Biochar Production using Forest Residuals

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Waste to Wisdom: Biochar Production Using Forest Residuals

November 16, 2015
12:00 PM – 1:00 PM (PST)

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Webinar Outline

1. Background
   - Waste to Wisdom project overview
   - Biochar uses and benefits
   - Biochar production description
2. Biochar Machine Testing
   - Objectives
   - Methods
   - Results
3. System Integration Concepts
4. Challenges
5. Future work

Waste to Wisdom Project Overview

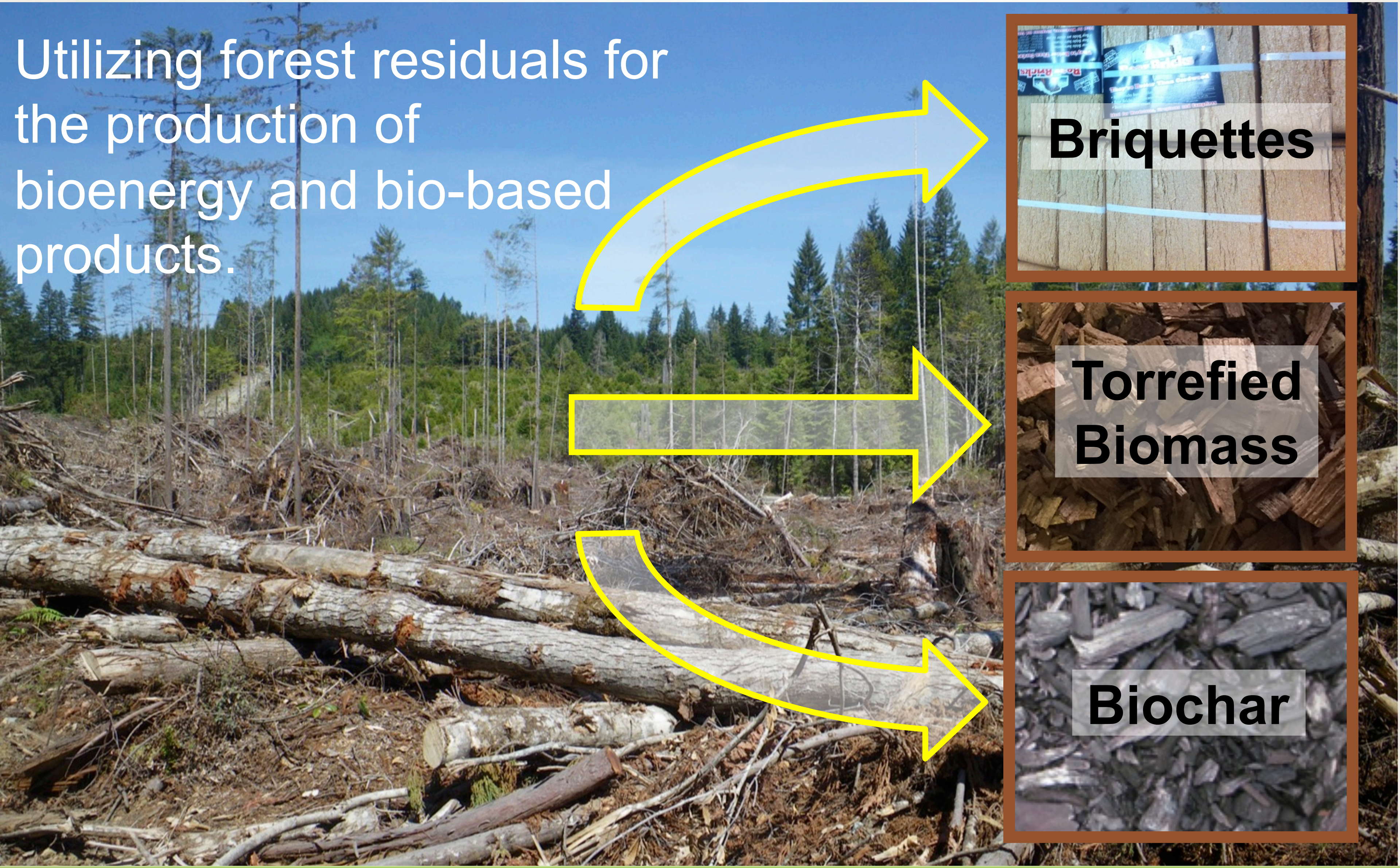
Forest residuals and slash are an immense, underutilized resource.

But transportation costs are prohibitively expensive due to their low bulk density and low market value.

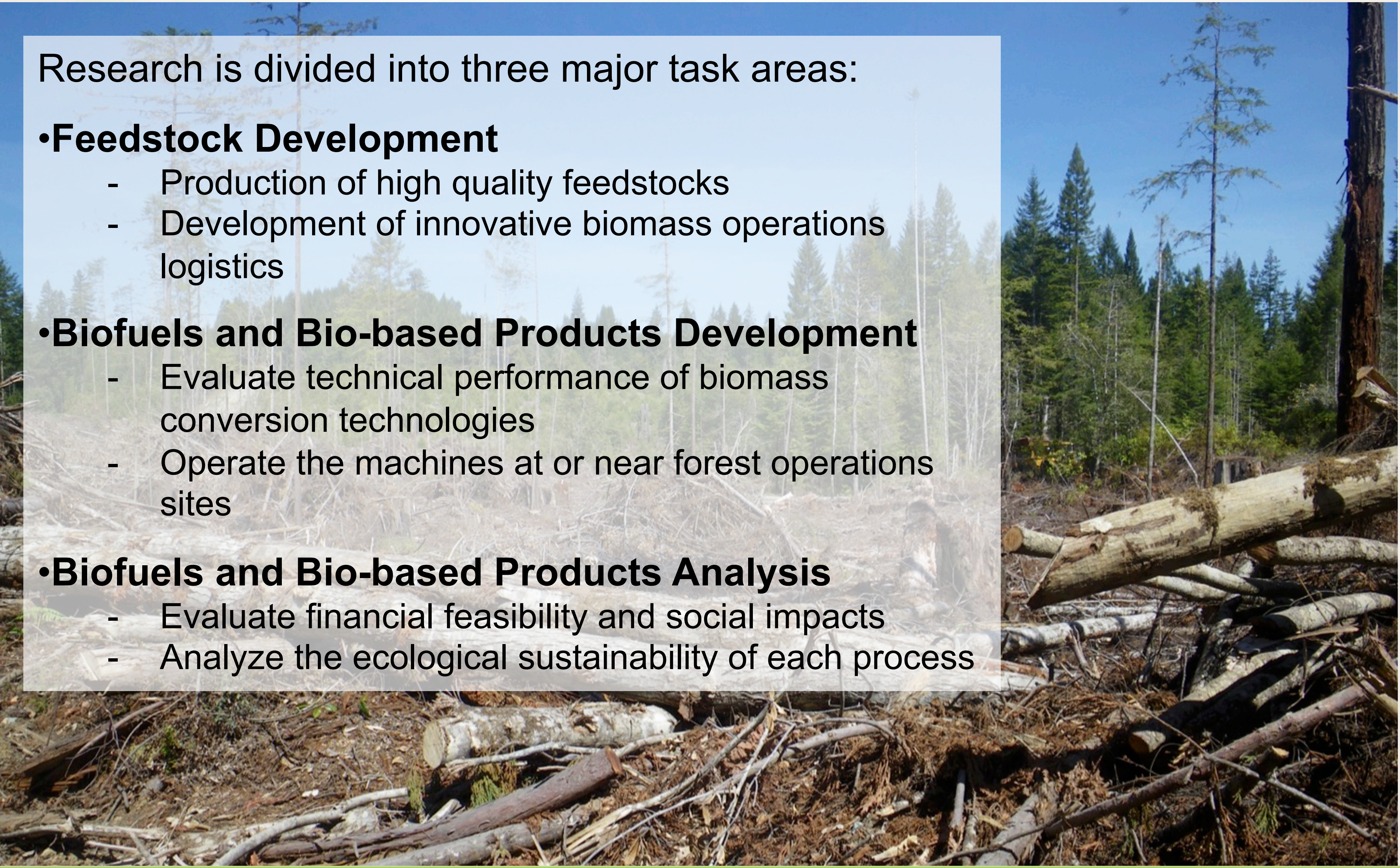
These economic barriers can be overcome by
- increasing the transportation efficiency, or
- increasing the value of the residuals before transport.

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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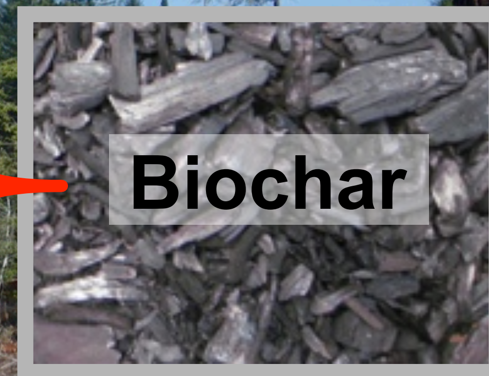


Biochar Uses and Benefits

Biochar has many uses including:

- Water remediation and filtration (Mohan, 2014)
- Production of activated carbon (Azargohar, 2006)
- Bioremediation (Qin, 2013)
- Soil amendment (Lehmann, 2012)

As a soil amendment, biochar has been shown to:

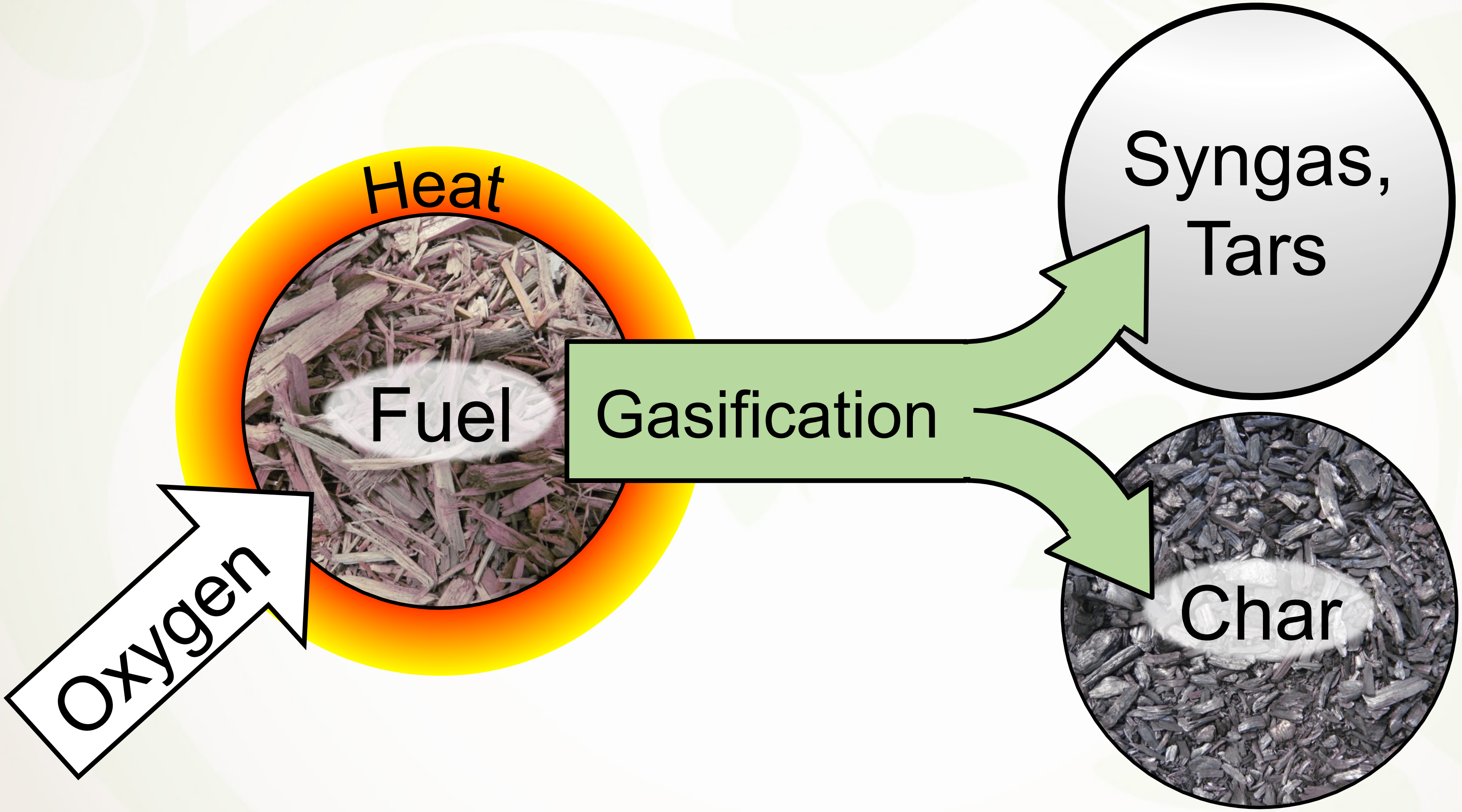
- Increase water retention (Laird, 2010)
- Reduce nutrient leaching (Novak, 2009)
- Improve cation-exchange capacity (Liang, 2006)
- Stimulate soil microbial activity (Steiner, 2008)

Furthermore, biochar helps mitigate climate change by:

- Sequestering fixed carbon in soil (Woolf, 2010)
- Reducing N_2O emissions from soil (Zhang, 2010)
- Producing renewable energy from syngas (Gaunt, 2008)

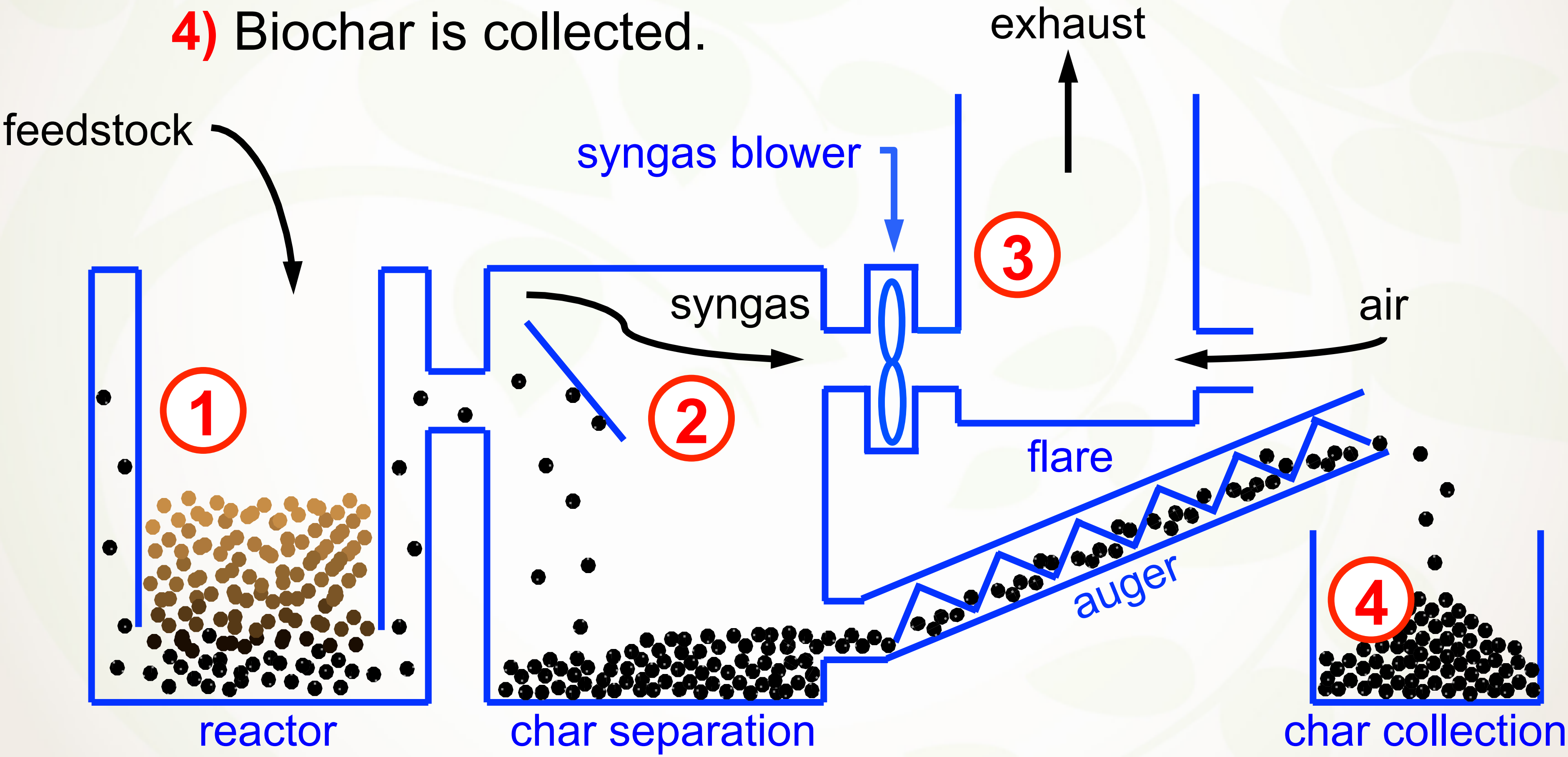
Biochar Production

Biochar is produced through thermal decomposition of biomass in an oxygen-limited environment, a process known as gasification.



Process Diagram for Biochar Solutions, Inc. Machine

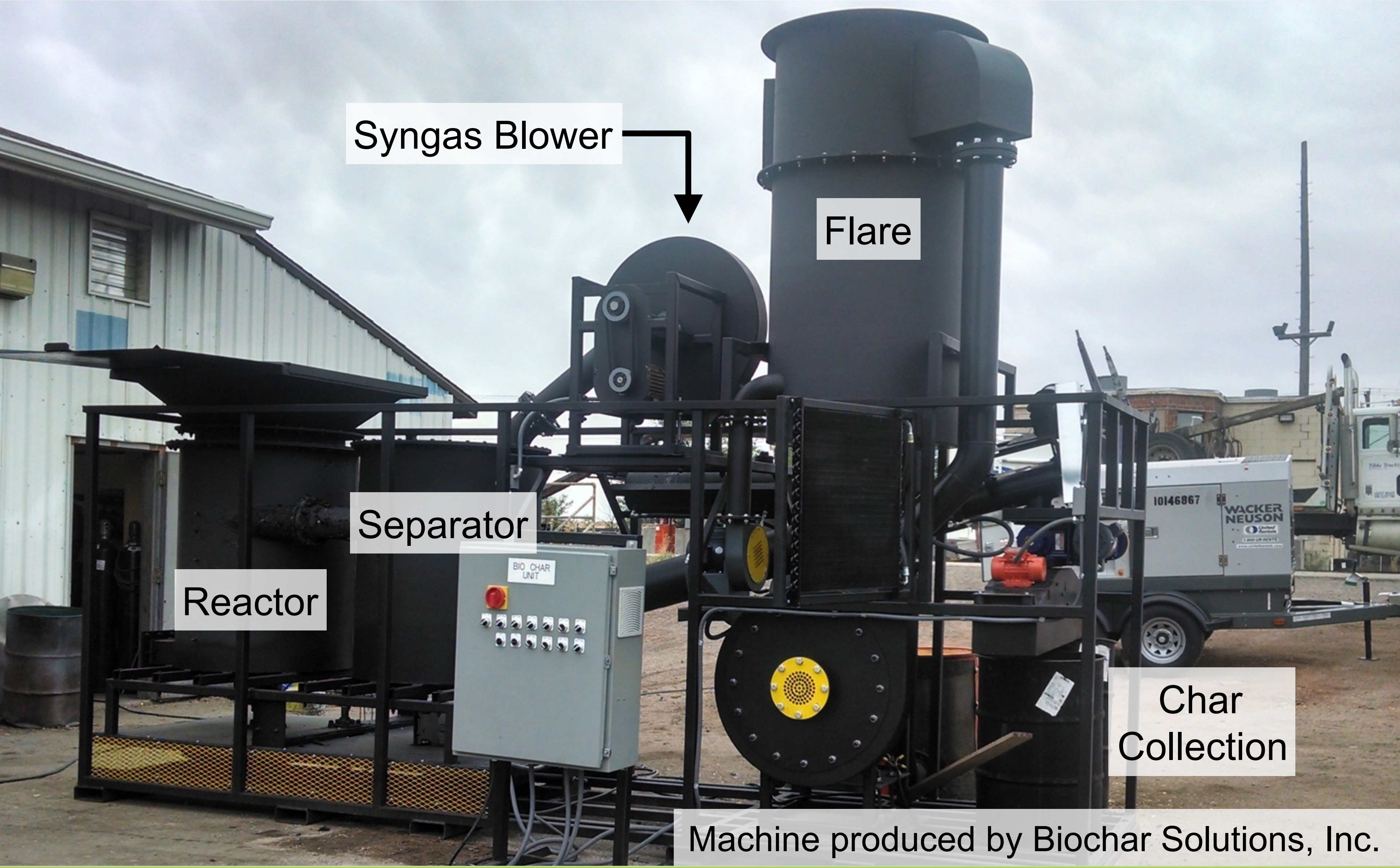
1) Biomass undergoes gasification in the reactor.
2) Char is separated from the syngas.
3) Syngas is burned in a flare.
4) Biochar is collected.



Biochar Production Machine

Machine produced by Biochar Solutions, Inc.

Biochar Production Machine



Machine produced by Biochar Solutions, Inc.

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

Machine undergoing testing in California

Test Methods

- Instruments were installed to collect energy and mass flow data.
- Hour-long steady state tests were conducted with various feedstocks including replicates.
- Feedstock and biochar samples were collected for laboratory analysis.

Data Collection Hardware

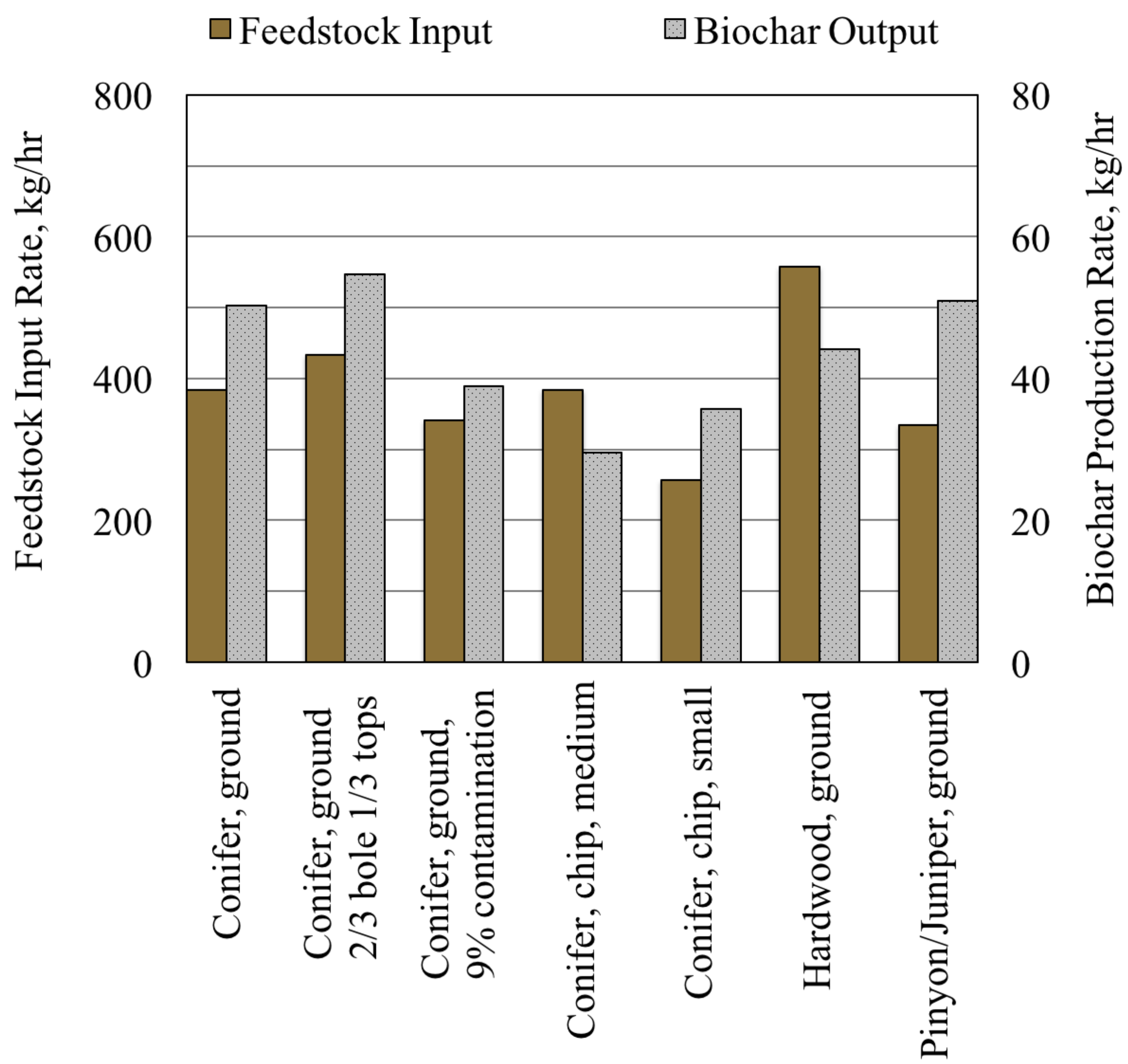
Feedstock Test Matrix

Species	Conifer		Conifer		Conifer		Conifer		Conifer		Hardwood		Juniper	
Comminution Method	Ground		Ground		Ground		Chip		Chip		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	

* Contamination was not added; the juniper feedstock was highly contaminated as received.

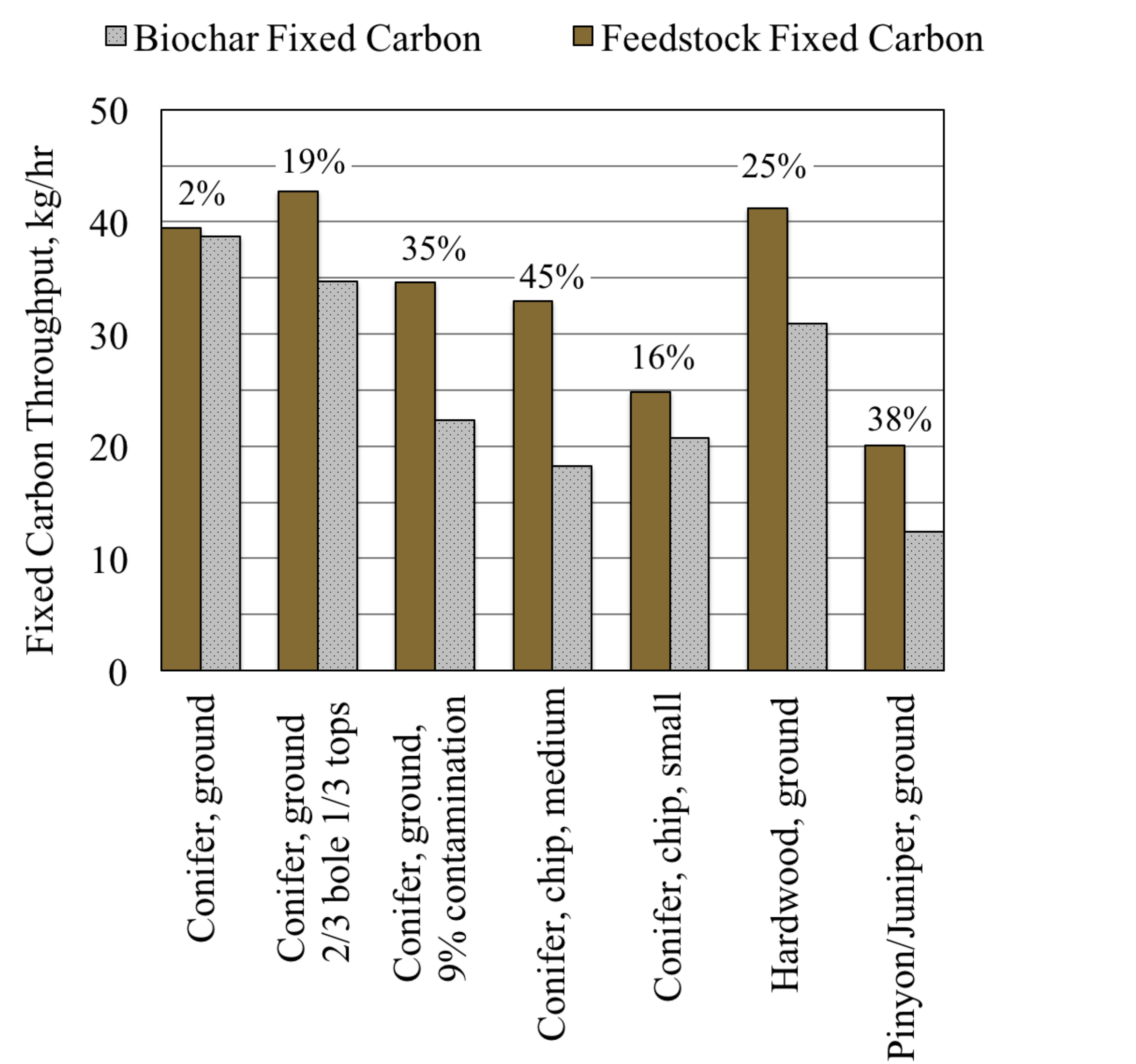
Throughput Rates on an As-Received Basis

- Average of 380 kg/hr feedstock input and 43 kg/hr biochar production.
- Average biochar yield is 12% by mass
- These results are skewed because they do not account for biochar quality.
- Pinyon/Juniper shows high biochar production, but the majority was ash.



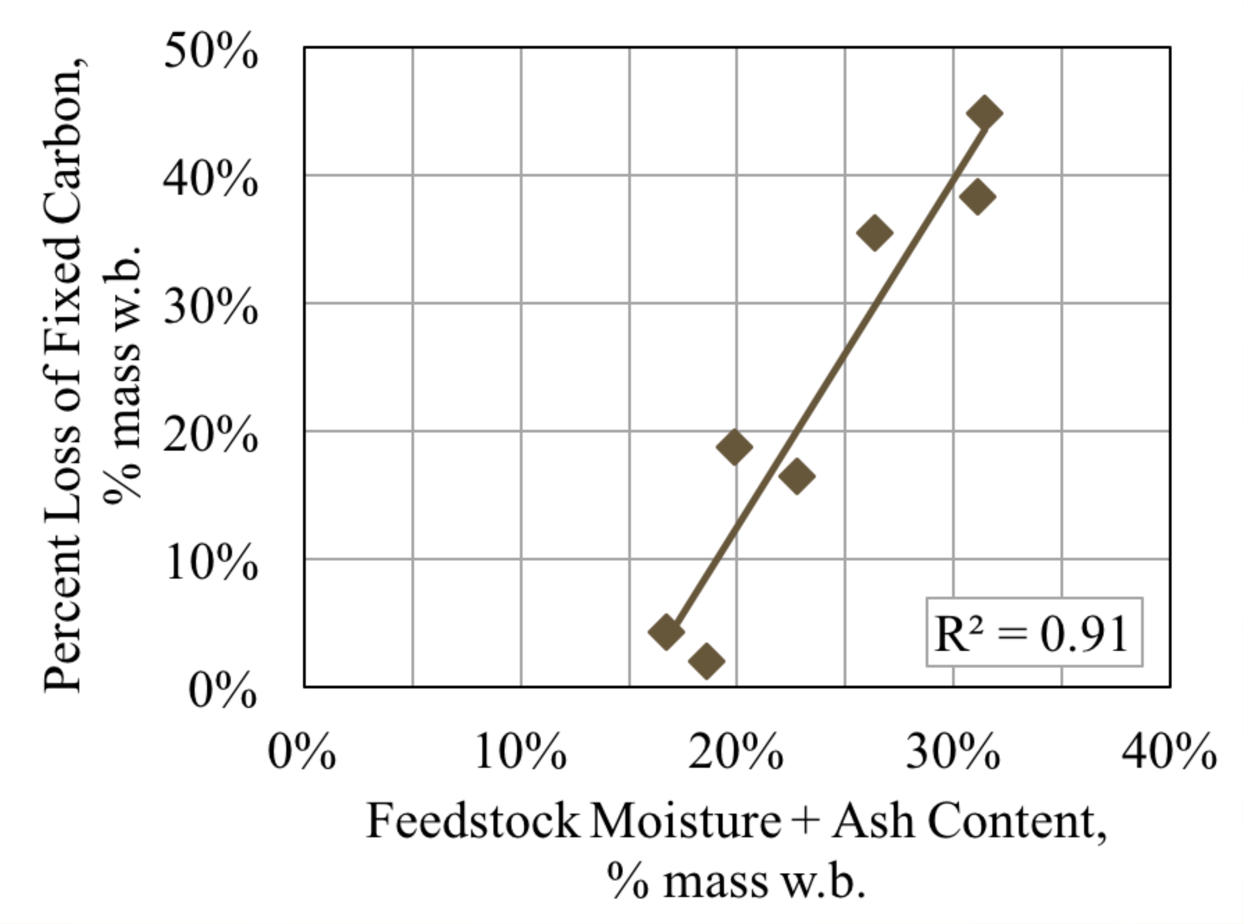
Fixed Carbon Throughput Rates

- Fixed carbon is lost due to through combustion in the reactor to sustain heating.
- Percent decrease in fixed carbon (above the bars) depends on feedstock contamination of ash or moisture.



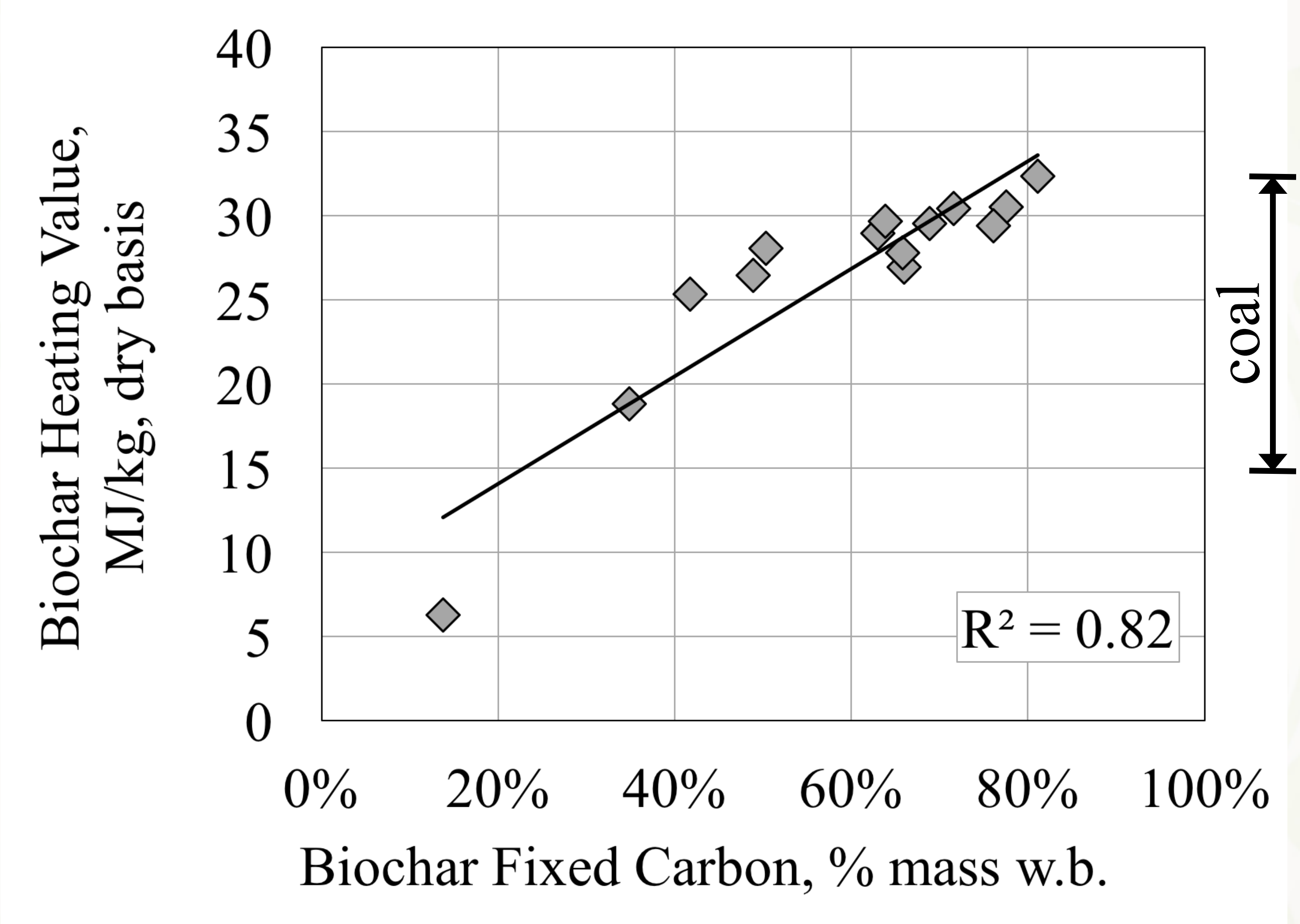
Fixed Carbon Loss in Biochar

More fixed carbon is lost in the biochar as moisture and ash content in the feedstock increases.



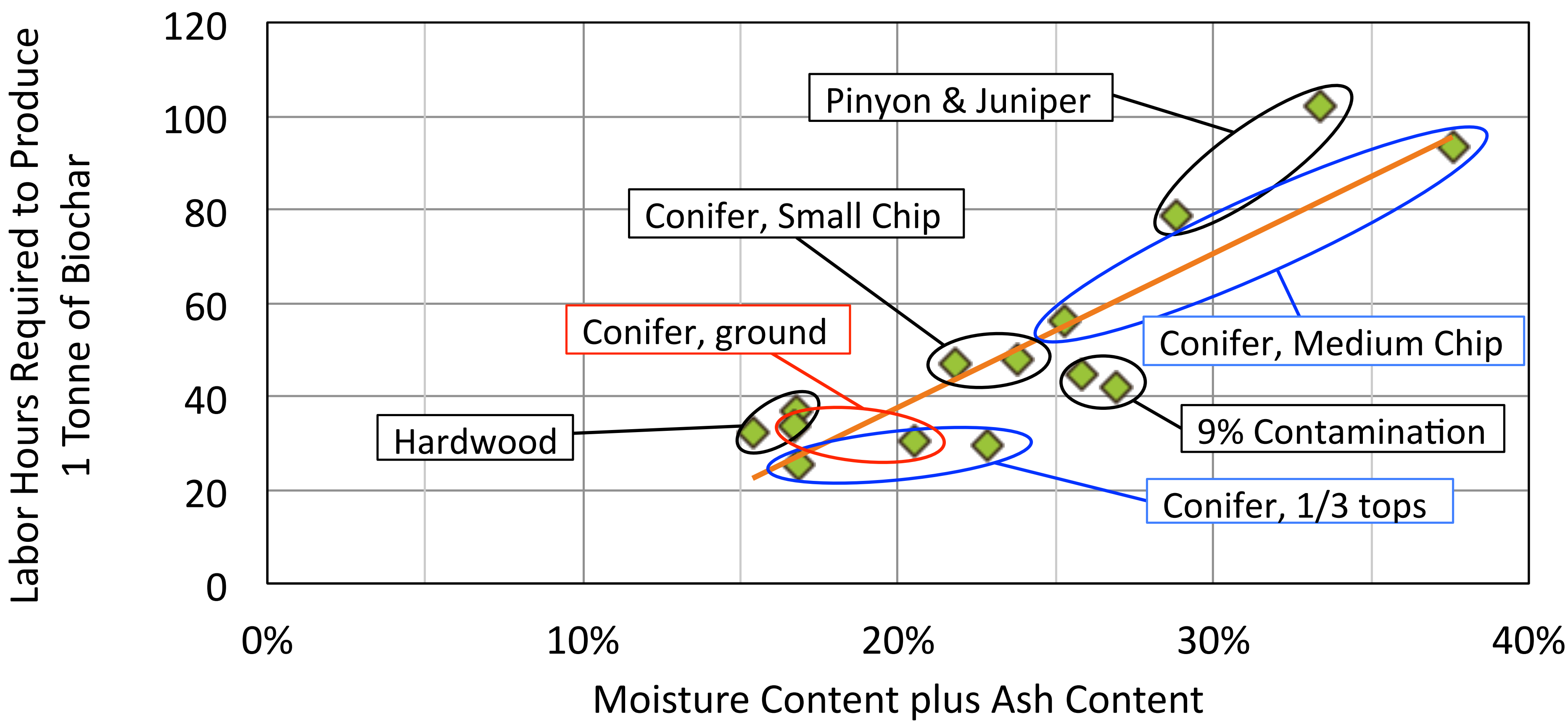
Fixed Carbon and Heating Value

High fixed carbon content in biochar sequesters more carbon as a soil ammendment. Furthermore, fixed carbon content directly increases biochar heating value.



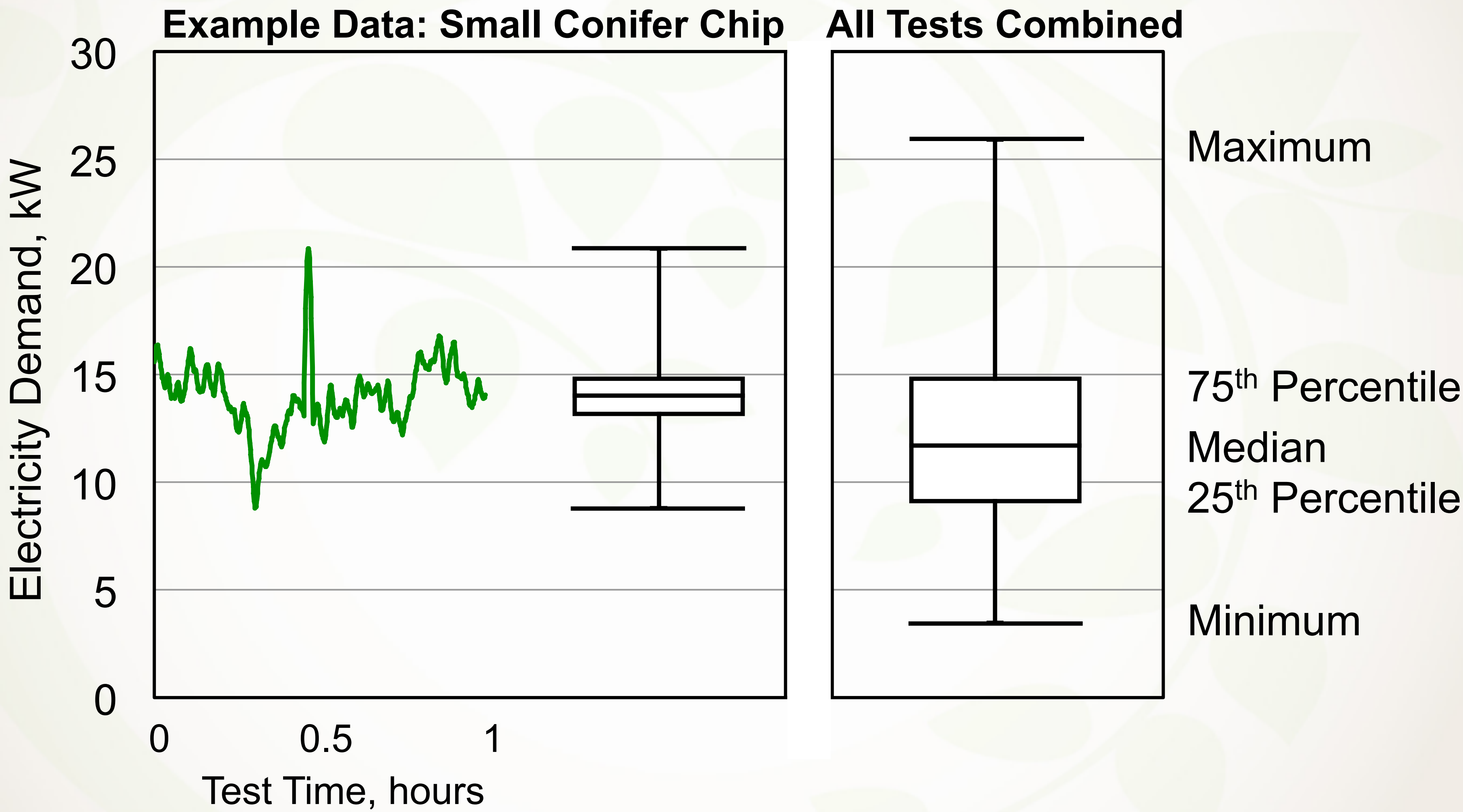
Estimated Labor Hours

Labor requirements increase with moisture and ash content in the feedstock.



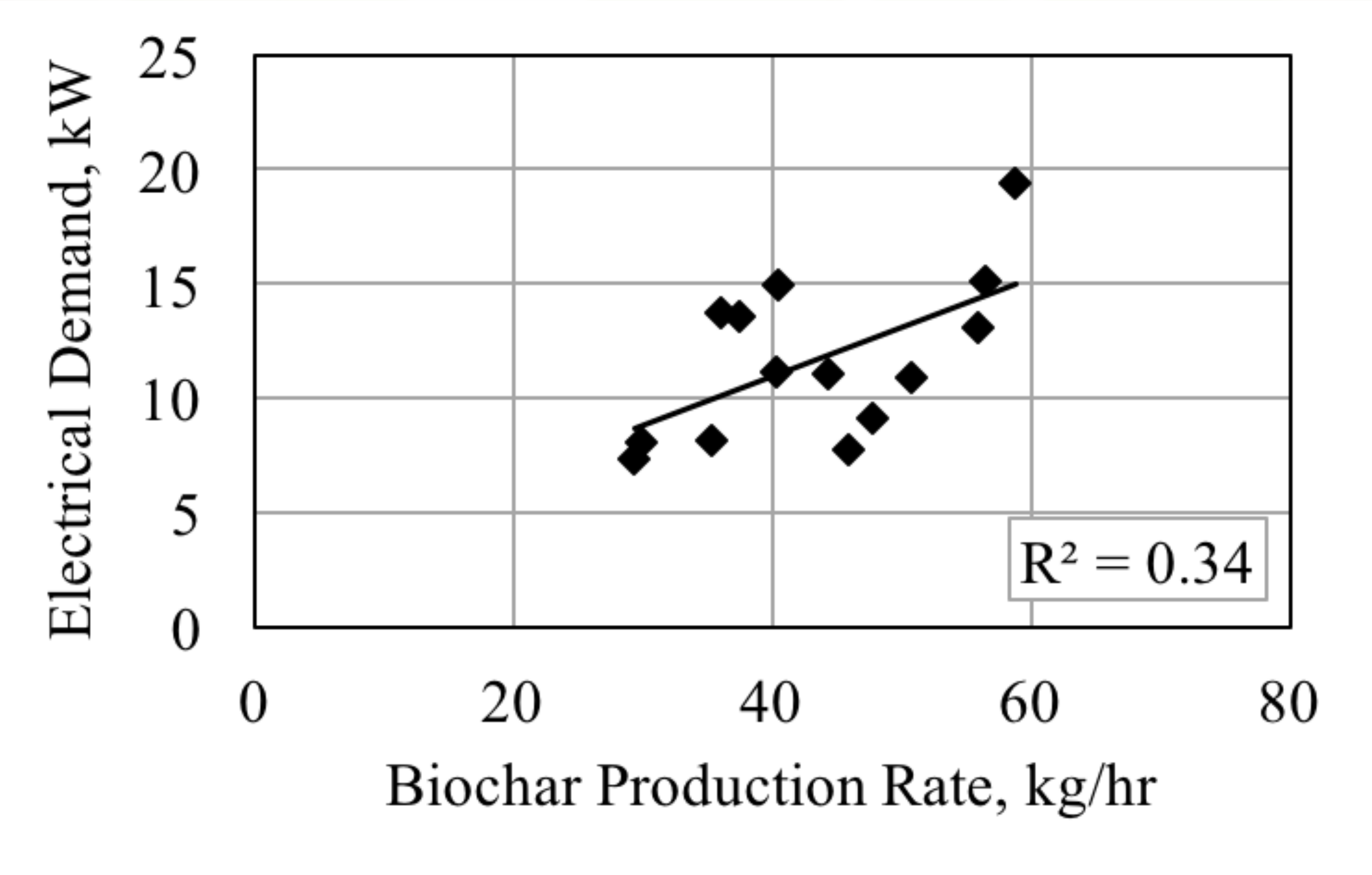
Electricity Requirements

Average electricity demand is 12 kW, but can vary by ±10 kW within every hour.
Generators must provide peak power at 26 kW and sustained power at 12 kW.



Electricity Demand

Electricity demand is weakly correlated with biochar production rate.



Electricity Variation

We hypothesize that electricity demand is a function of bed depth, where a deeper bed requires more power from the main blower to overcome the increased pressure drop and more power from the stirrer motor to move the larger bed of chips.

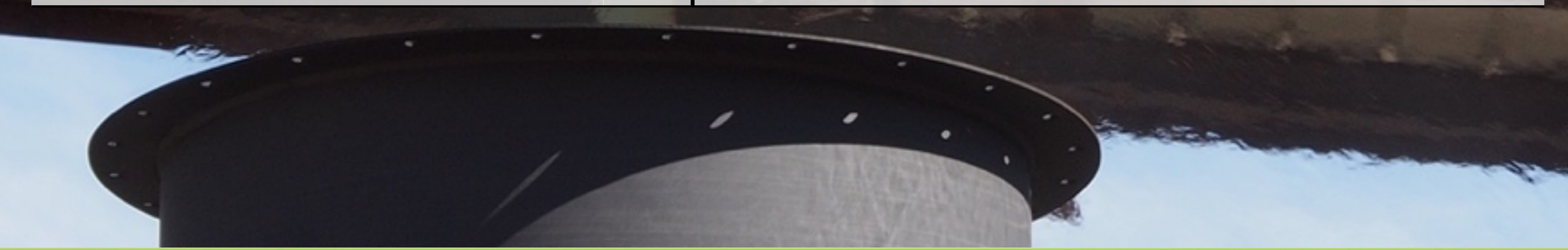
Fire Hazards: Embers from Exhaust Stack

Embers emitted from the stack pose the greatest fire hazard.

Biochar Solutions has designed and built a spark arrestor for the machine, which is currently undergoing test validation.

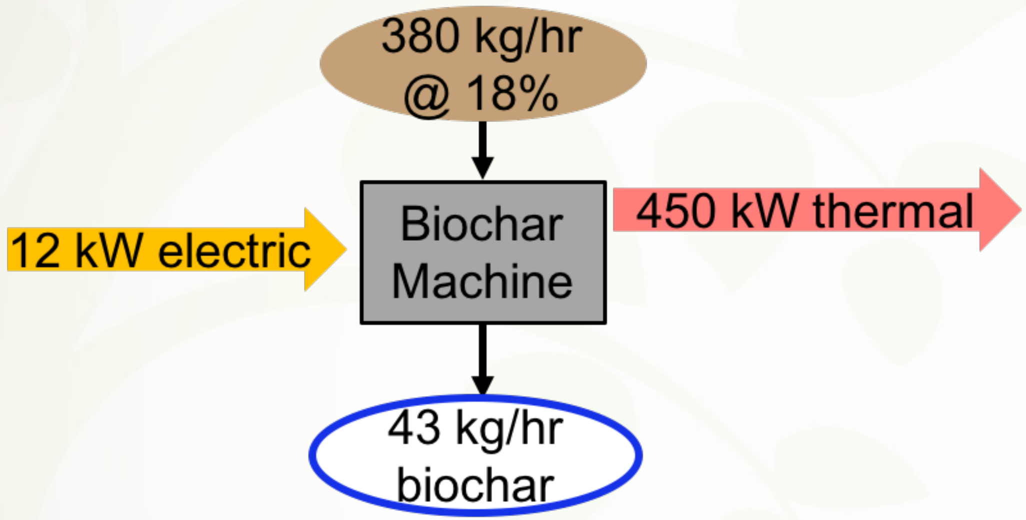
Fire Hazards: Overview and Mitigation Measures

Fire Risk	Mitigation Measure
Embers emitted from stack	- Install spark arrestor
Dust collection around machine	- Clean machine daily - Install dust collection device around conveyor - Screen out fine particles before feed hopper
Dust cloud above reactor	- Install dust collection device above reactor - Screen out fine particles before feed hopper
Biochar exits machine very hot	- Increase effectiveness of biochar auger cooling system by repositioning radiator
Reactor backfire	n/a
Integrated dryer burns chips	- Reduce dryer heat exchanger outlet air temperature



System Integration: Biochar Machine Only

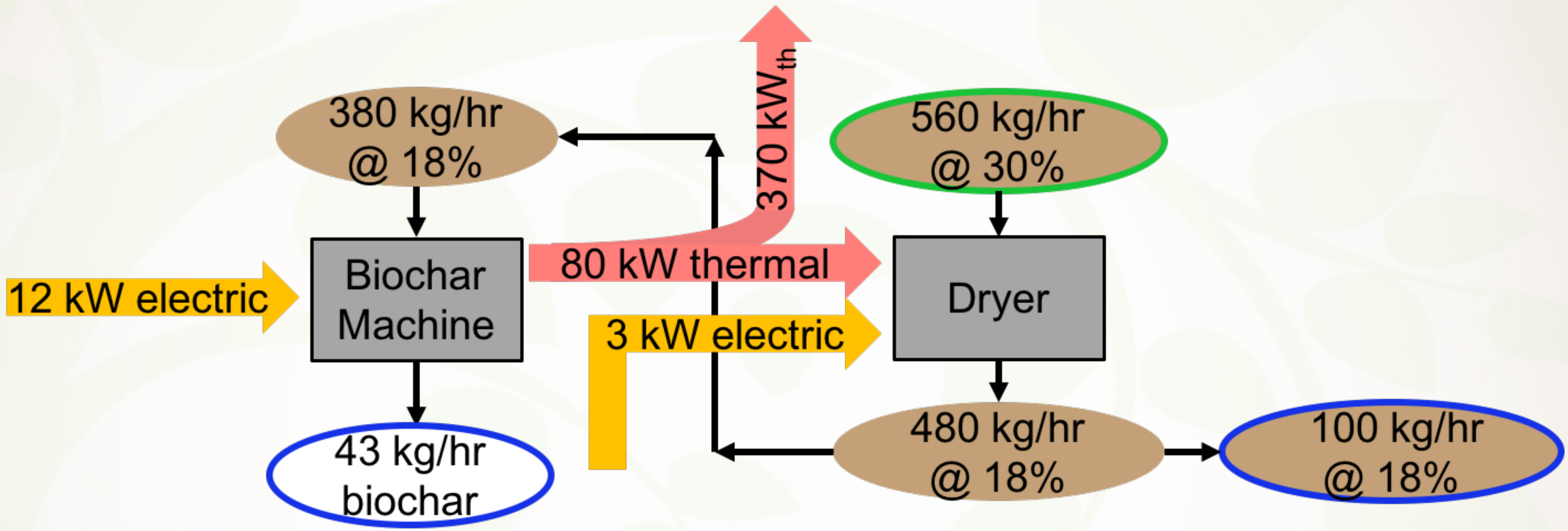
Flow diagram for biochar machine by itself.



Input:	Output:
380 kg/hr biomass at 30%	43 kg/hr biochar
12 kW electric	450 kW thermal

System Integration: Biochar Machine with Dryer

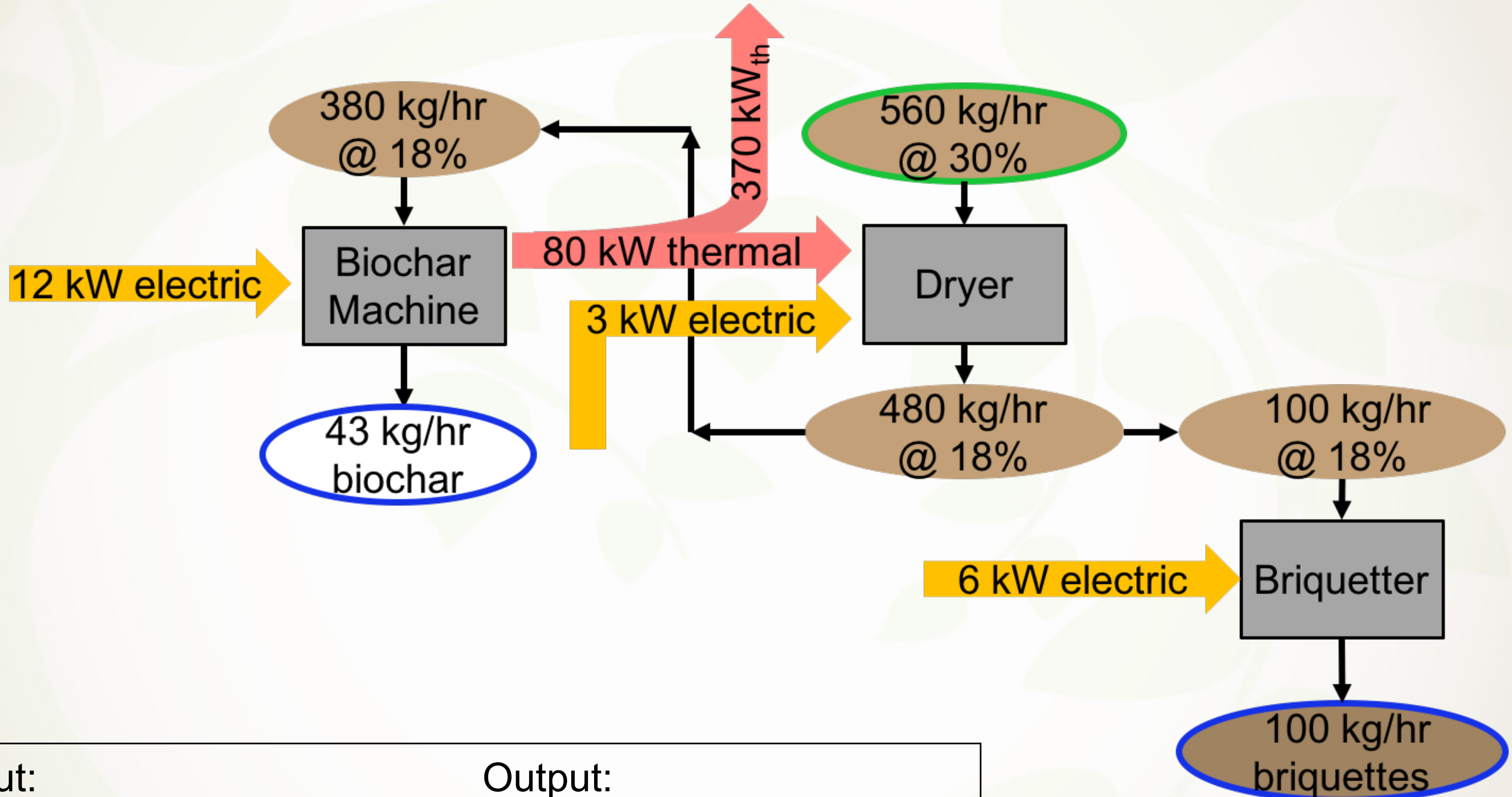
Biochar machine coupled with a dryer using integrated heat exchanger in stack.



Input:	Output:
560 kg/hr biomass at 30%	43 kg/hr biochar
15 kW electric	100 kg/hr biomass at 18%

System Integration: Biochar Machine and Briquetter

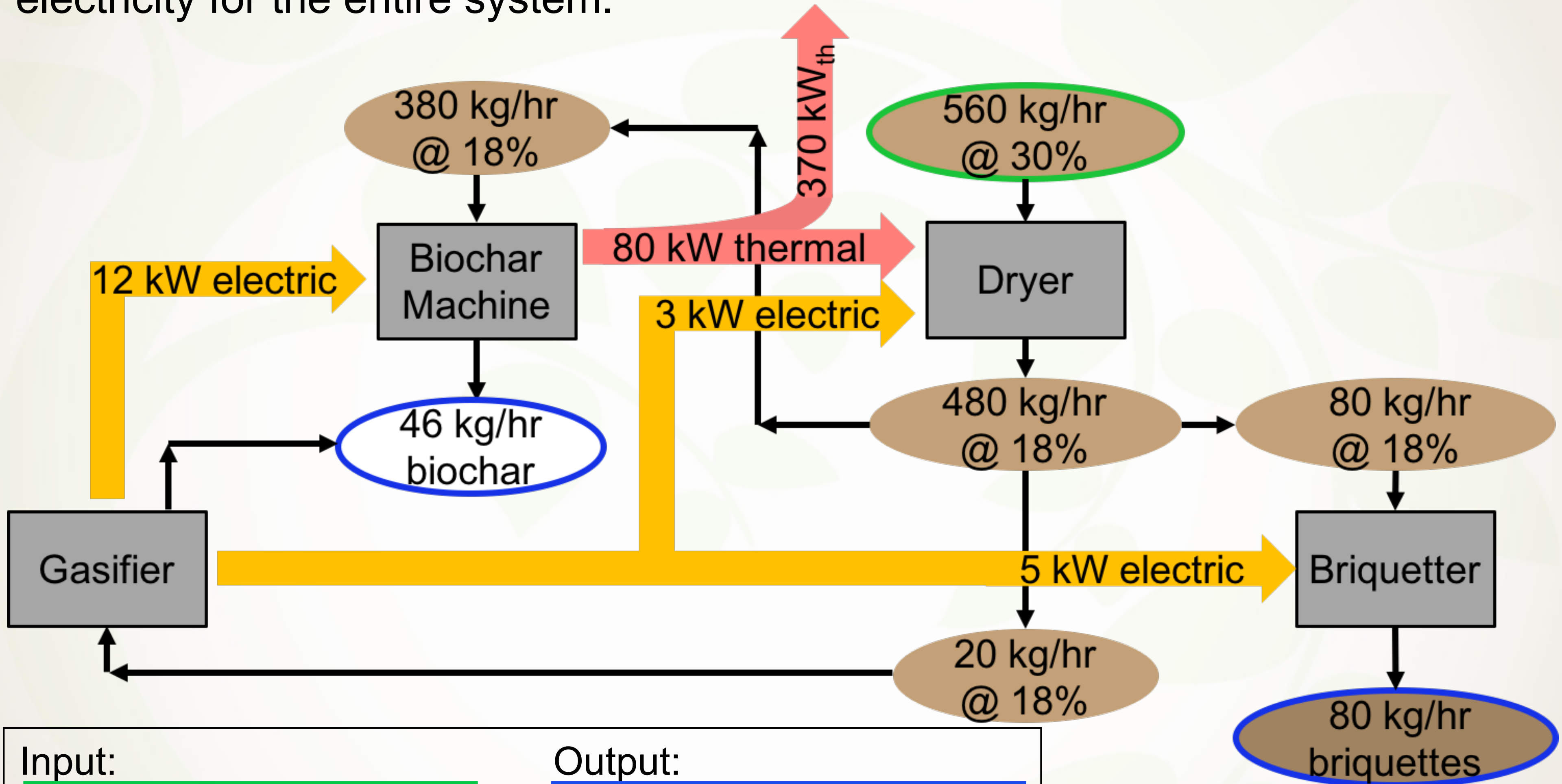
Use excess dried feedstock to produce briquettes.



Input:	Output:
560 kg/hr biomass at 30%	43 kg/hr biochar
21 kW electric	100 kg/hr briquettes

System Integration: Stand-Alone System

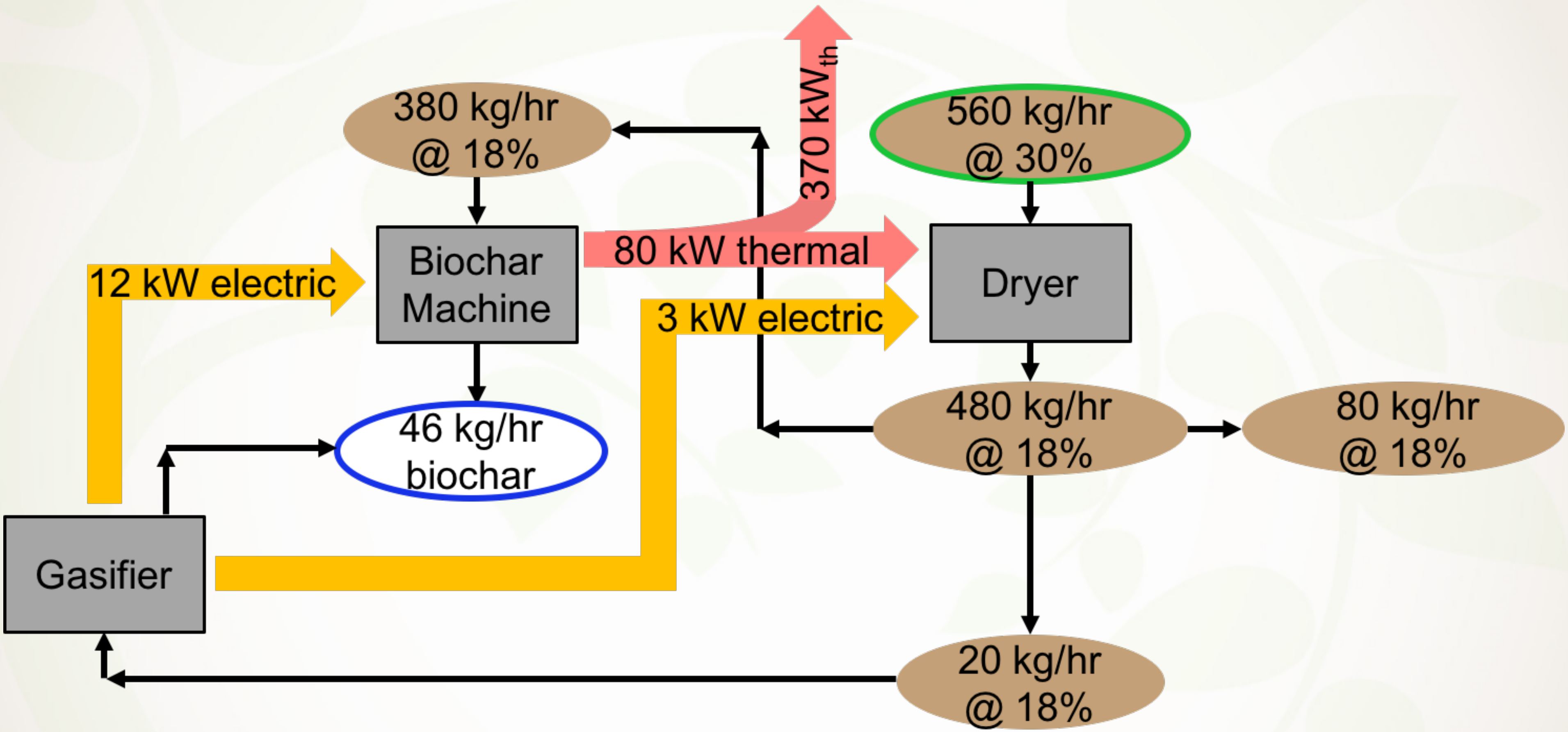
Use a portion of the dried feedstock to operate a gasifier which can provide electricity for the entire system.



Input:	Output:
560 kg/hr biomass at 30%	46 kg/hr biochar
	80 kg/hr briquettes

System Integration: 2016 Test Plan

Testing of this system will occur in Spring 2016 in Mendocino County, California.



Input:
560 kg/hr biomass at 30%

Output:
46 kg/hr biochar
80 kg/hr biomass at 18%

Challenges

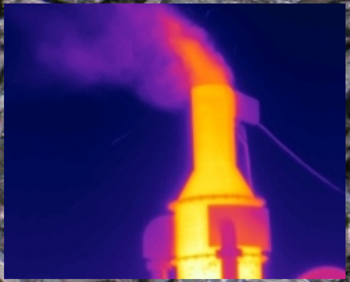
The challenges to operate a biochar machine at near or in woods environments have been illustrated above. The main challenges include:

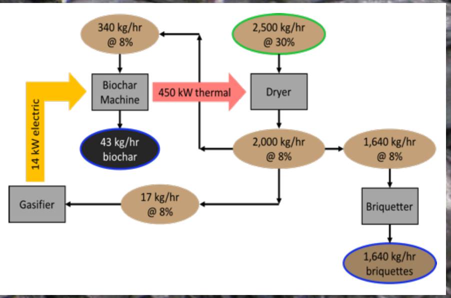
Feedstock Quality has a large influence on biochar quality and operational intensity.

Fire Hazards have been observed; a list of mitigation measures have been outlined.

Electric Power is variable and difficult to provide in remote locations. A small biomass gasifier can be used as an alternative to a diesel generator.

System Integration of the biochar machine with a dryer, briquetter, and gasifier may provide the most benefit.





Future Work

Ongoing testing activities and improvements continue with this project. The next steps include:

Fire Hazard Mitigation - the spark arrestor has been installed and performance will be verified in Spring 2016.

Dryer Performance – a Belt-o-matic 123B dryer will be integrated with the biochar machine in Spring 2016. Waste heat from the stack will be used to dry incoming feedstock in Spring 2016.

Gasifier Electricity Production – a 20 kW gasifier will be integrated with the biochar machine in Spring 2016 for stand-alone testing.

Throughput Increase – BSI is currently working to double the throughput on a new machine.

Automated Feed Contol – BSI is currently automating the input conveyor to reduce operational requirements.

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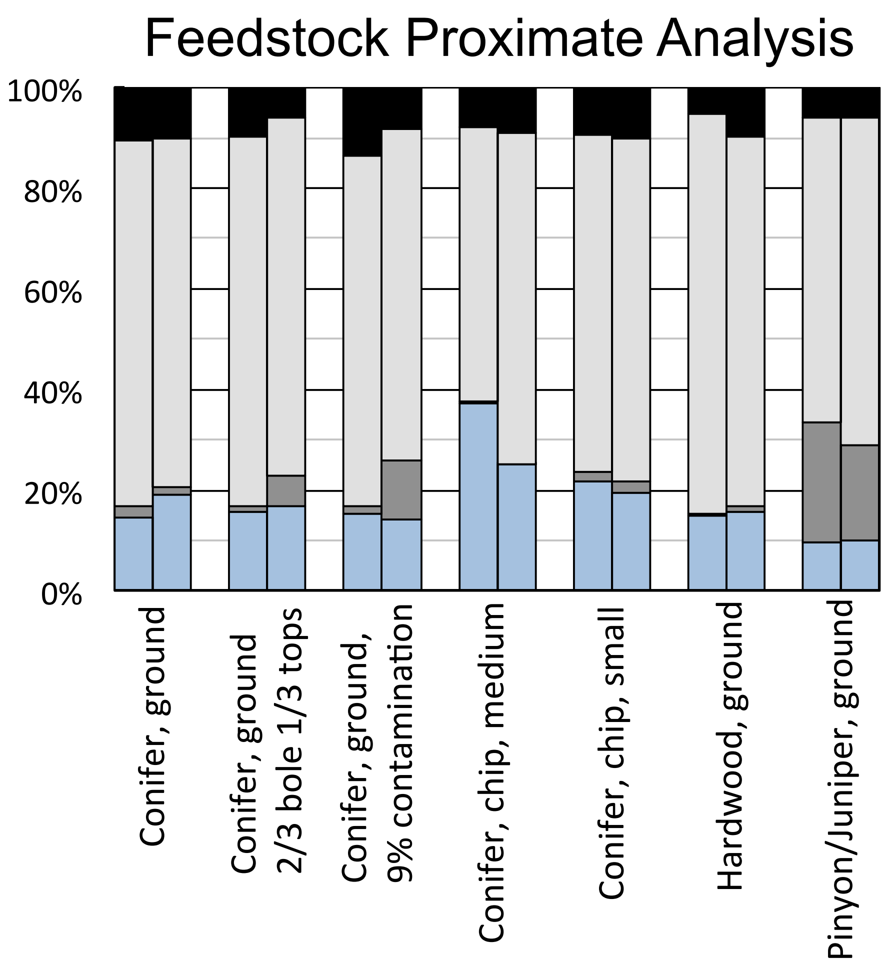
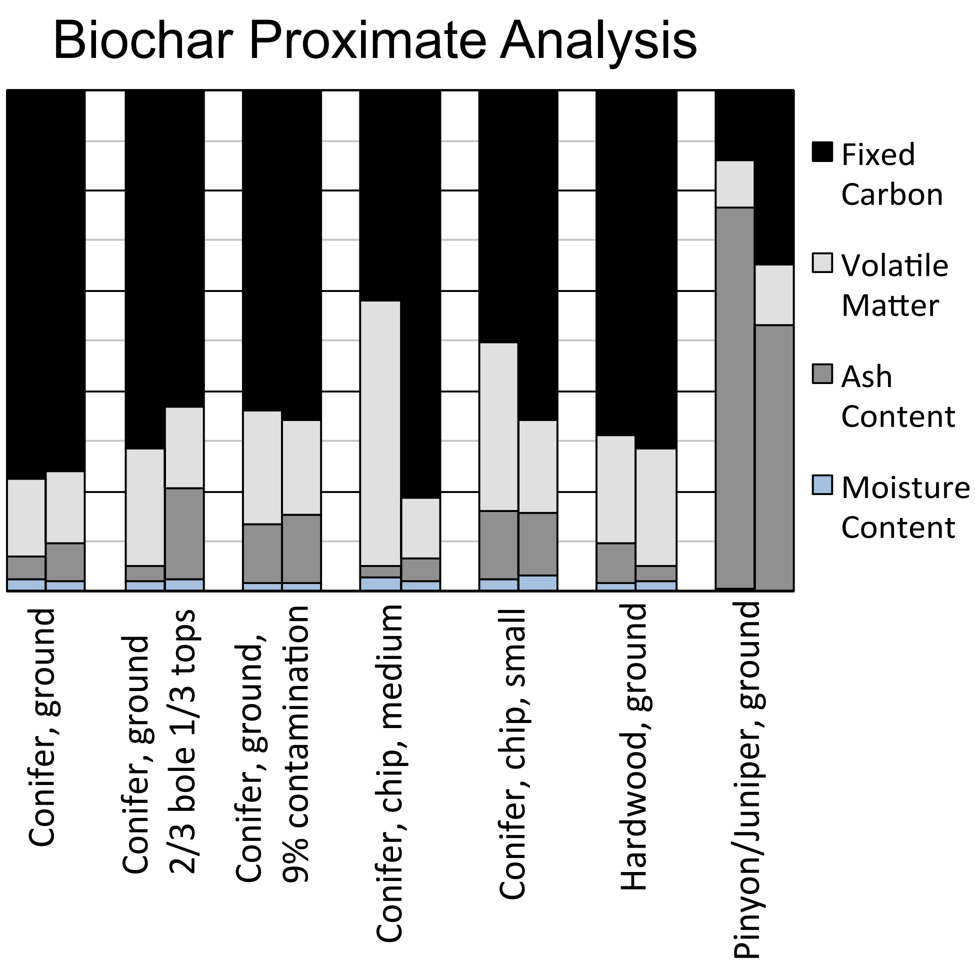
Questions and Discussion

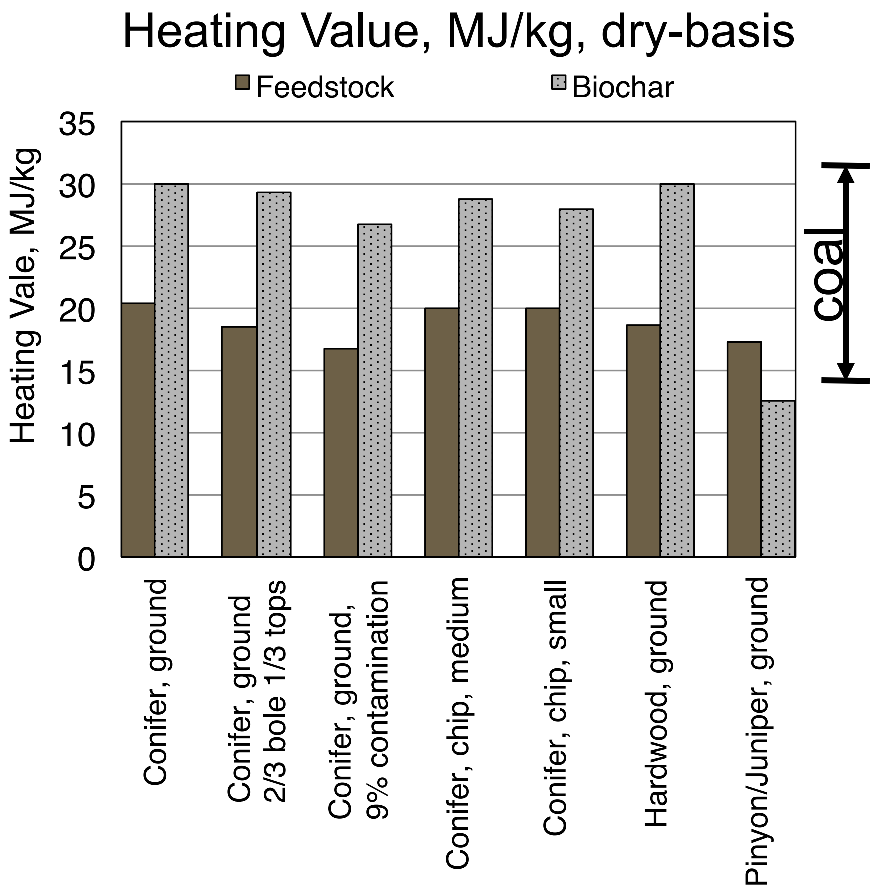
Appendix: Proximate Analysis

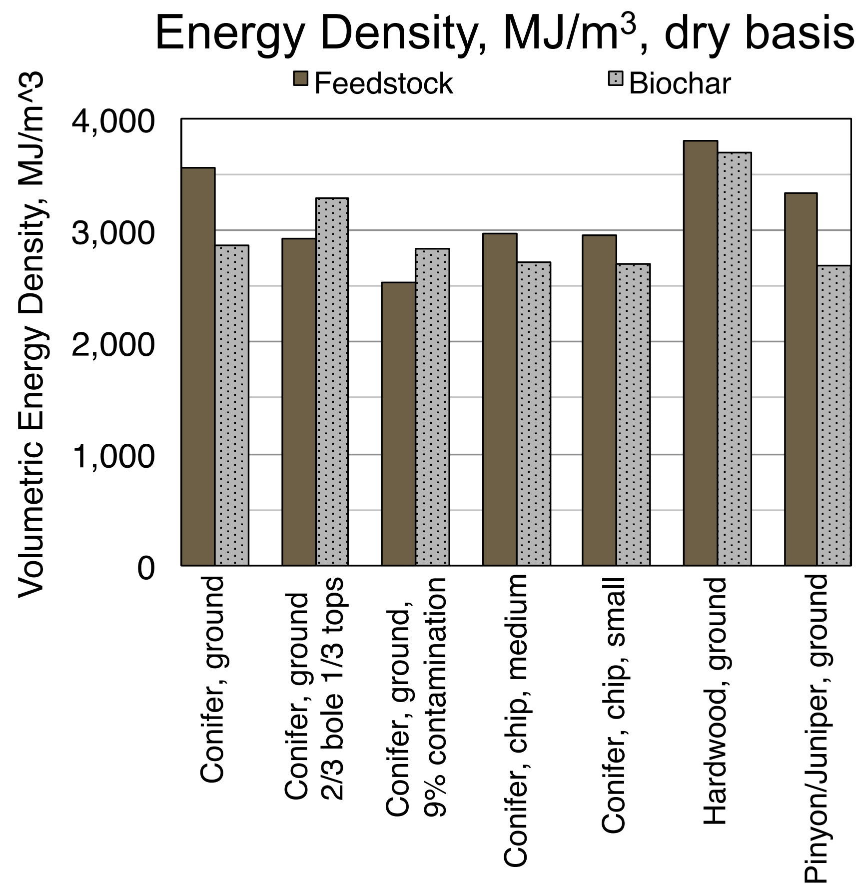




Appendix: Biochar's Value as an Energy Product

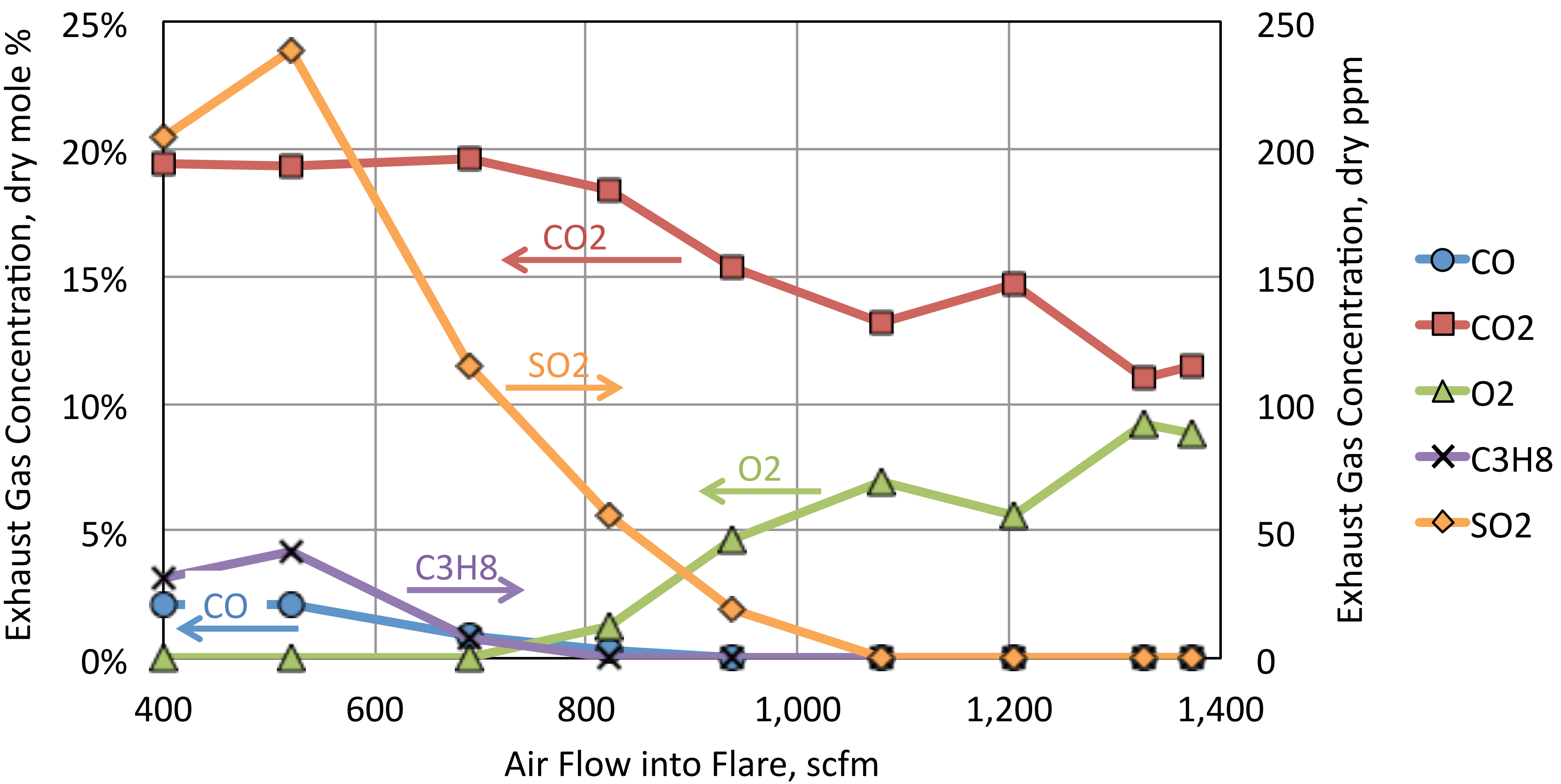
- The heating value of biochar is 50% greater than raw biomass.
- However, their energy densities are similar.
- Biochar heating value is equivalent to high quality coal, but must increase bulk density by 3-9 times to be equal to the energy density of coal.





Appendix: Emissions

Emissions from this machine depend on combustion characteristics of the flare.
CO, Propane, and SO2 emissions were originally high due to incomplete combustion in the flare. These emissions are reduced by increasing the air flow rate into the flare.



Appendix: Fire Hazards – Dust Collection

Dust collects around the reactor and machine after handling and conveyance. This fuel can easily combust with embers from the stack.

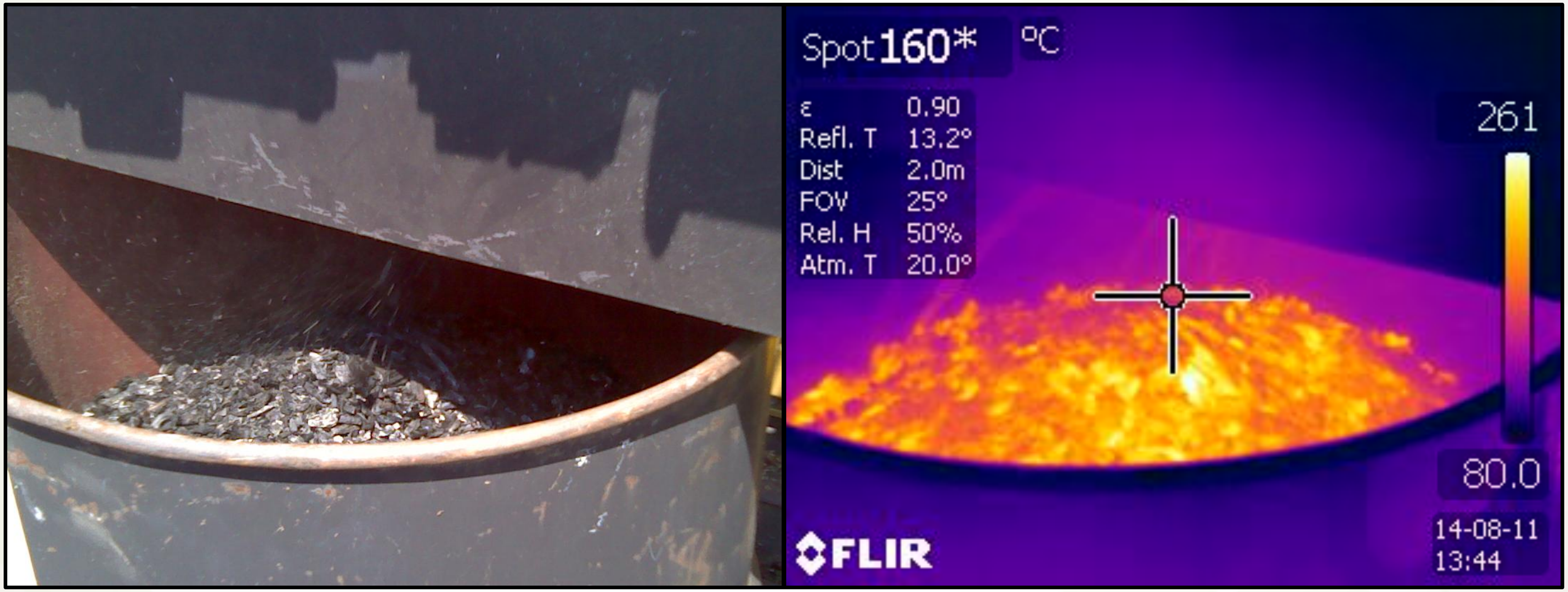
This hazard can be mitigated by:

- Requiring daily cleaning around the machine
- Installing dust collection system around conveyor
- Screening out fine particles and dust in the feedstock

Appendix: Fire Hazards – Hot Biochar

Biochar ejected from the machine can be as hot as 260ºC. Water must be added to the biochar collection drums, otherwise the char will smolder into ash.

The biochar exits the machine in a water-cooled auger, however the heat rejection from the coolant is insufficient. The biochar could be cooled substaintially by redesigning the biochar auger cooling system.



Appendix: Fire Hazards – Integrated Dryer

An integrated batch dryer was included in the initial design, however hot air to the dryer exceeded 200ºC and combusted wet chips in the dryer bin.

The dryer heat exchanger has since been redesigned to provide air at a lower temperature. Testing of this heat exchanger is currently underway.

Integrated dryer after wet chips combusting

Appendix: Briquettes Produced from Slash