Measure consumption and production rates
  - Document operational intensity and labor requirements
  - Determine energy requirements
  - Assess environmental impact and fire hazards

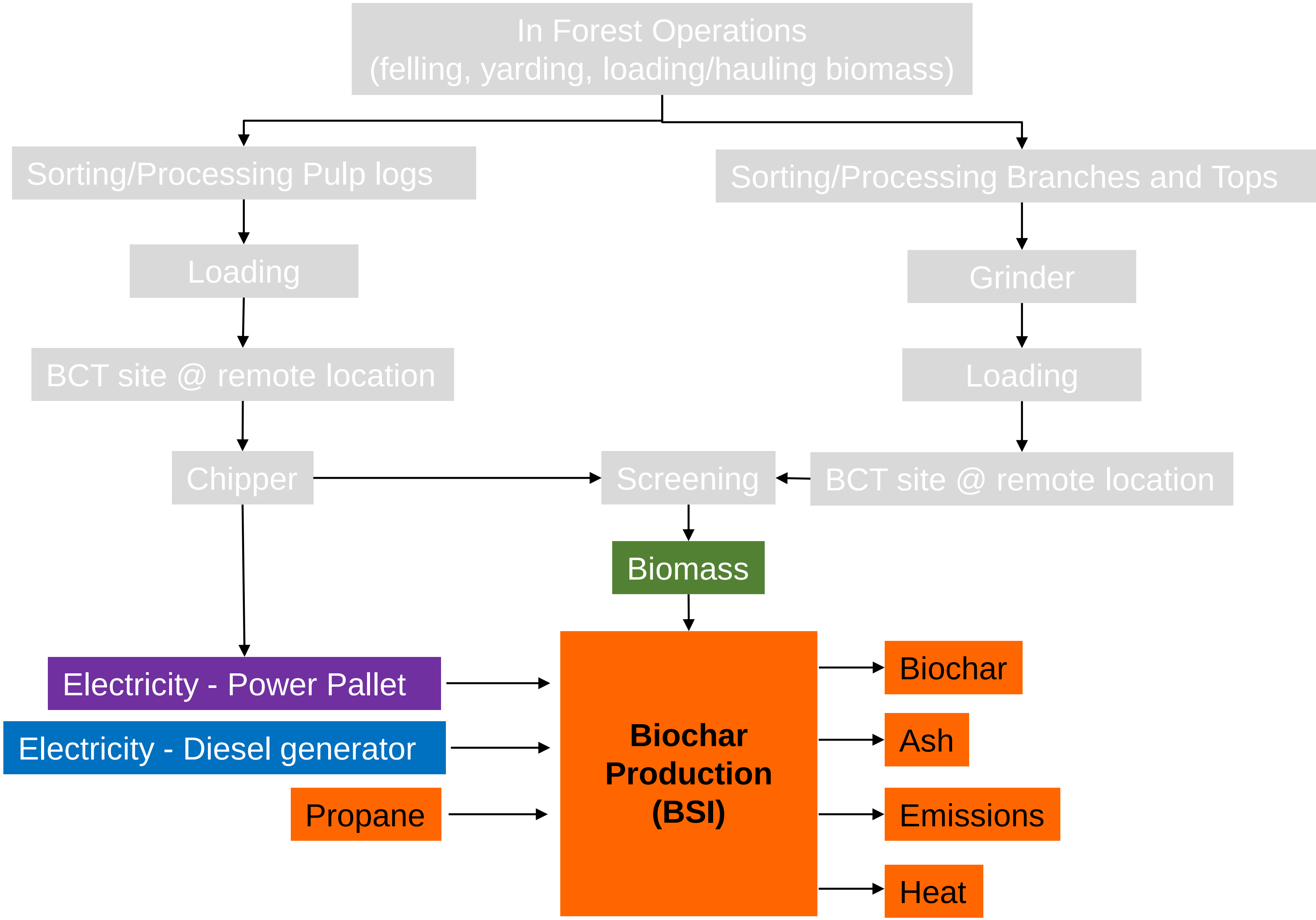
Work credit: David Carter, and Mark Severy

Machine undergoing testing in California



Machine produced by Biochar Solutions, Inc.

LCA System Boundary



Feedstocks

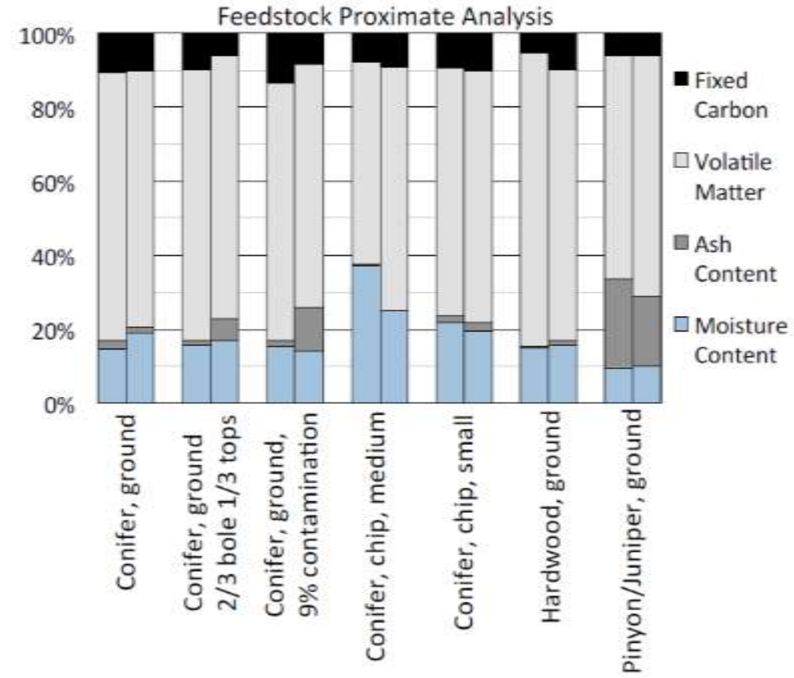


Figure 8. Proximate analysis of feedstock.

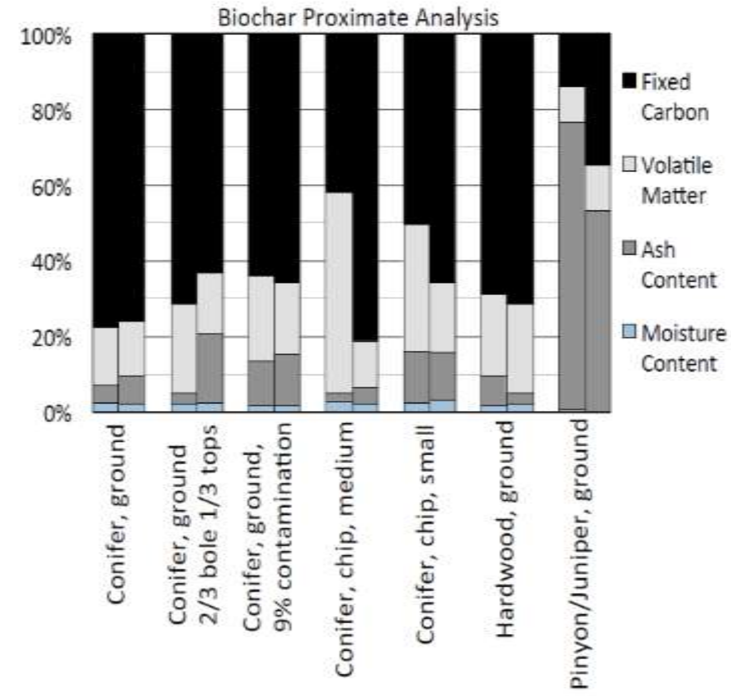


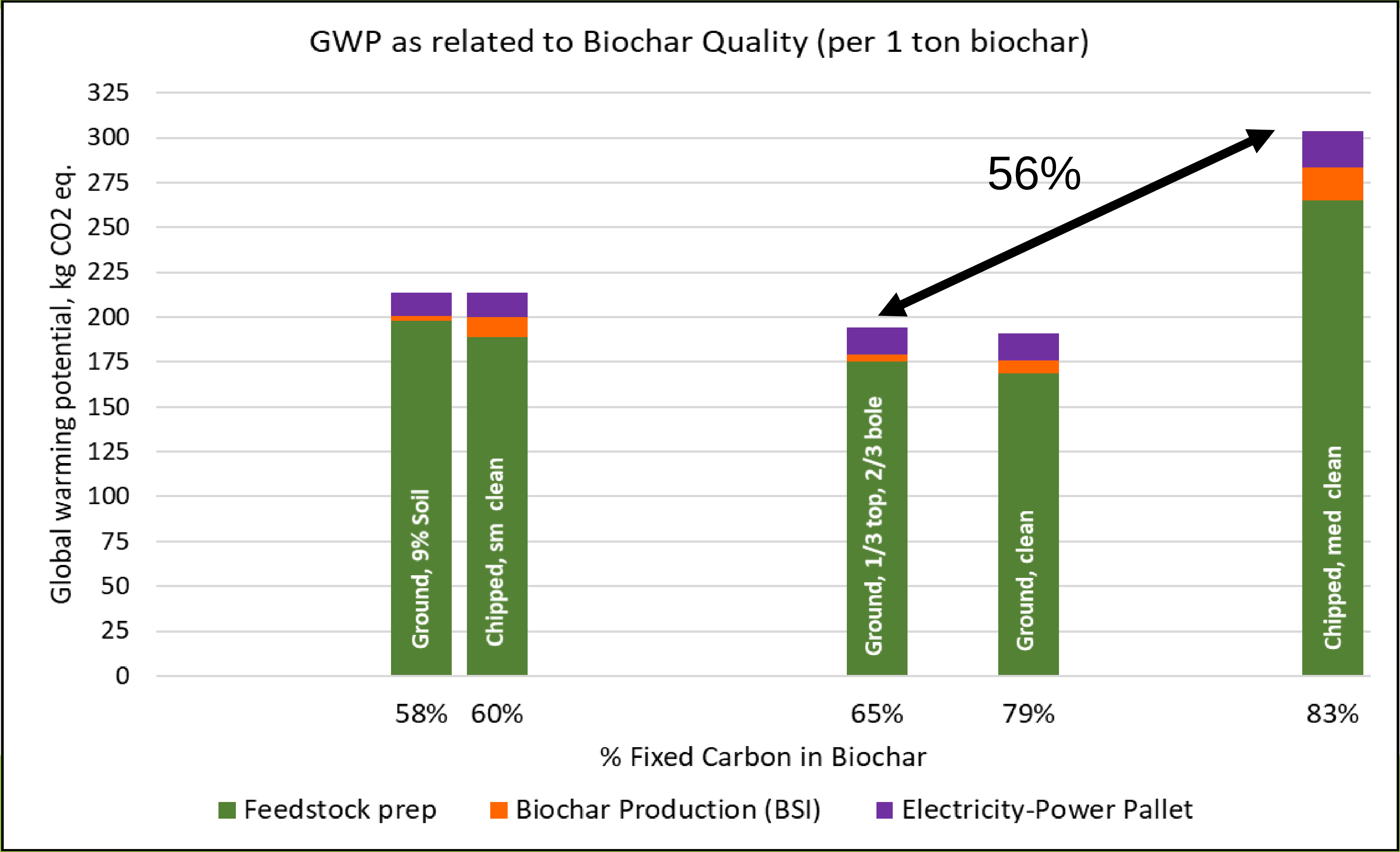
Figure 9. Proximate analysis of biochar.

LCA feedstock criteria
< 25% MC wb
<15% ash

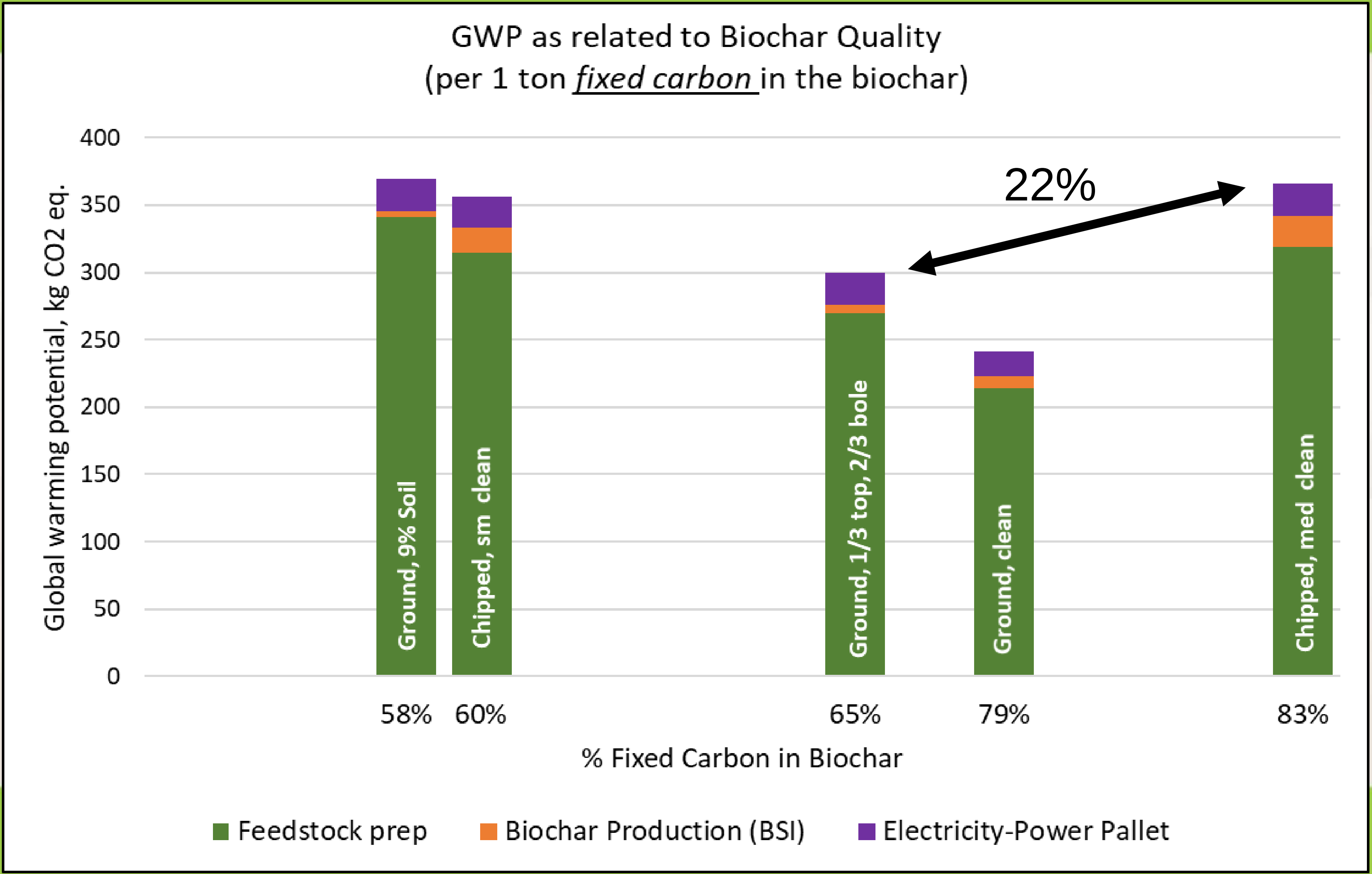
Feedstocks

Species	Conifer	Conifer	Conifer	Conifer	Conifer	Hardwood	Juniper
Comminution Method	Ground	Ground	Ground	Chip med	Chip small	Ground	Ground
Contaminant	none	2/3 bole, 1/3 tops	9% soil	none	none	none	as received*
Moisture Content	15% / 19%	17% / 15%	14% / 16%	37% / 25%	22% / 20%	15% / 16%	10% / 10%
Ash Content	2% / 2%	7% / 2%	14% / 14%	0.7% / 0.1%	3% / 3%	0.3% / 1%	26% / 21%
Particle Size (% mass) (<0.1"/0.1"-1"/>1")	12/80/9	14/77/9	14/77/8	1/99/0	31/69/0	20/79/1	28/64/8

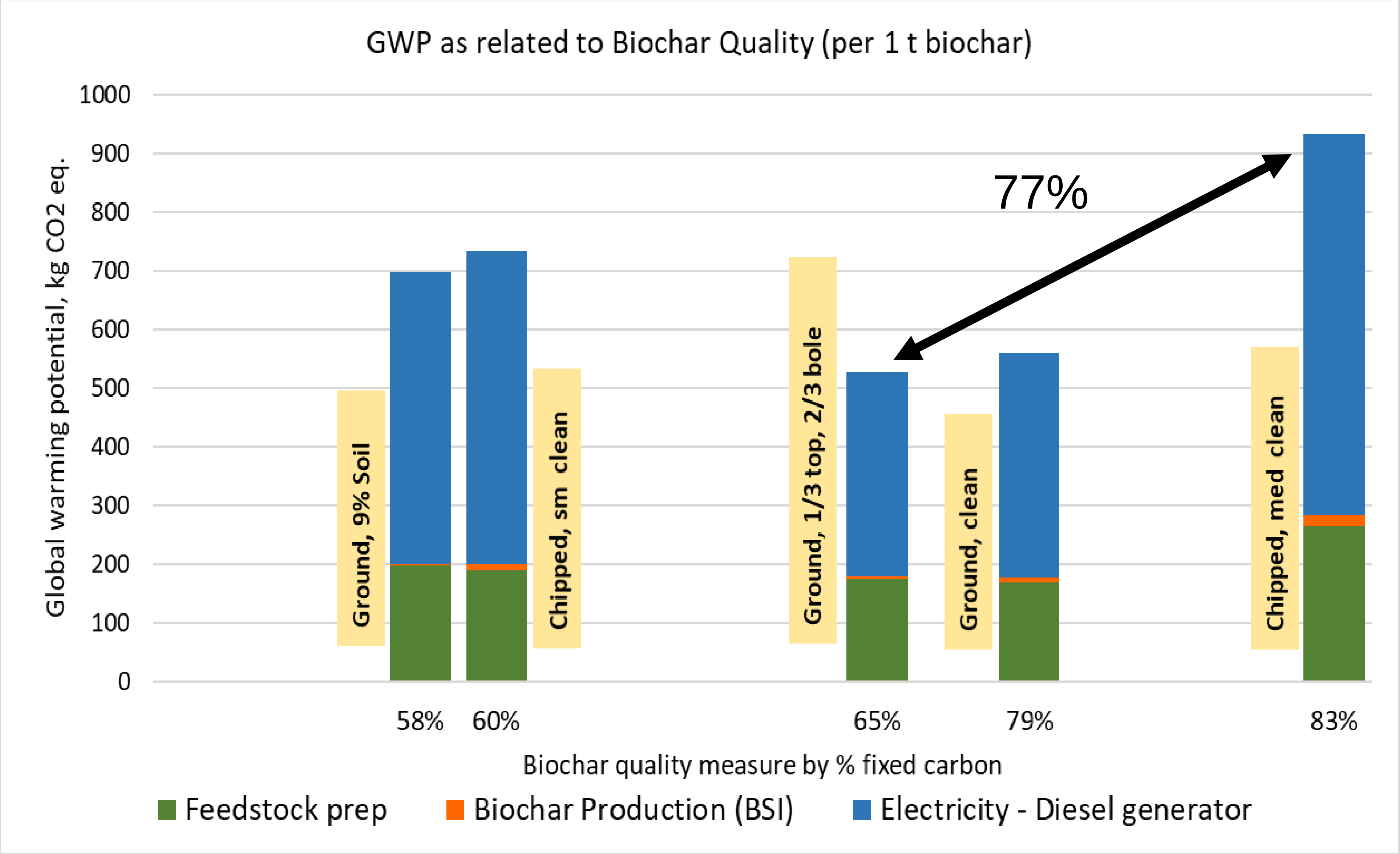
Results - Power Pallet – 1 mton of Biochar



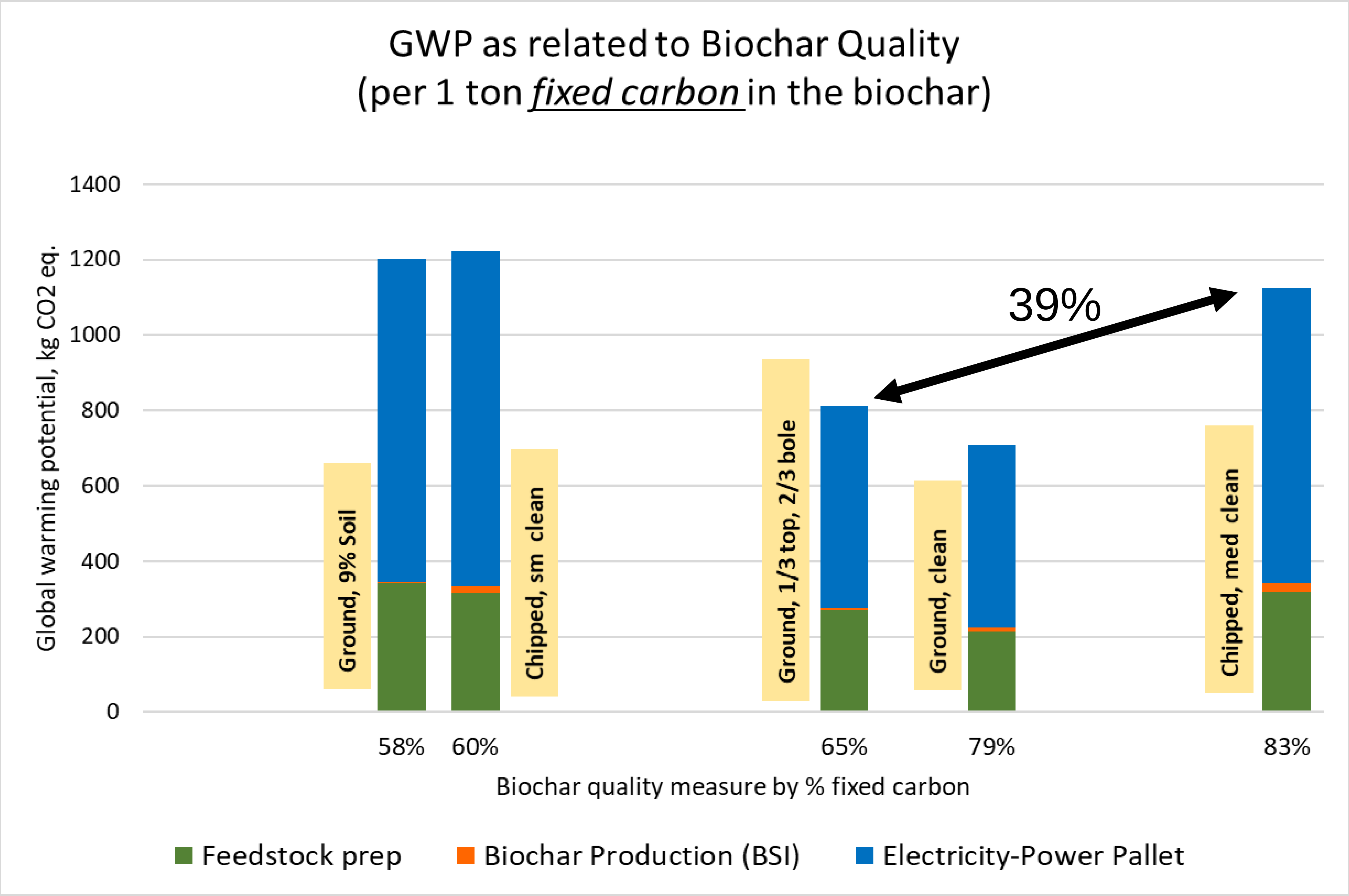
Results – Power Pallet - 1 mton of Fixed Carbon



Results-Diesel Generator- 1 mton of Biochar



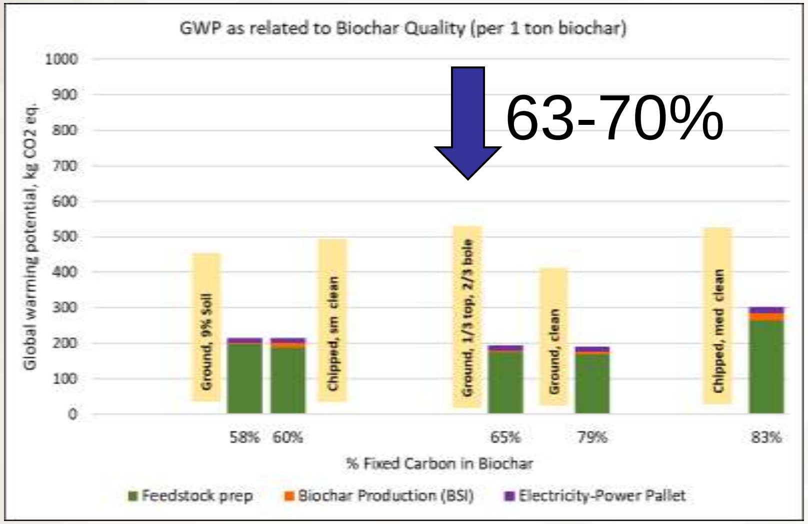
Results-Diesel Generator-1 mton of **Fixed Carbon**

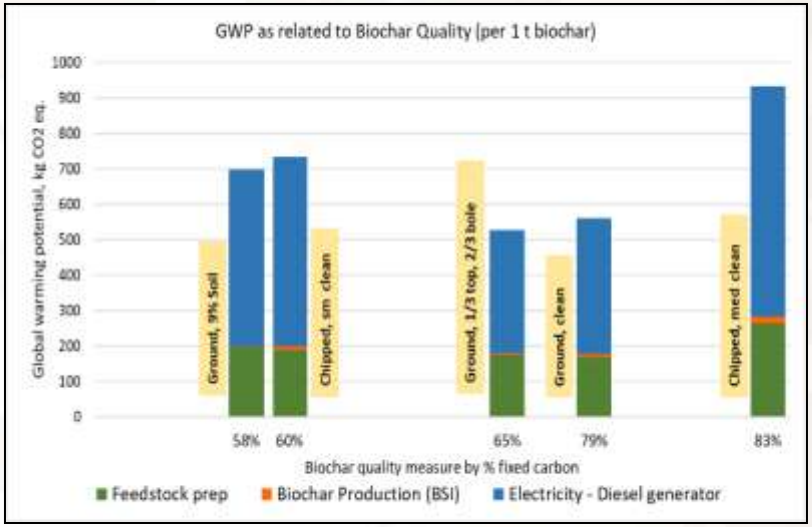


Conclusions - LCA of Biochar

- Relationship between biochar quality and CO_2 emissions
- Biochar Production (BSI): Feedstock should have <25% MC_{wb} and <15% ash

Conclusions - LCA of Biochar





Power Pallet (small gasification generator used to power the biochar machine and/or the drying system) reduced overall kg CO2 eq (GWP) emissions by 63-70% over use of a diesel generator, depending on the feedstock used.

Conclusions - LCA of Biochar

- Does quality come with an environmental cost?
  - Biochar equivalent output - higher quality biochar resulted in a higher GWP impacts
  - When the impact was scaled to a ton of fixed carbon
    - the differences in overall impact based on biochar quality was reduced
    - Lower biochar quality had the highest environmental cost.

Conclusions – Next steps

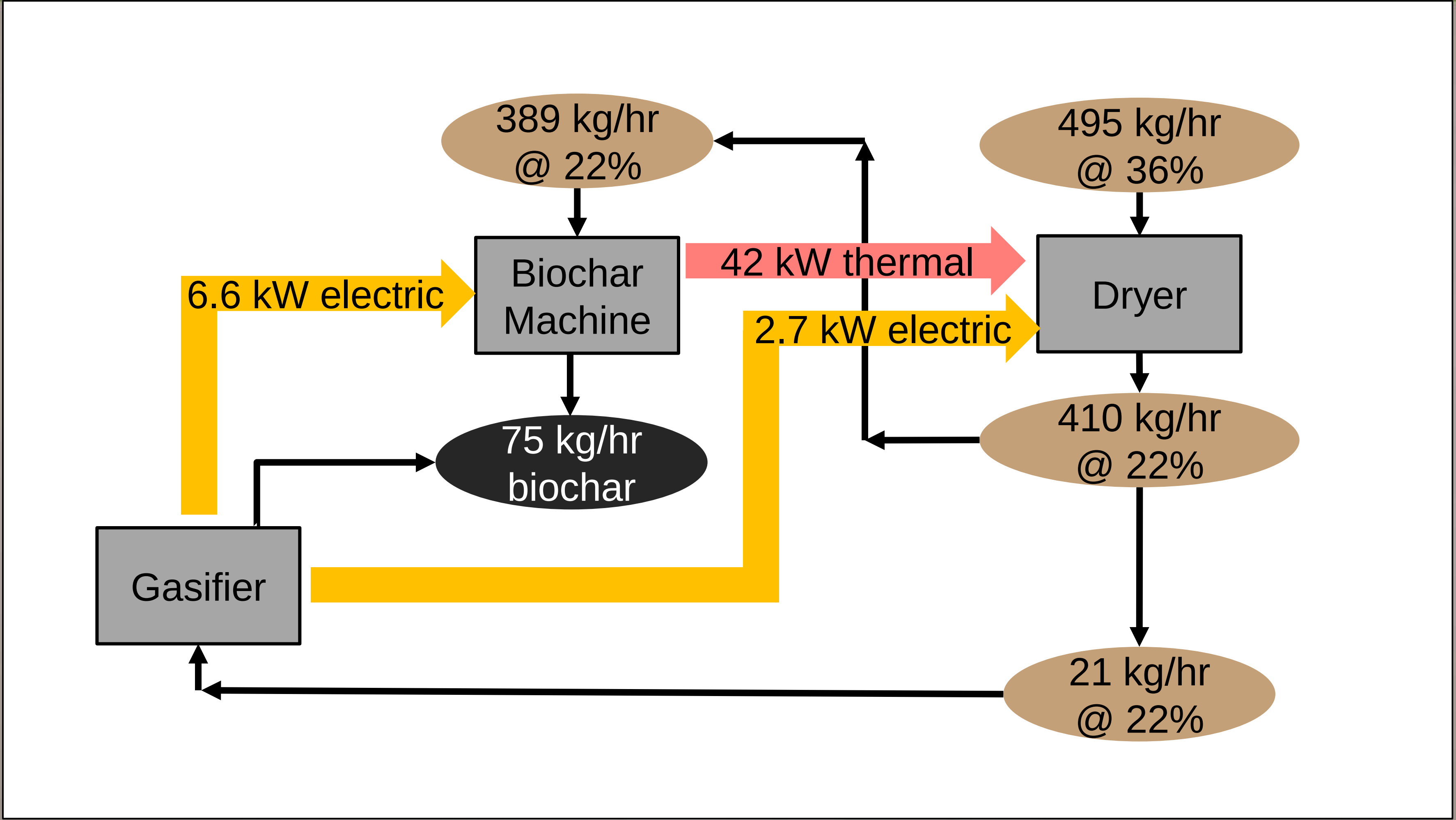
- Setting standards for biochar (% fixed carbon)
  - –What amount of environmental impact are we willing to accept for biochar quality?
  - –What is an acceptable quality of feedstock and biochar to make the production process a “carbon benefit”
  - –Do other impacts categories respond to biochar quality like GWP?
- Impact of taking the forest residues (feedstocks) to town for processing?
- Other biochar production systems (eg. Oregon Kiln, Air Burners)?

The Economics of Near-Forest Woody Biomass Biochar Manufacture

E.M. (Ted) Bilek
Economist
USDA Forest Service, Forest Products Laboratory
p. 608-231-9507
tbilek@fs.fed.us
www.fs.fed.us

Biochar Integrated System Design

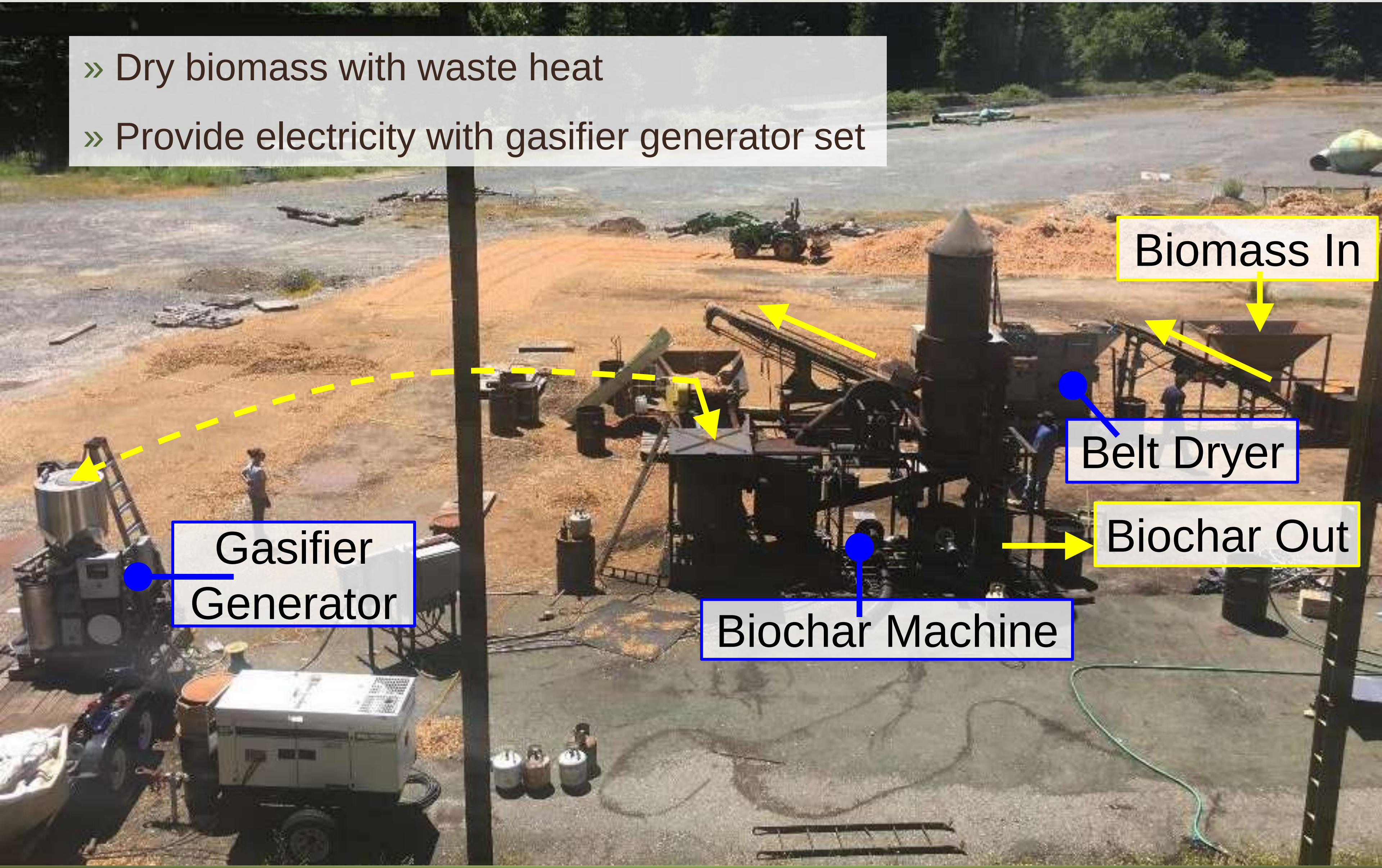
- Produced 75 kg/hr of biochar with no external inputs.
- System can be operated by one person.



Biochar Integrated System Design

» Dry biomass with waste heat

» Provide electricity with gasifier generator set



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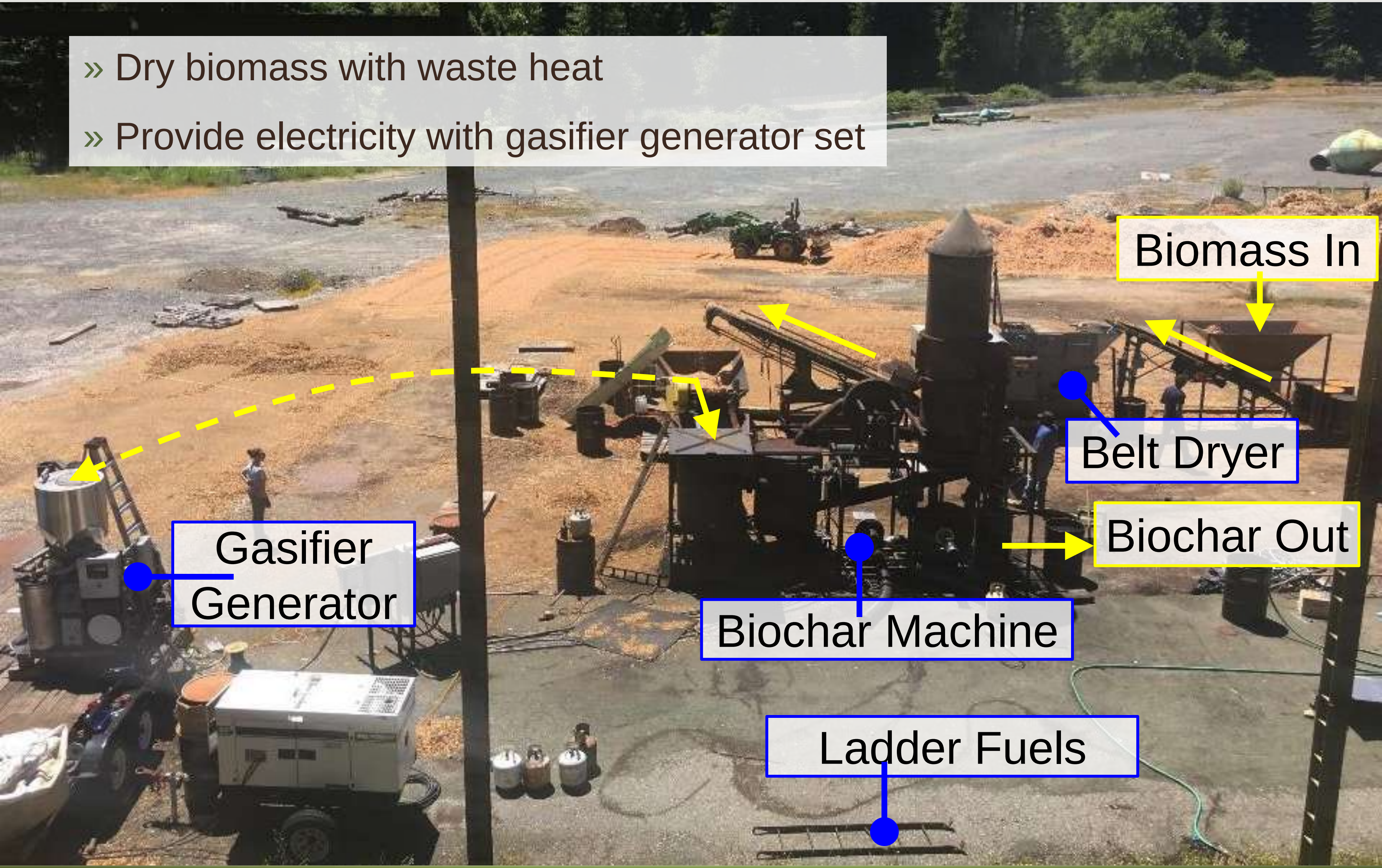

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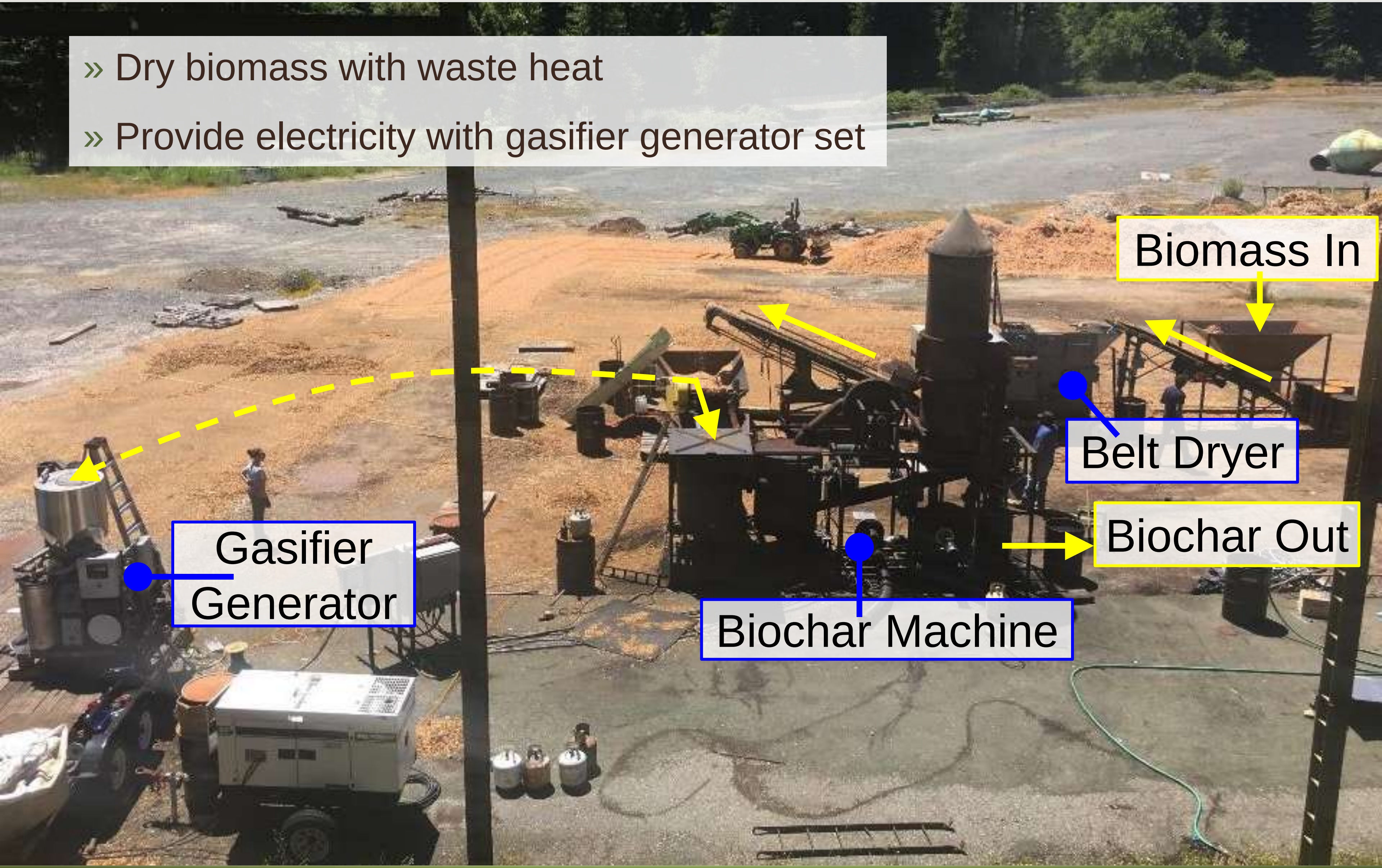
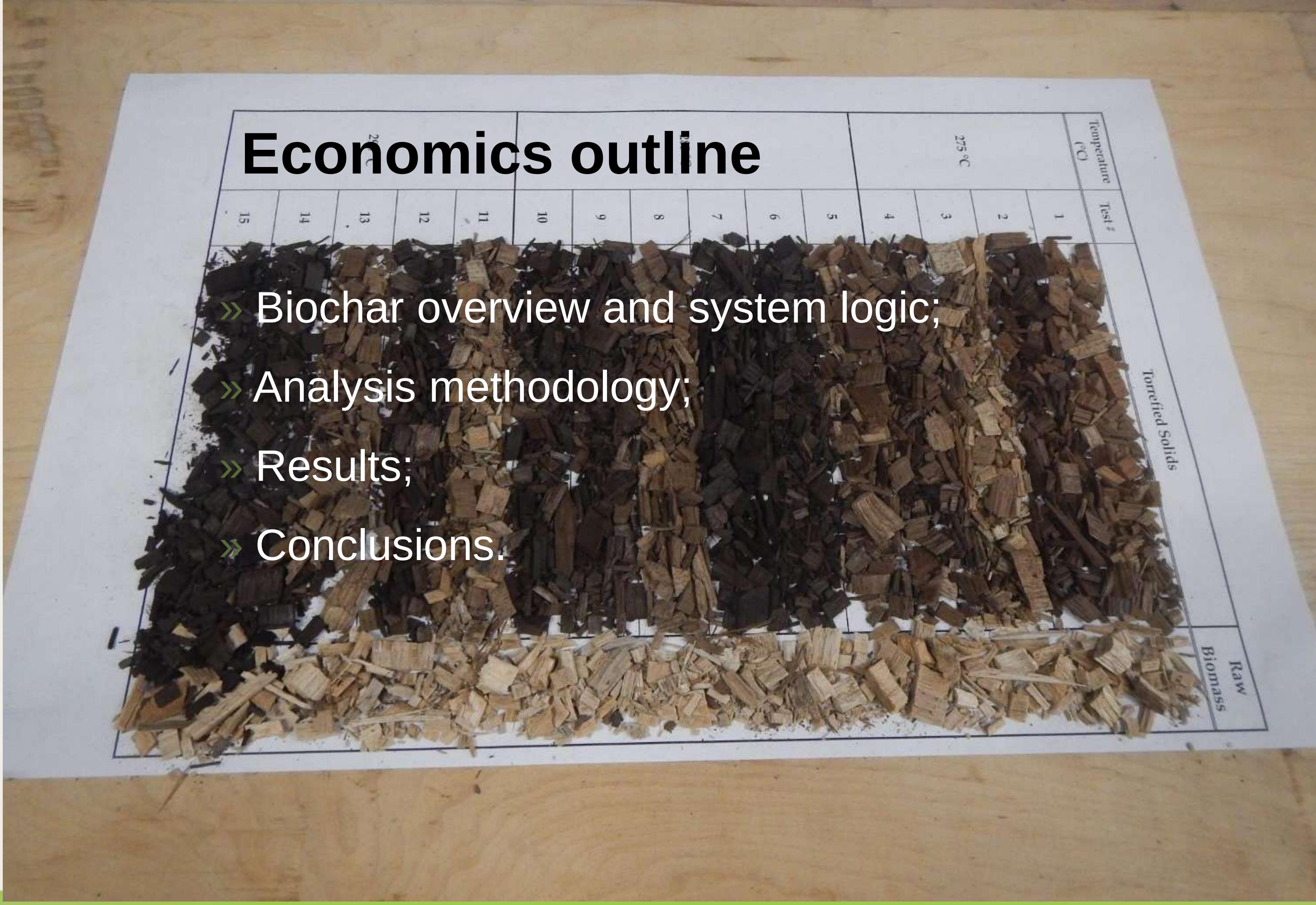


Economics outline

- Biochar overview and system logic;
- Analysis methodology;
- Results;
- Conclusions.



What to use to make biochar?

Preferably, a feedstock without much variation…

wood chips (<3/4 inch) | micro-chips (<1/4 inch) | sawdust (<5/32 inch)

Biochar-ready feedstock production costs

Biochar feedstock input is 0.50 BDT/PMH

Basic biochar production assumptions:

- Commercial-scale system cost: $489,500 (120 tons/year)
  - Biochar unit: Biochar Solutions machines @ $250,000 & $400,000
  - Dryer: Norris Thermal Technologies Belt-o-matic 123B @ $45,000
- Economic life: 10 years (8 hours/day, 250 days/year)
- Salvage value: 20%
- Feedstock throughputs: 0.354 & 0.502 BDT/PMH
- Biochar mass conversion = 13.5% & 15.9%
- Operation = 2,500 SMH @ 80% productivity
- Feedstock = Microchips @ $13.12/BDT (= $8.43/green ton, including loader, but not transport)

Other important assumptions:

- Electricity supply: PowerPallet (PP20) gasifier genset from All Power Labs @ $0.3869/kWh – also provides drying heat
- Loader cost @ $22.57/SMH
  (machine cost calculation w/o labor)
- Discount rate: 10%
  (pre-tax nominal w/ cost & revenue inflation @ 1% & 0% respectively)
- Product value: $2,000/BDT, FOB plant
- Tax losses are: recognized immediately
  (not carried forward or lost)
- Loan = 40% of initial capital cost
- Loan terms: 6 years at 6.00% with monthly payments

Methodology: Discounted Cash Flow Analysis

BASIC ASSUMPTIONS

Note: all costs and revenues are in Year 0 dollars.

Overall project assumptions

Project planning life		10 years
Standard operating days/year		250
Scheduled daily machine operating hours (daily SMH)		8.0
Cost inflation rate		1.0%
Revenue inflation rate		0.0%

Project financing

Required mininum nominal pre-tax risk premium on invested capital		8.5%
Deposit interest rate (APR)		1.50%
Initial gearing (% of total start-up cost that is financed)		40.0%
Loan interest rate (APR)		6.00%
Loan term		6.00 years
Loan and deposit payments per year		12
Working capital required as a percentage of next year's sales		2.0%

Capital assets

Deperciation code		DB
Terminal asset value multiplier		100%

Fixed operating costs

General administration ($/year)	$	2,000
Administration staff (number)		-
Site lease ($/year)	$	-
Equipment lease ($/year)	$	-
Annual insurance percent		1.6%
Other annual fixed costs ($/year)	$	-

Taxes

Income tax rate		40.0%
Tax losses or net tax credits are…		recognized immediately
Biomass utilization tax credit	$	-
Ad valorem (property) tax mill rate		-

Variable operating costs

Plant operators		1.00
Variable labor cost ($/worker/scheduled hour)	$	33.25
Electricity cost ($/kWh)	$	0.3869
Binder cost ($/lb)	$	-
Standardized repairs & maintenance percentage		20.0%
Repairs & maintenance function		Uniform
Liquid propane ($/gallon)	$	2.39
Periodic consumables cost		
Additional periodic consumables cost		
Misc. variable operating costs ($/scheduled hr.)	$	22.570
Other variable consumables cost ($/ton biochar	$	-
Finished goods transport cost ($/ton)	$	-

Conversion variables

Biochar system feedstock throughput (bone-dry tons/PMH)	0.50
Biochar system mass conversion/bone-dry ton of feedstock (%)	15.9%
Feedstock removal (bone-dry tons/acre)	18.00
Electrical energy required	9 kW
Binder required (lb/Biochar ton)	-
Liquid propane (gallons/productive hour)	-
Thermal production (million Btu/Bone-dry ton feedstock throughput)	2.94
Feedstock moisture content	35.8%
System start-up time (hours/day)	1.21
System shut-down time (hours/day)	0.79

Demonstration-scale Results (72 tons/year)
(w/product price = $2,000/BDT)

Summary Financial Measures: Semi-mobile Biochar Conversion System from Biochar Solutions	*Before-finance & tax*	*Before-tax*	*After-tax*
NPV ($000)	$ (351)	$ (338)	$ (210)
Real IRR (adjusted by cost inflation at 1.0%)	-21.4%	-26.2%	-17.3%
Nominal IRR	-20.6%	-25.5%	-16.4%
NOTE: Nominal discount rates used to calculate NPVs and B-E values	10.00%	8.40%	5.04%
(Assuming 1.0% cost inflation, 0.0% revenue inflation, and 40.0% gearing at 6.00%)		*IRR seed =*	-50%
Break-even avg. Biochar product value ($/ton)	$ 2,839	$ 2,750	$ 2,662
Break-even delivered yr. 1 feedstock cost ($/green ton)	$ (62)	$ (54)	$ (47)
Medium-term operating B-E avg. product value ($/ton)		$ 2,171	
Short-term operating B-E avg. product value ($/ton)	$ 2,040		

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For-profit biochar production at a demonstration scale (72 tons/year) is not recommended without additional capital or operating subsidies.

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- Break-even feedstock costs are the costs (or subsidies) at which NPVs=$0

Demonstration-scale Results (72 tons/year)
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- Break-even product values are the prices at which NPVs=$0
- Break-even feedstock costs are the costs (or subsidies) at which NPVs=$0
- Medium and short-term product values will keep the plant open either for the next year or for the next day.

Commercial-scale Results (120 tons/year)
(w/product price = $2,000/BDT)

Summary Financial Measures: Semi-mobile Biochar Conversion System from Biochar Solutions	Before-finance & tax	Before-tax	After-tax
NPV ($000)	$ 8	$ 68	$ 90
Real IRR (adjusted by cost inflation at 1.0%)	9.2%	10.8%	8.8%
Nominal IRR	10.3%	11.9%	9.9%
NOTE: Nominal discount rates used to calculate NPVs and B-E values	10.00%	8.40%	5.04%
(Assuming 1.0% cost inflation, 0.0% revenue inflation, and 40.0% gearing at 6.00%)		*IRR seed =*	-50%
Break-even avg. Biochar product value ($/ton)	$ 1,989	$ 1,910	$ 1,831
Break-even delivered yr. 1 feedstock cost ($/green ton)	$ 10	$ 17	$ 25
Medium-term operating B-E avg. product value ($/ton)		$ 1,384	
Short-term operating B-E avg. product value ($/ton)	$ 1,277		

- NPVs are positive and nominal IRRs are all above the discount rates;

Commercial-scale Results (120 tons/year)
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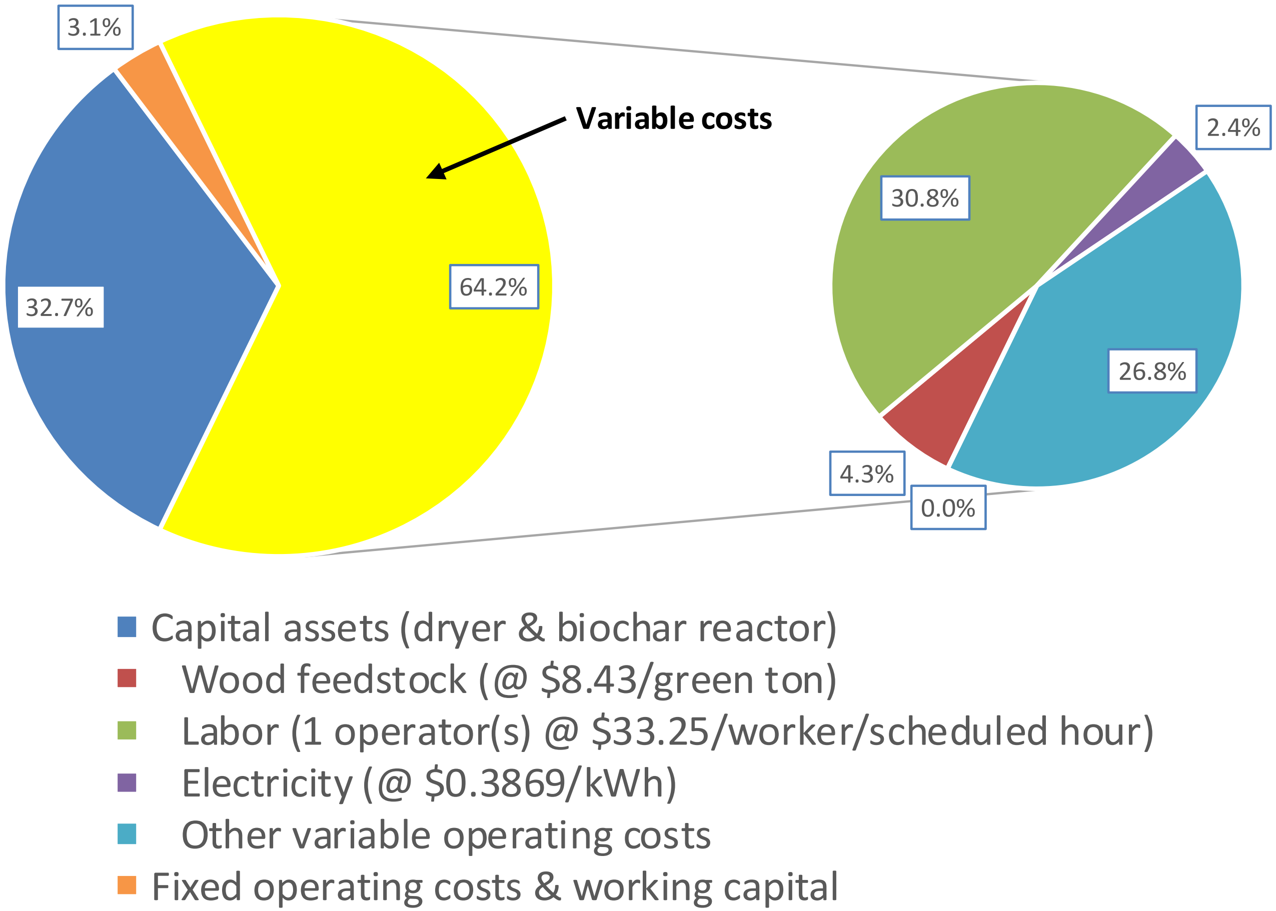
- NPVs are positive and nominal IRRs are all above the discount rates;
- Break-even product values are below the target price.
- Feedstock prices are positive.

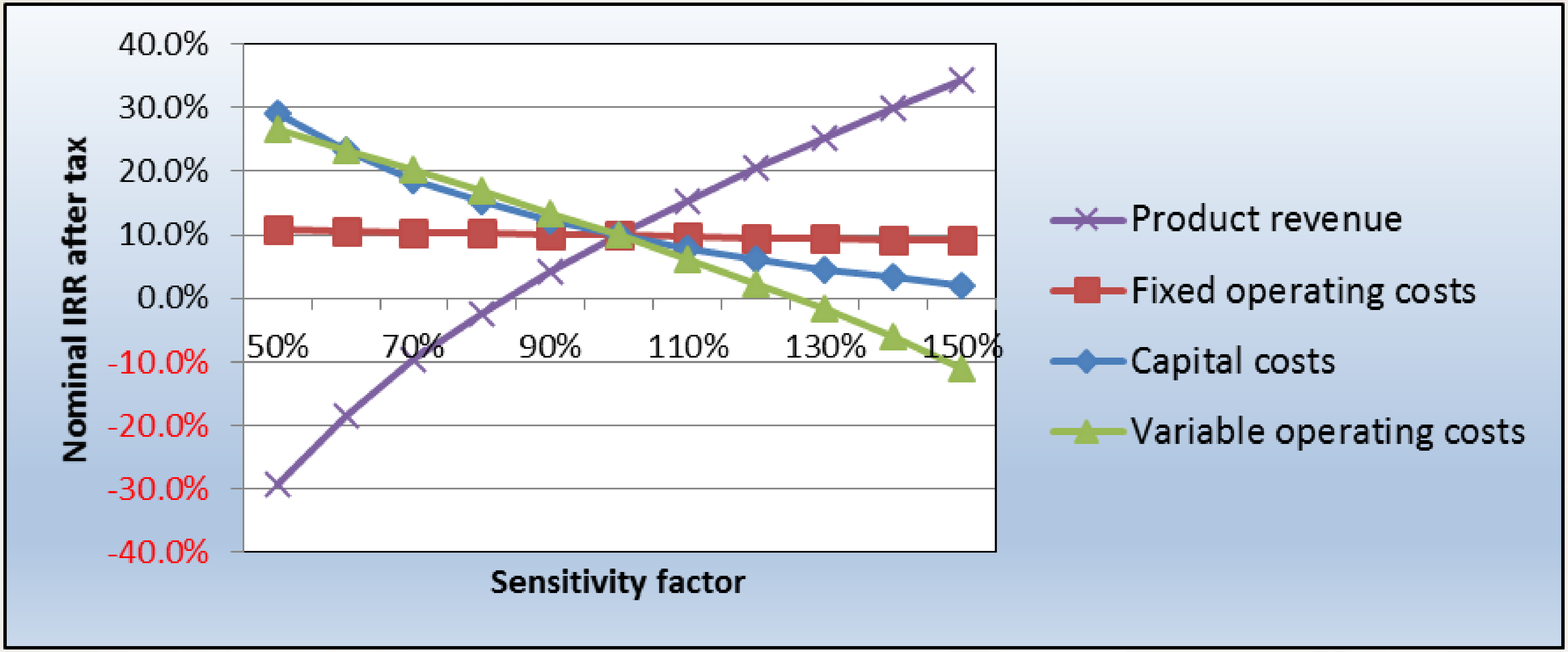
Cost breakdown: Before-finance & tax



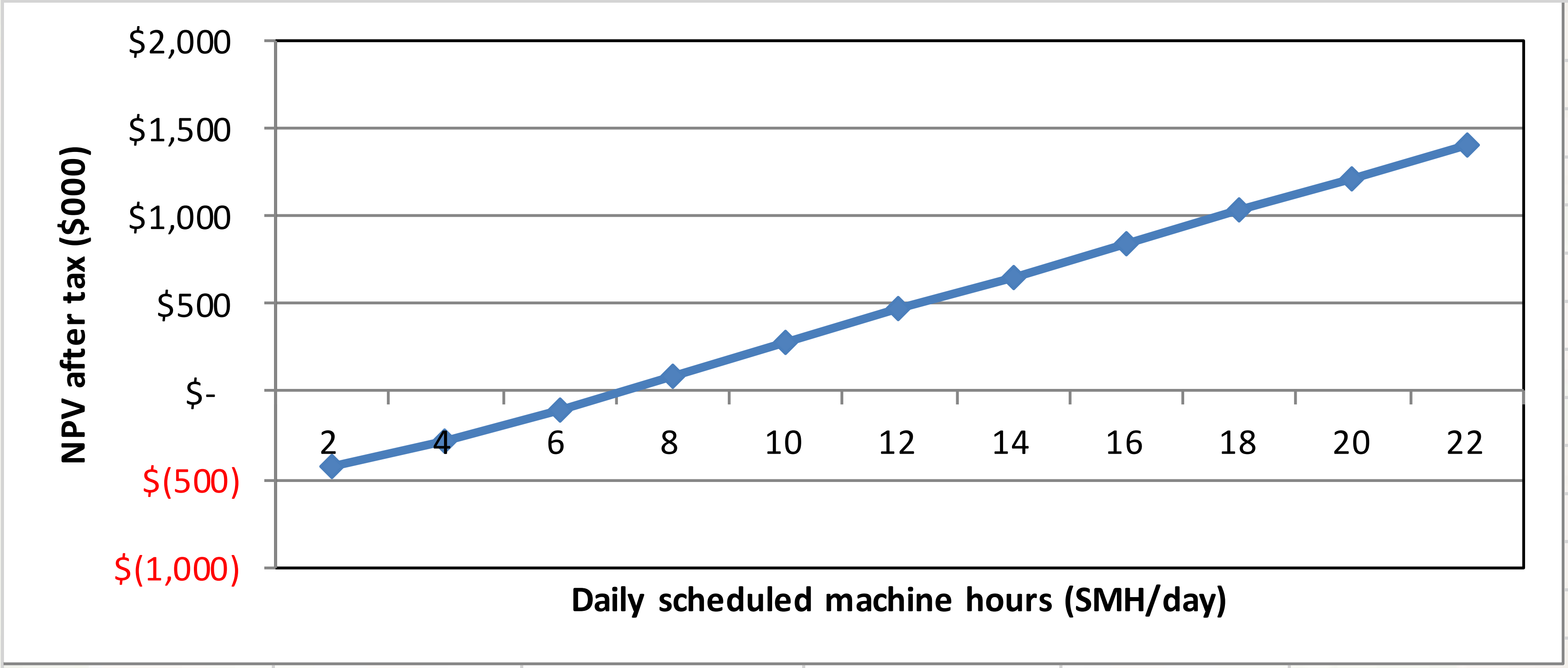
Total costs discounted at 10.00% nominal before-finance & tax over 10 years with variable costs highlighted

NOTE: Total annualized costs = $226,595 and total annualized revenues = $227,895

Biochar plant's simple sensitivity analysis



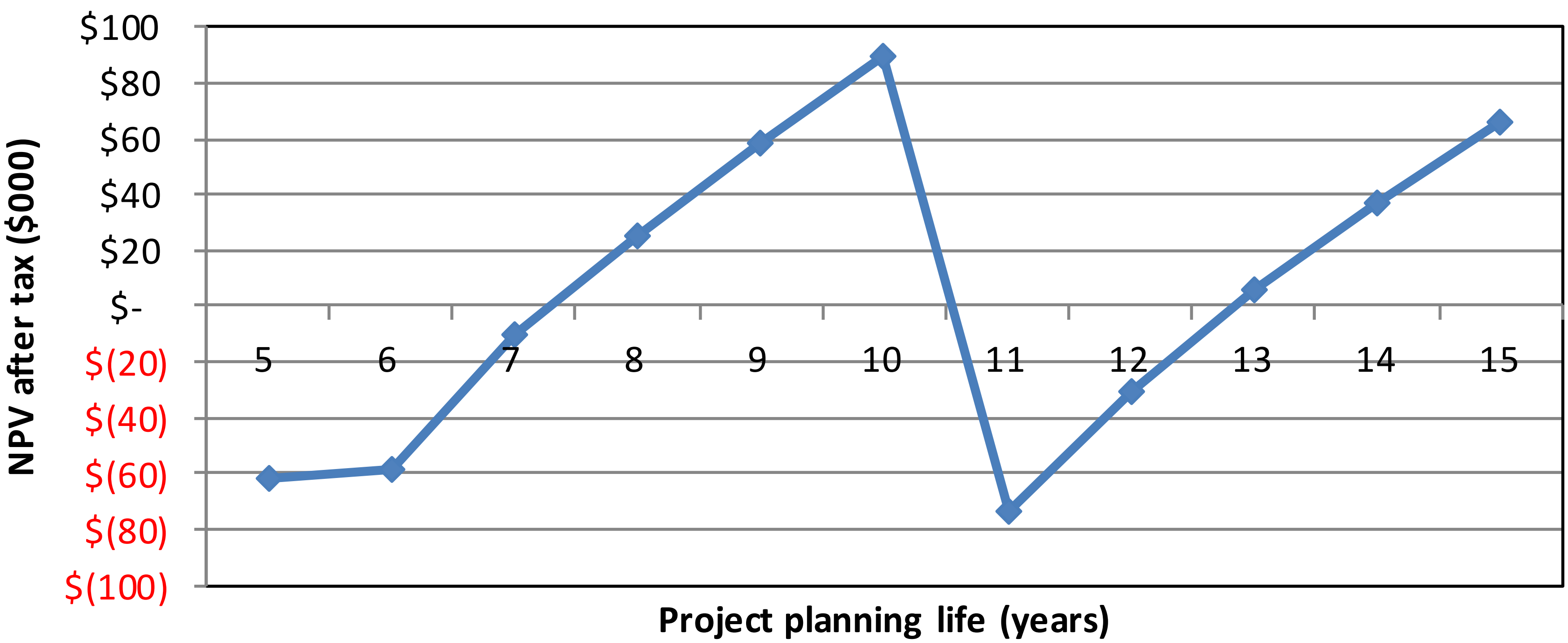
Biochar plant's profitability sensitivity to the operating day length



Sensitivity of Biochar Plant's NPV after tax to the Standard operating day (scheduled hours/day)

NOTE: NPV after-tax discount factor is 4.00% real, or 5.04% nominal with 1.00% cost inflation

Biochar plant's profitability sensitivity to the project planning life



Sensitivity of Biochar Plant's NPV after tax to the Project planning life (years)

NOTE: NPV after-tax discount factor is 4.00% real, or 5.04% nominal with 1.00% cost inflation

Economic Drivers

- Alternative disposal costs
  - Pile burn ($150-$850/acre)
  - Torrefaction (value = $200-$250/ton delivered)
  - Other energy
- Markets…

Biochar Markets

- » Soils (primary market)
  - » Need to match specific biochars to crops and soil types
  - » Biggest potential lies where crops are higher-valued, especially where water is scarce or costly
  - » Even larger value-added potential lies in possible replacement for activated carbon (esp. trace mercury removal or soil decontamination, water or air filtration, public health/sanitation, etc.)
- » Composting (can reduce composting time, GHG emissions, and odors)
- » Growing media (i.e. vermiculite and perlite and peat moss substitutes)
- » Other bio-based wastes can also be made into biochar
- » Chicken & egg issues with respect to biochar's cost-effectiveness (which lead to financing issues which limit scale economies)
- » Carbon sequestration

Conclusions

» Small-scale near-woods biochar production may make economic sense.

- » Costs are relatively high;
- » Labor is a big part of the total cost.
- » Costs as presented could be lowered.

» Biochar represents a highly value-added product made from waste resources. It can be used directly and offers the opportunity to be combined with other ingredients to create additional value. It can be produced near a forest and offers opportunities to concentrate biomass value to facilitate more cost-effective transport.

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More research is needed.

Thank You

Questions?

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General Contact Info at: http://www.wastetowisdom.com/contact-us/

Debbie Page-Dumroese.
Research Soil Scientist
USDA Forest Service
Rocky Mountain Research Station
Moscow, ID
ddumroese@fs.fed.us

E.M. (Ted) Bilek, Ph.D.
Economist
USDA Forest Service
Forest Products Laboratory, Madison, WI
tbilek@fs.fed.us

Maureen Puettmann
Forestry Consultant
WoodLife Environmental Consultants
Corvallis, OR
maureen.puettmann@woodlifeconsulting.com