Techno-economic Analysis of Biochar Production Using Portable Systems

Kamalakanta Sahoo

Richard Bergman

E.M. (Ted) Bilek

Forest Products Laboratory, United States Forest Service, One Gifford Pinchot Drive, Madison, WI

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Forest Products Laboratory and Research Priorities

- Founded in 1910 by the U.S. Forest Service and located in Madison, WI
- The Nation's source for unbiased wood research and technical information
- A long history of cooperative research and public service

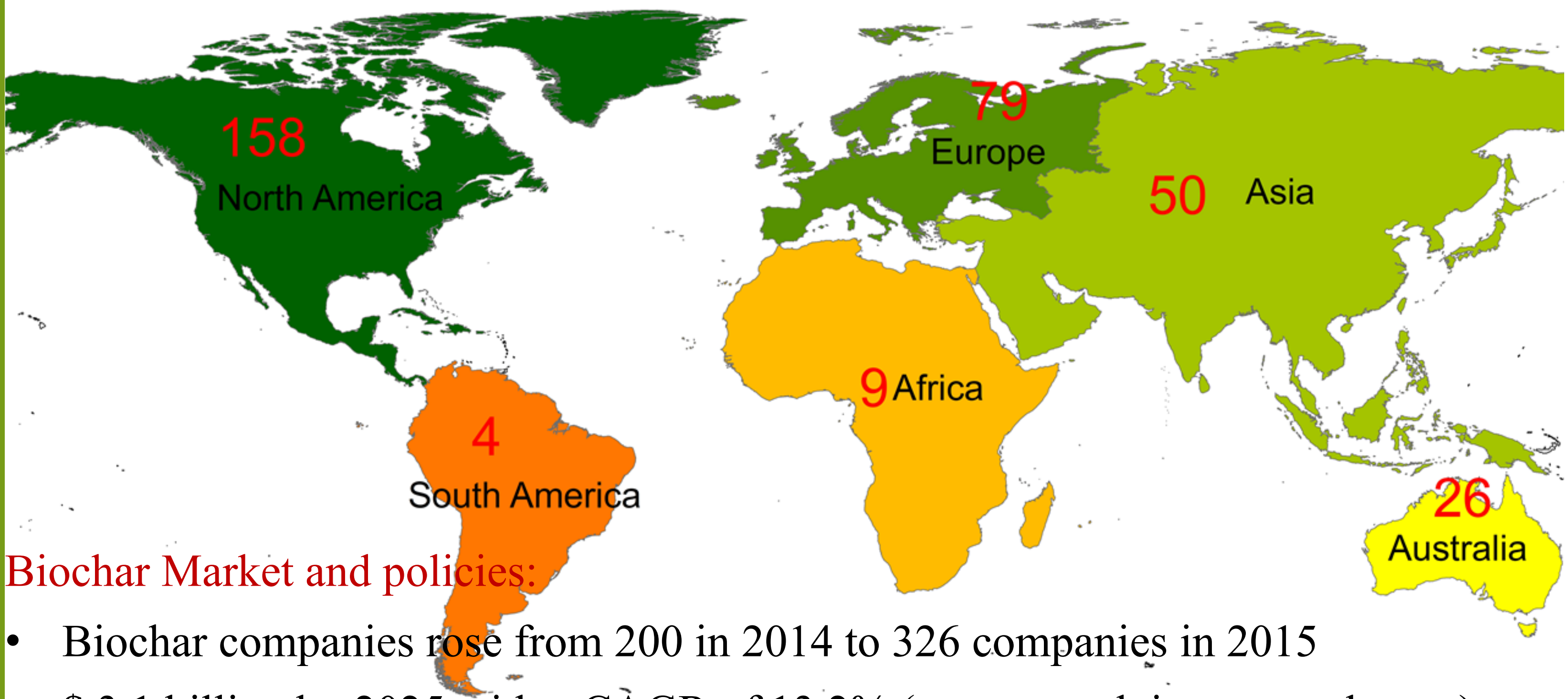
- Advanced Composites
- Advanced Structures
- Forest Biorefinery
- Nanotechnology
- Woody Biomass

- Life cycle assessment and techno-economic analysis of forest based products
- Supply chain modeling, simulation and optimization

Biochar market: Present and Future

Biochar companies in 2015

Source: International Biochar Initiative (IBI)



Biochar Market and policies:

- Biochar companies rose from 200 in 2014 to 326 companies in 2015
- $ 3.1 billion by 2025 with a CAGR of 13.2% (www.grandviewresearch.com)
- US biochar production- 94,000 tonnes in 2014 to 285,000 tonnes by 2025.
- ~35 US policies that support biochar production (15 are commercial financial incentives)
- Biochar price in the US varies between ($1360-3864/ton)

Background: Why biochar?

Piling residues: **$150-200/hectare**

Site preparation:**$750-2000/hectare**

Air quality issues, Wild fires

(81-116 million dry tons of forest biomass)

Liquid biofuels


Heat and electricity

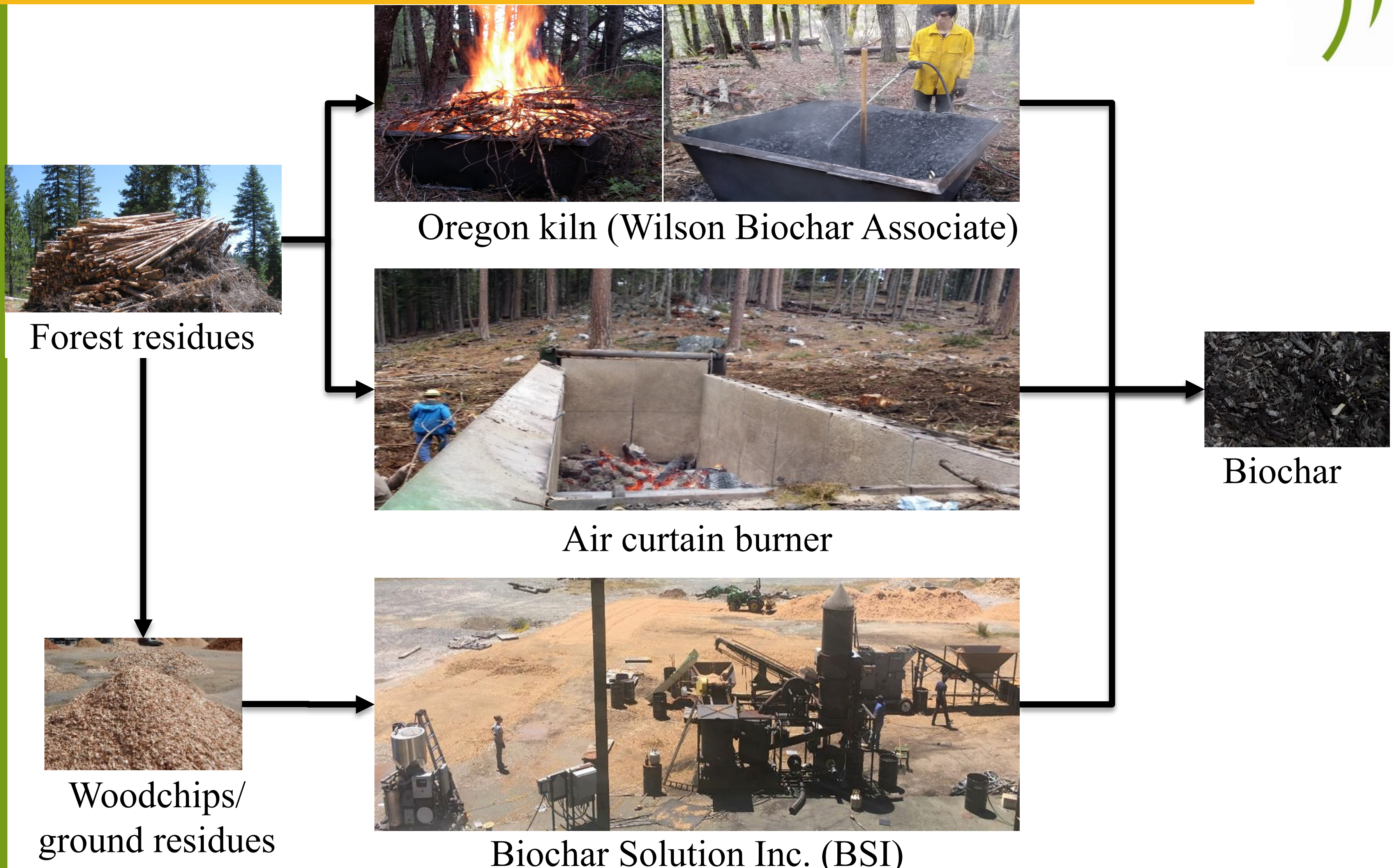
- Require higher quality feedstock (less contamination, low moisture content, uniform-size, etc.)
- Large plant (high capital investment & risks, Higher logistics cost, Uncertainties

Objectives

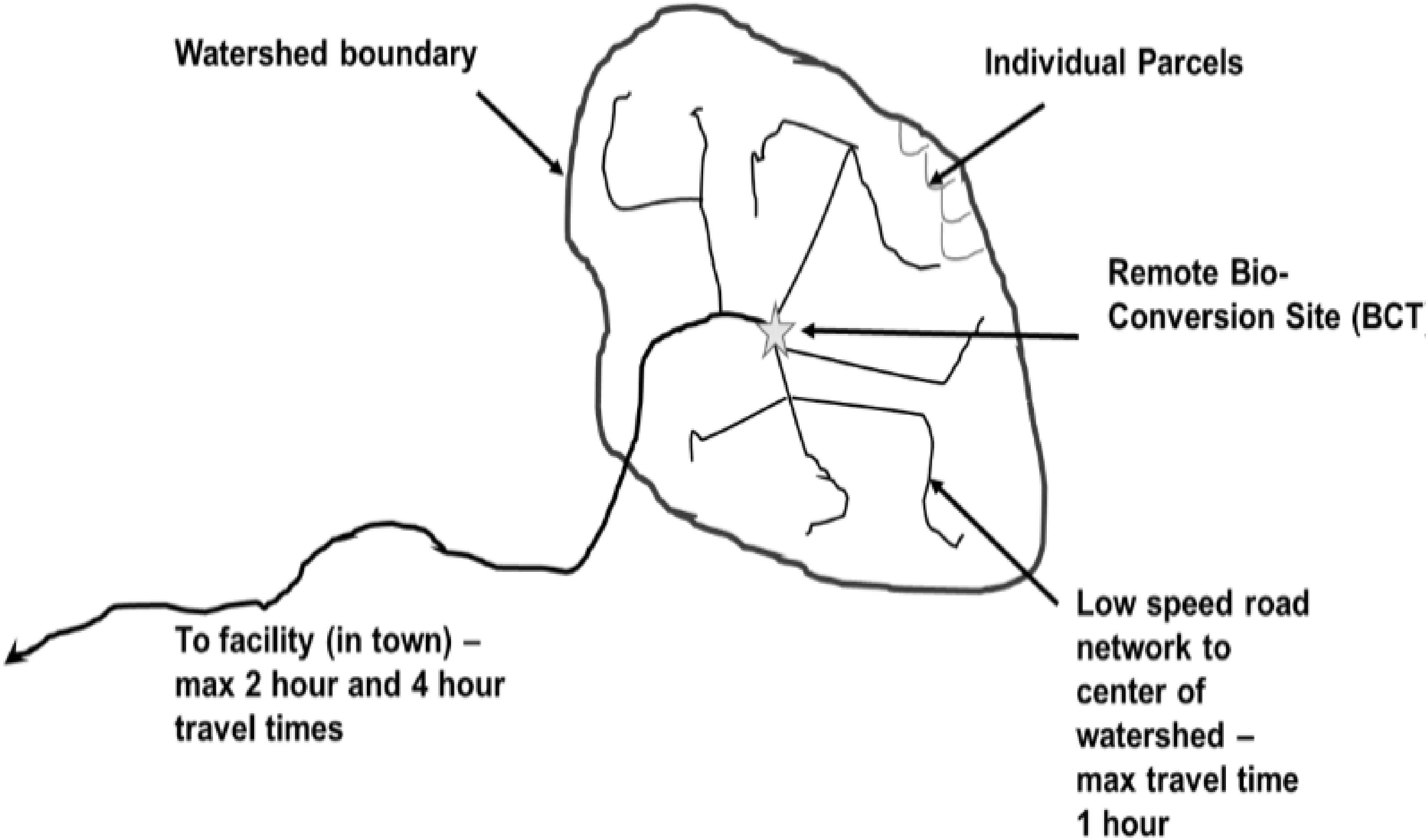
- To analyze the economic feasibilities [i.e., estimate minimum selling price (MSP)] of portable biochar production systems at near-forest (remote sites) and in-town locations.

- To perform sensitivity analyses to identify critical factors affecting economic performances of portable systems and suggest improvements.

Biochar production using portable systems



BSI portable system



Oregon kiln and Air burners portable systems

Oregon kiln

In forest operations
(felling, yarding, loading/hauling biomass)

↓

Sorting boles, branches, and tops

↓

Processing site

↓

Further processing using chainsaws

↓

Biomass

↓

Water → | Biomass production with Oregon kiln | → Biochar
Diesel → | | → Ash
Propane → | | → Emissions

Biochar production with Oregon kiln

Air curtain burners

In forest operations
(felling, yarding, loading/hauling biomass)

↓

Processing site

↓

Biomass

↓

Loading

↓

Water → Biochar production with Air burner → Biochar
Diesel → → Ash
Propane → → Emissions

Feedstocks specifications and system throughput

Species	Contaminant	Comminution method	Moisture content (wet basis)	Portable system	Throughput (*kg/hr/unit) or **kg/batch/unit	Biochar yield (%)
Conifer	None	Ground	16.93%	BSI	*386	14.8%
Conifer	9% soil	Ground	14.91%	BSI	*341	11.7%
Conifer	none	Chip, medium	25.18%	BSI	*351	10.5%
Conifer	none	Chip, small	20.66%	BSI	*268	14.4%
Conifer	2/3 bole, 1/3 tops	Ground No No	16.20%	BSI Oregon kiln Air curtain burner	*434 **45 *10,000	13.2% 20% 20%

Critical assumptions for economic model

- No grants and subsidies included in this study
- Forest residues at no-cost
- 8 hours/day x 100 days of operations in a year (But BSI system with drying unit can work all year with addition of feedstocks drying units)
- BSI system can be used to produce biochar at the near-forest and in-town locations
- Oregon kiln and Air curtain burner used in-forest locations
- 2 BSI units or 12 Oregon kilns or 1 Air curtain burner for the base case
- 10 years economic life of the project
- 15% Required Returns on Invested Capital (ROIC), 2% inflation for cost and revenue, 6% loan interest rate, loan (40% of total capital investment), etc.
- 40% income tax

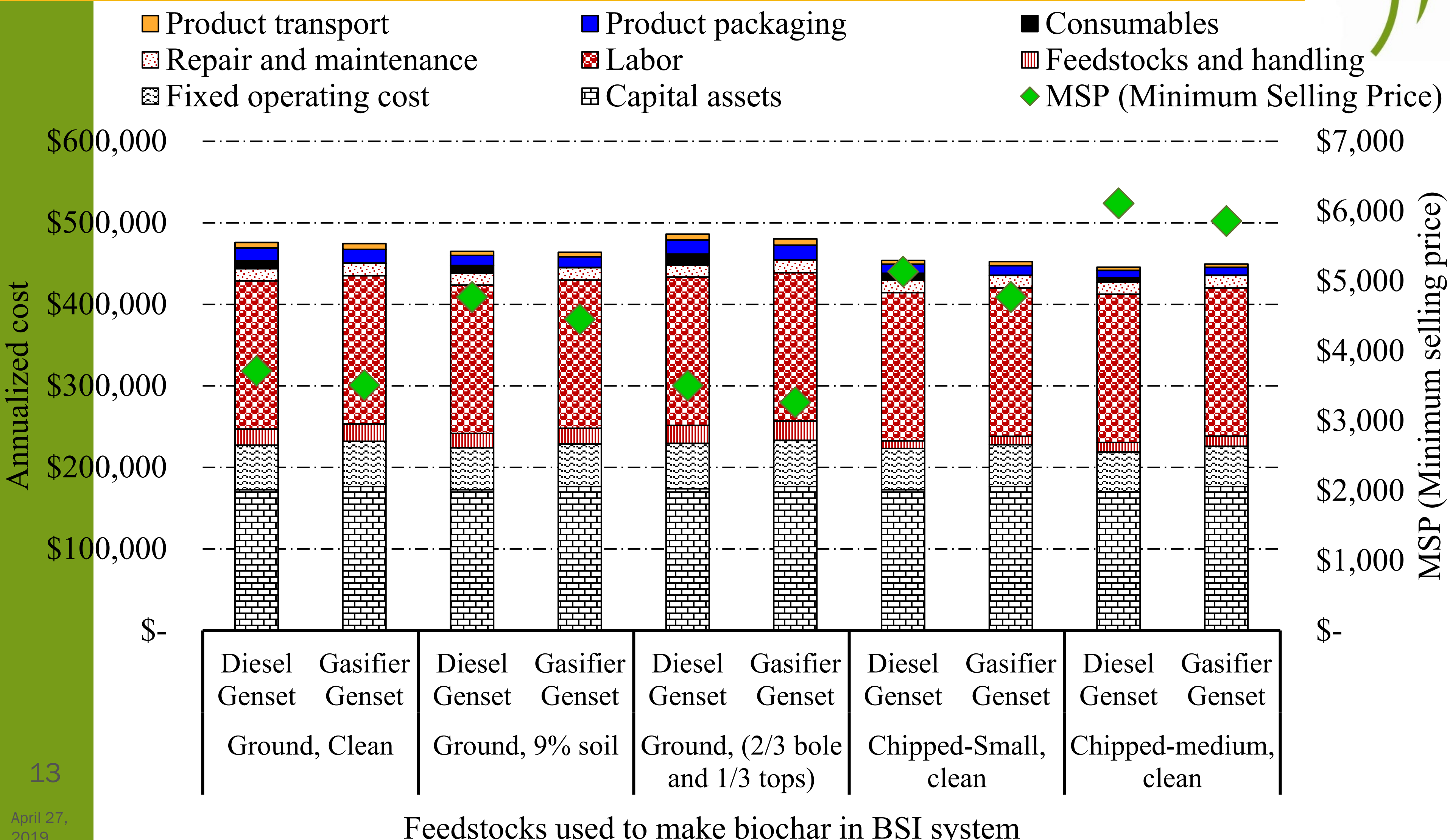
Input data:
Capital costs

	No of units	Equipment	Description	Purchase price($)	Economic life (year)	Salvage Value (%)
BSI	1	Tractor	Front-end loader	15,000	10	20
	2	Dryers	Beltomatic 123B	45,000	10	20
	2	Biochar machines	Biochar Solutions, 0.5 Tonnes/hr	340,000	10	20
	2	Gasifier-Gensets	20 kW, PP20GT gasifier	35,000	10	20
	1	Diesel-Genset	Diesel generator, 40 kW	40,000		
			BSI, Total	***$955,000***		
Oregon Kiln	12	Kiln	Oregon kiln	850	10	0
	6	Shovel		50	10	0
	1	Chain saw		500	10	0
	2	Propane torch		300	10	0
	2	Skidder	CAT-70hp	32,000	10	20
			Oregon Kiln, Total	***$78,100***		
Air burner	1	Air curtain burner	S-327	169,000	10	20
	1	Loader	John Deere 2954D	433,000	10	20
			Air burner, Total	***$602,000***		

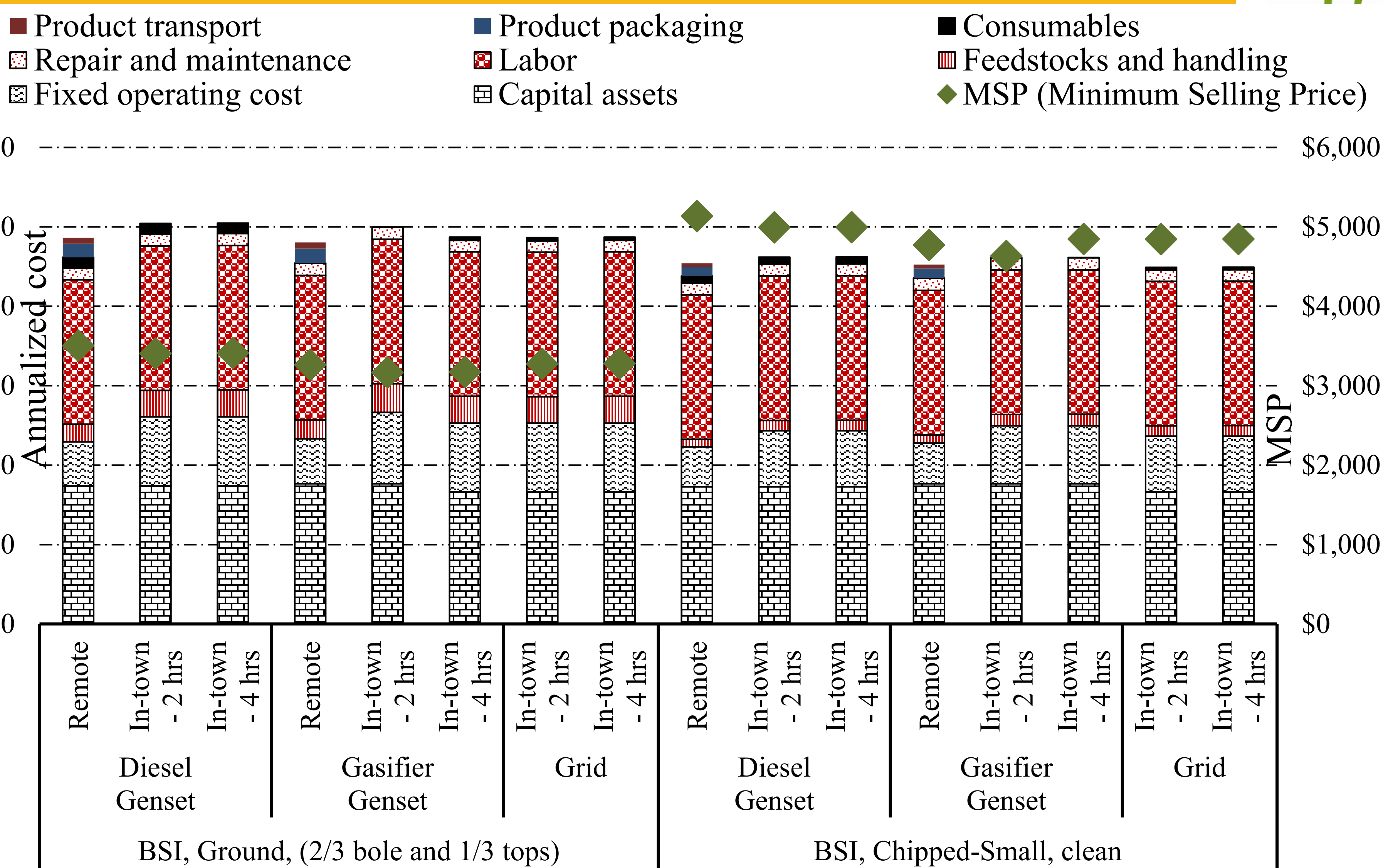
Input data: Operational costs

Descriptions	Units	BSI	Oregon Kiln	Air Burner	Comments
Feedstocks	$/tonne	10-30	-	-	Chipping/grinding and transportation for BSI system
Relocations	$/site	11,300	500	1000	Assuming two relocations in a year
Repair and maintenance	% capital cost	20%	10%	10%	Straight line depreciation
Consumable	Propane Diesel	0.54 l/hr -	2.03 l/batch -	1.6 l/batch 14.3 l/hr	
Packaging	$/dry tonne	124.1	-	-	Transport: Remote locations to consumers in town
Finished good transportation	$/dry tonne	52.0	-	-	
Technician: Loader operator: Non-skilled labor:	$50.5/hr $22.5/hr $16.8/hr	1 - 2	- 2 6	1 1 1	Includes 35% fringe benefits

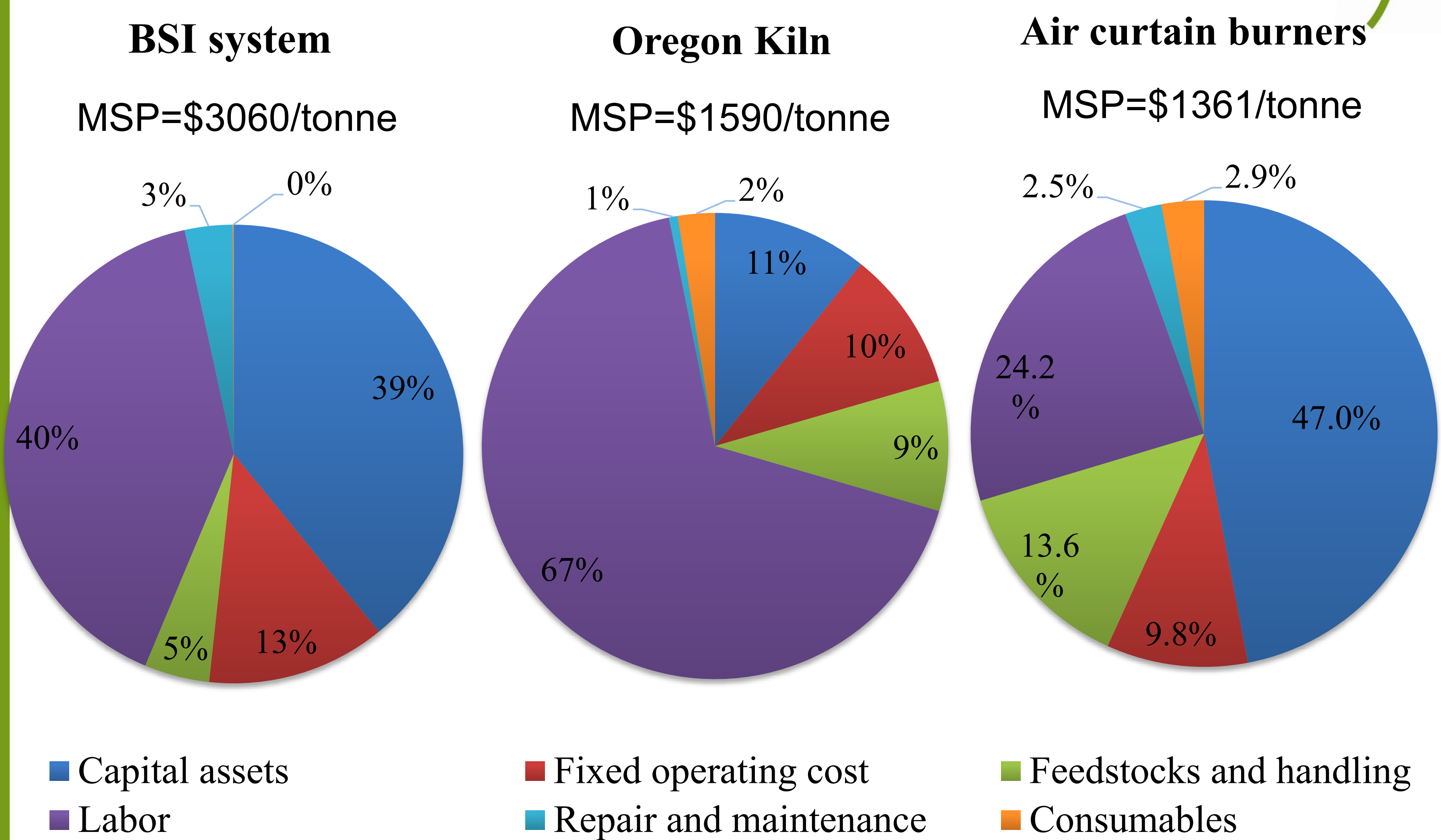
Results: Remote site/Near-forest locations: Cost components and MSP of biochar produced using BSI system



Results: Remote site Vs In-town locations (2-hrs and 4-hrs): Biochar production with BSI system, including power from grid

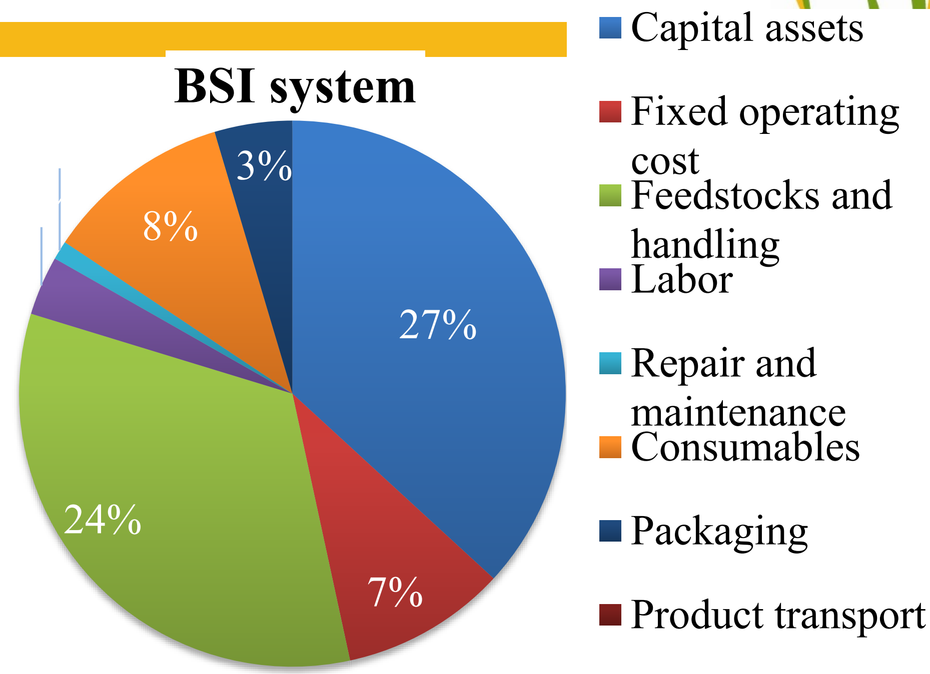


Results: Comparison of biochar MSPs between portable systems at the remote sites (100 days/year working)



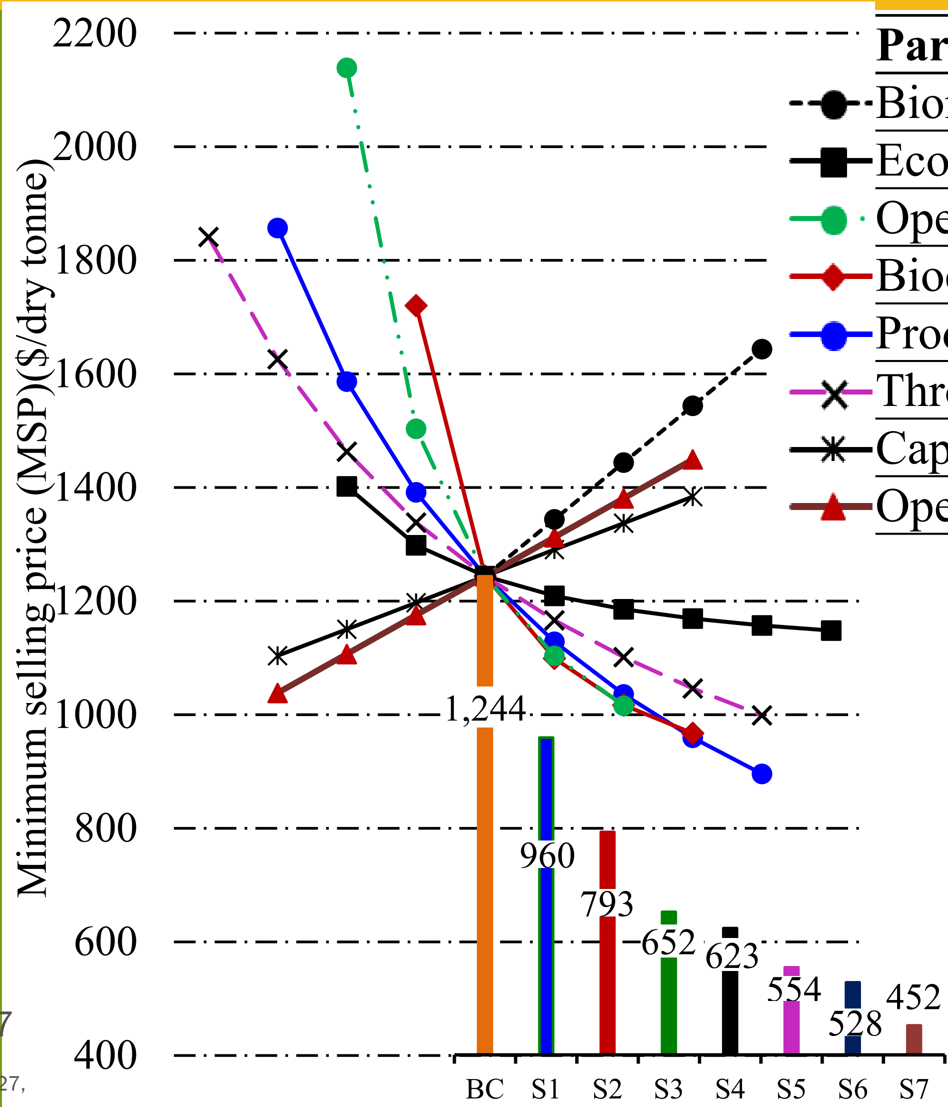
Impacts of drying feedstocks and technological improvements on financial performances of BSI system

- Drying units was added to the BSI system (higher feedstocks moisture content and wide operations days, i.e., 300 days/year)
- Double augur added to BSI improved the throughput (22%) and biochar yield (21%).



	Before-finance & tax	Before-tax	After-tax
MSP (Minimum Selling Price)	1,244	1,137	1,163
Real IRR*	14.2%	17.5%	13.0%
Nominal IRR	16.5%	19.8%	15.3%
Break-even delivered feedstock cost ($/green tonne)	10.3	21.0	18.3
Medium-term operating B-E avg. product value ($/tonne)	860.5	-	-
Short-term operating B-E avg. product value ($/tonne)	714.6	-	-

BSI: Sensitivity Analysis



Parameters	Units	Base case	Range
Biomass cost	$/tonne	10	10-50
Economic life	Year	10	5-15
Operating hours	hrs/day	16	8-24
Biochar units	units/site	2	1-5
Product yield	%	16%	10%-24%
Throughput	kg/hr/unit	390	270 -520
Capital cost	M$	0.95	0.65 - 1.21
Operating cost	M$/year	0.56	0.4-0.73

BC	Base case MSP
S1	Biochar yield (16 → 22%)
S2	BSI units at site (2 → 4)
S3	Operating hours (16 → 24)
S4	Economic life (10 → 15) yr
S5	Throughput (390 → 470) kg/hr
S6	Capital cost (20% reduction)
S7	Operating cost (20% reduction)

Conclusions and future research

- A portable system at the near-forest setup can be **a potential option** to produce biochar from forest biomass.

- Estimated Minimum selling prices (MSPs) were **$1060, $1590, and $1361/ dry metric tonne** biochar for the BSI, Oregon kiln and Air curtain burner respectively.

- Major cost components are **capital investment** and **labor**.

- Biochar MSPs can be **reduced by more than half** with efficient portable systems and lowering their costs.

- Further, Biochar MSPs could possibly reduced with current government incentives and credits but this requires further research.

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Contact: Richard Bergman, PhD
Email: rbergman@fs.fed.us
Phone: (608) 231-9477