Biochar Production From Forest Residuals

Measured Performance Across Multiple Feedstocks and Lessons Learned

David Carter
Sr. Research Engineer
Schatz Energy Research Center
http://www.schatzlab.org/

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RFFI ecology, economy, equity

BIOCHAR SOLUTIONS

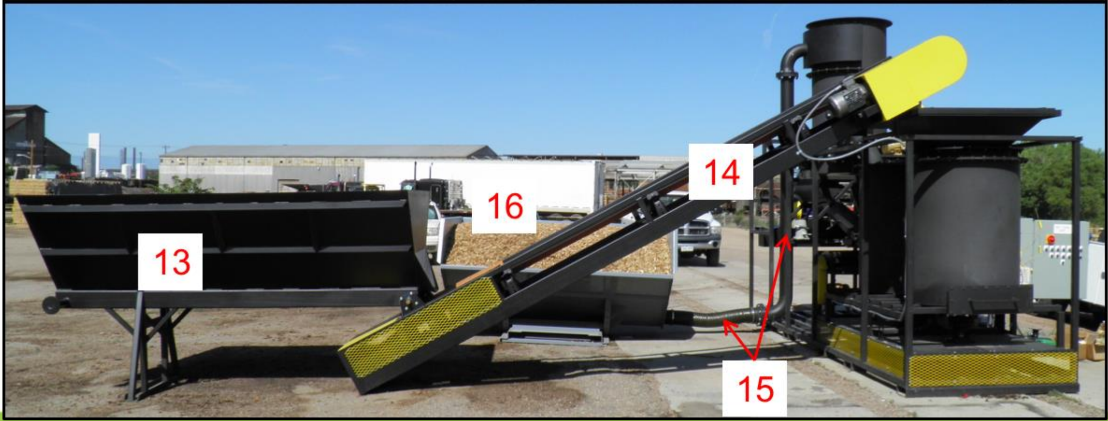
HUMBOLDT STATE UNIVERSITY Sponsored Programs Foundation

Presentation Outline

- Technology Description
- Experimental Design
  - Thermodynamic Control Volume
  - Process and Instrumentation Diagram
  - Data Acquisition System
  - Testing matrix
- Experimental Results
- Lessons Learned
- Recent Progress
- Conclusions

Technology Description

1: Reactor
2: Drop box
3: Flare
4: Heat exchanger
5: Reactor blower
6: Flare air blower
7: Heat exchanger inlet blower
8: Biochar cooling auger
9: Cooling auger radiator
10: Air lock
11: Biochar collection drum
12: Control panel
13: Feedstock hopper
14: Conveyor
15: Heat exchanger outlet
16: Dryer hopper



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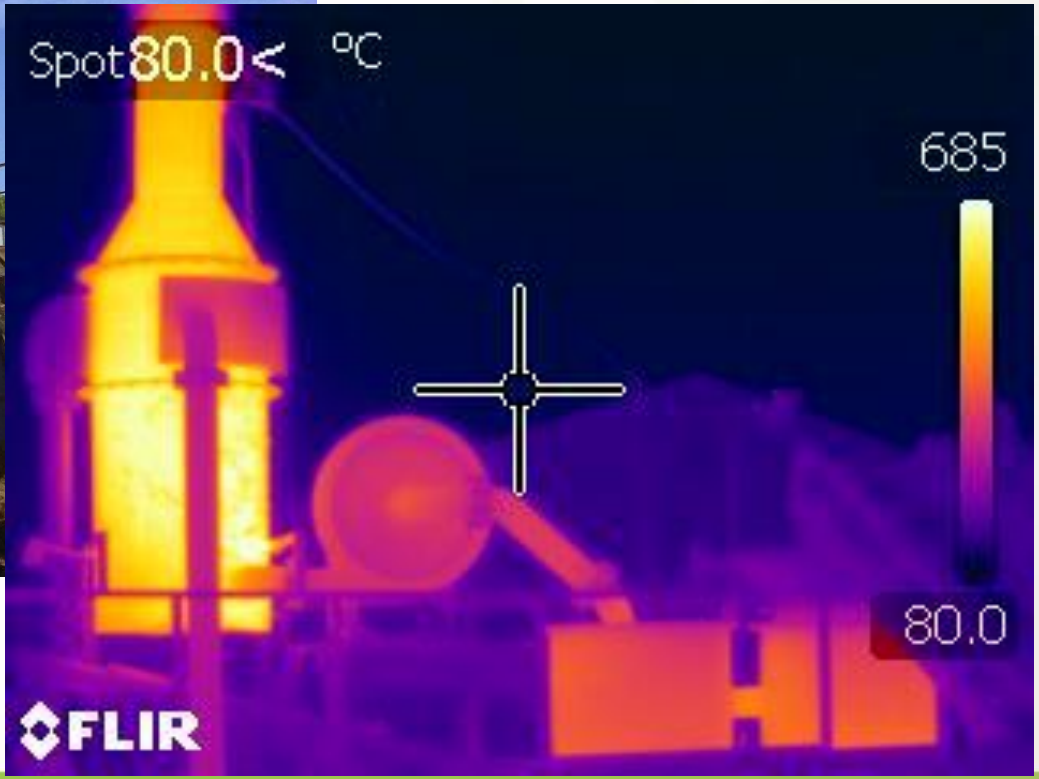
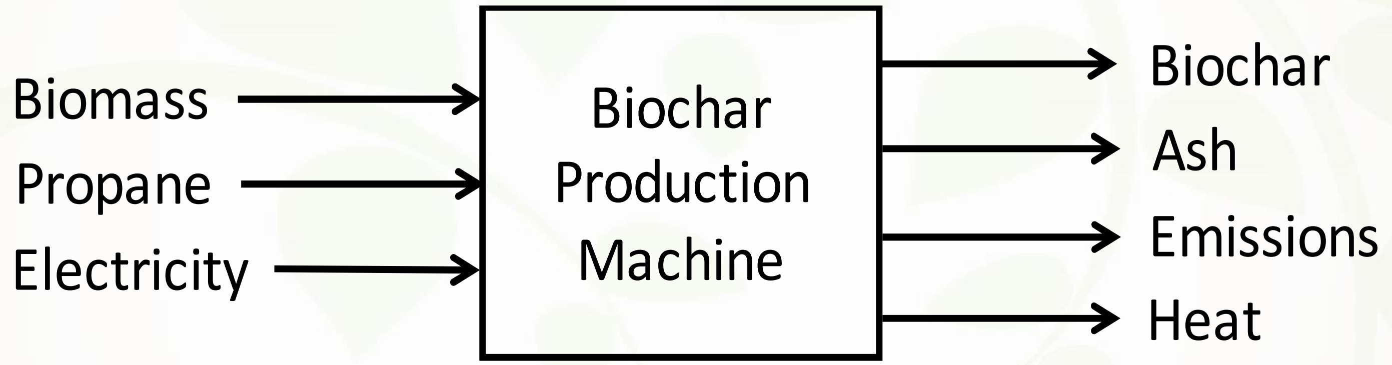
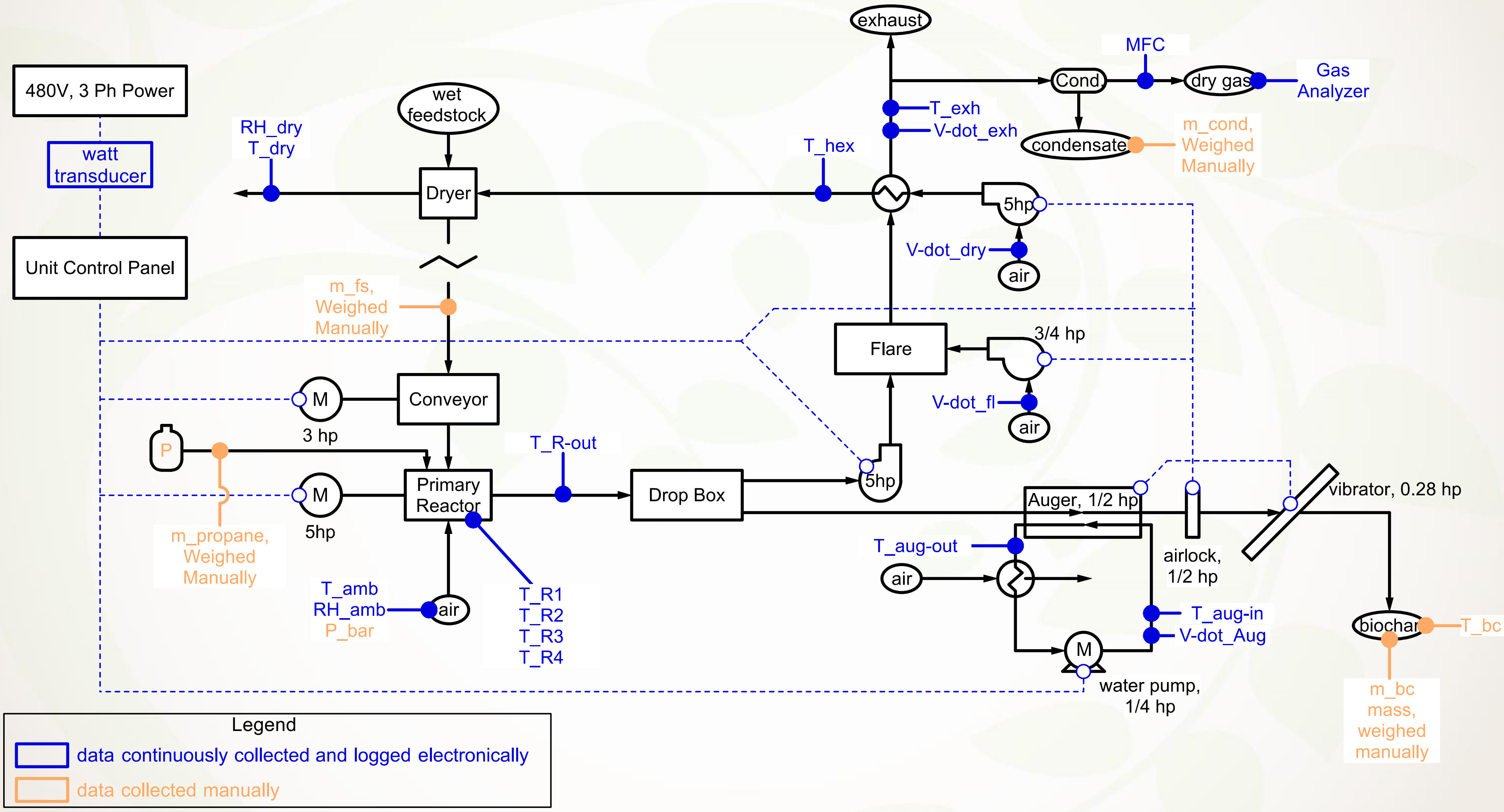


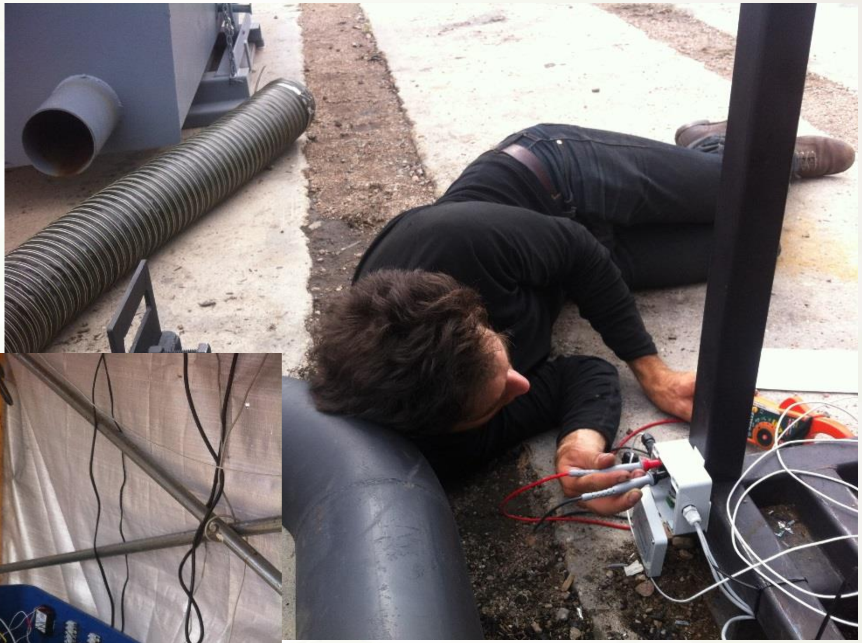
Thermodynamic Control Volume



Process and Instrumentation Diagram



Data Acquisition



Testing Matrix

The biochar machine was tested in August 2014 in Pueblo CO to determine the effect of feedstock species and quality on operational parameters.

Species	Conifer		Conifer		Conifer		Conifer		Conifer		Hardwood		Juniper	
Comminution	Ground		Ground		Ground		Med. Chip		Sm. Chip		Ground		Ground	
Contaminant	none		2/3 bole, 1/3 tops		9% soil		none		none		none		as received*	
Moisture	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, however the juniper feedstock was highly contaminated as received.

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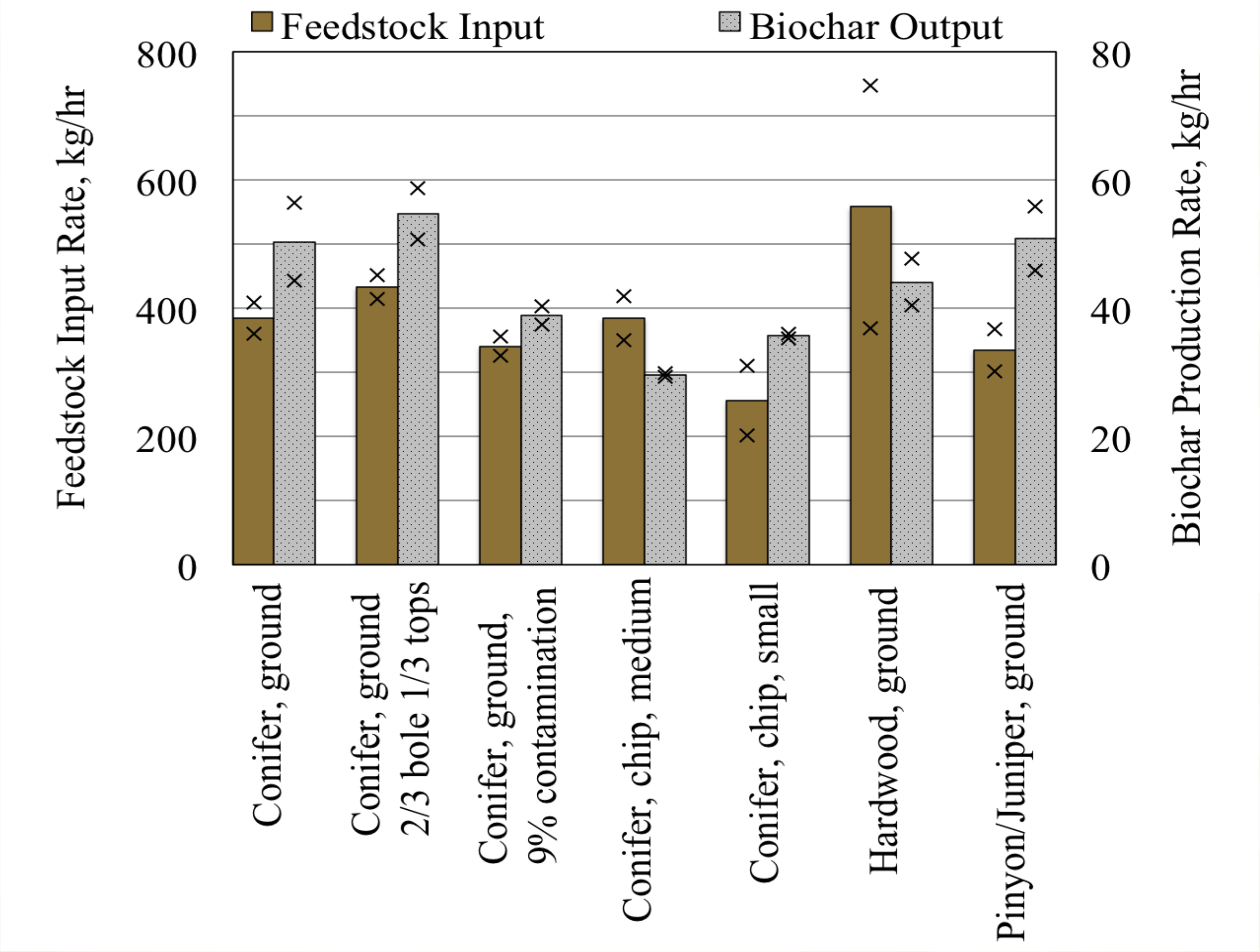
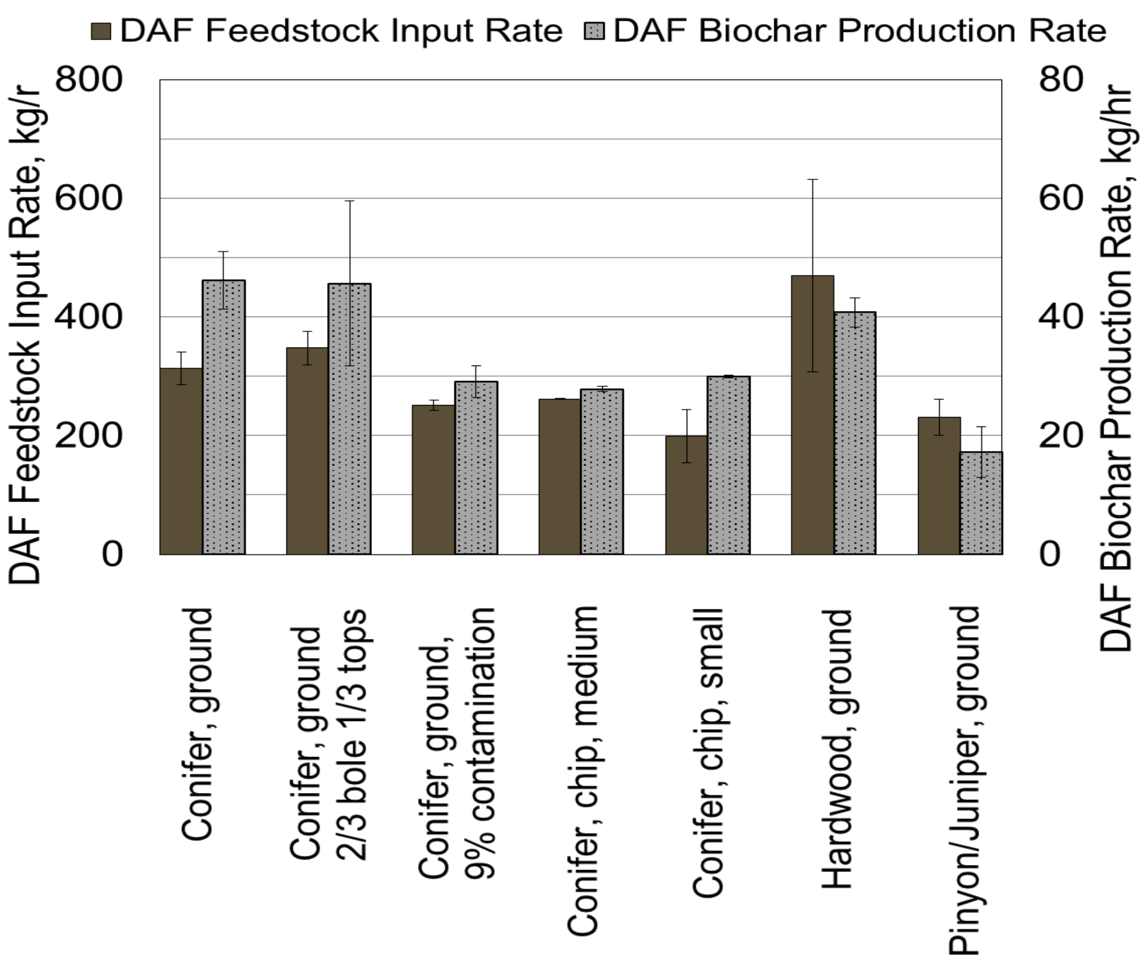
Feedstock and Product Throughput

Average feedstock input (left axis) and biochar production (right axis)



Feedstock and Product Throughput

Average feedstock input (left axis) and biochar production (right axis) on a dry ash-free (DAF) basis



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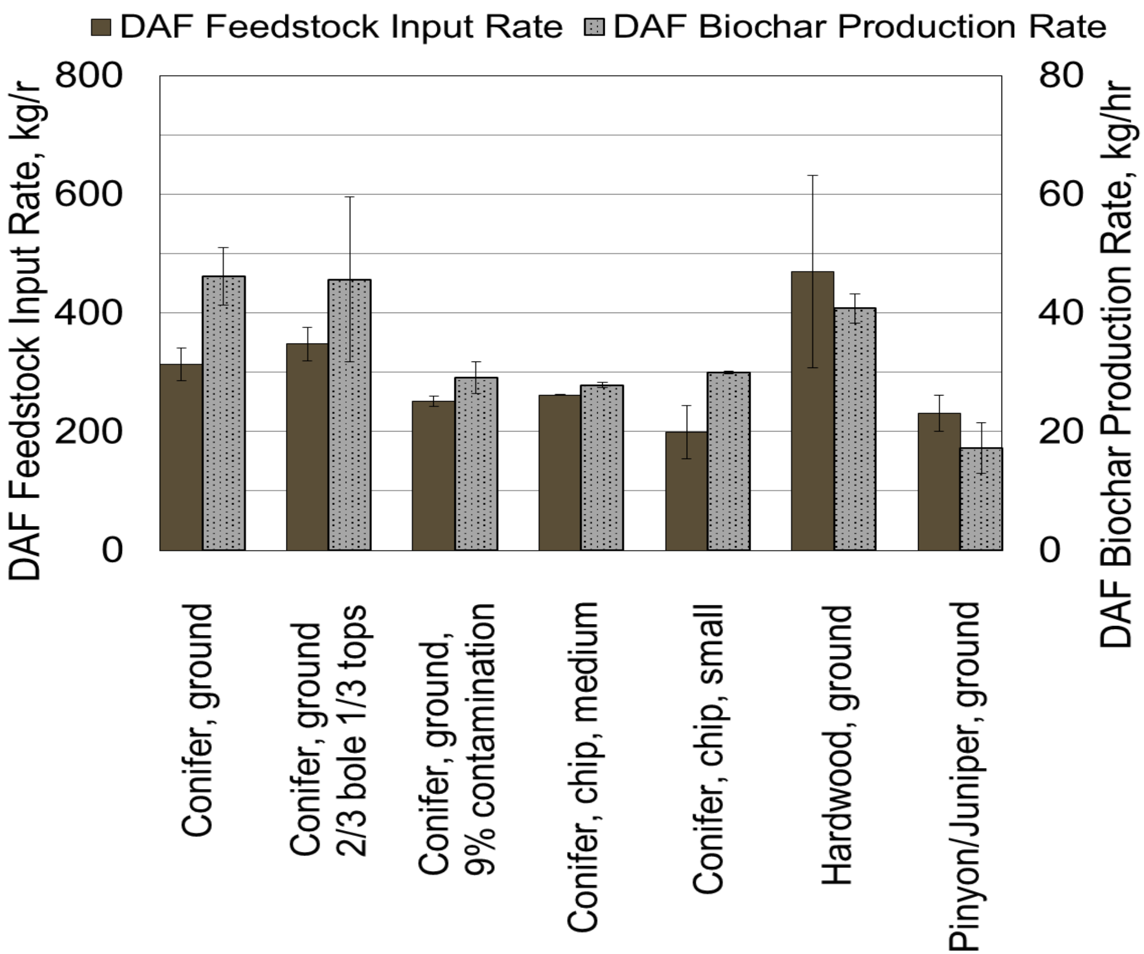
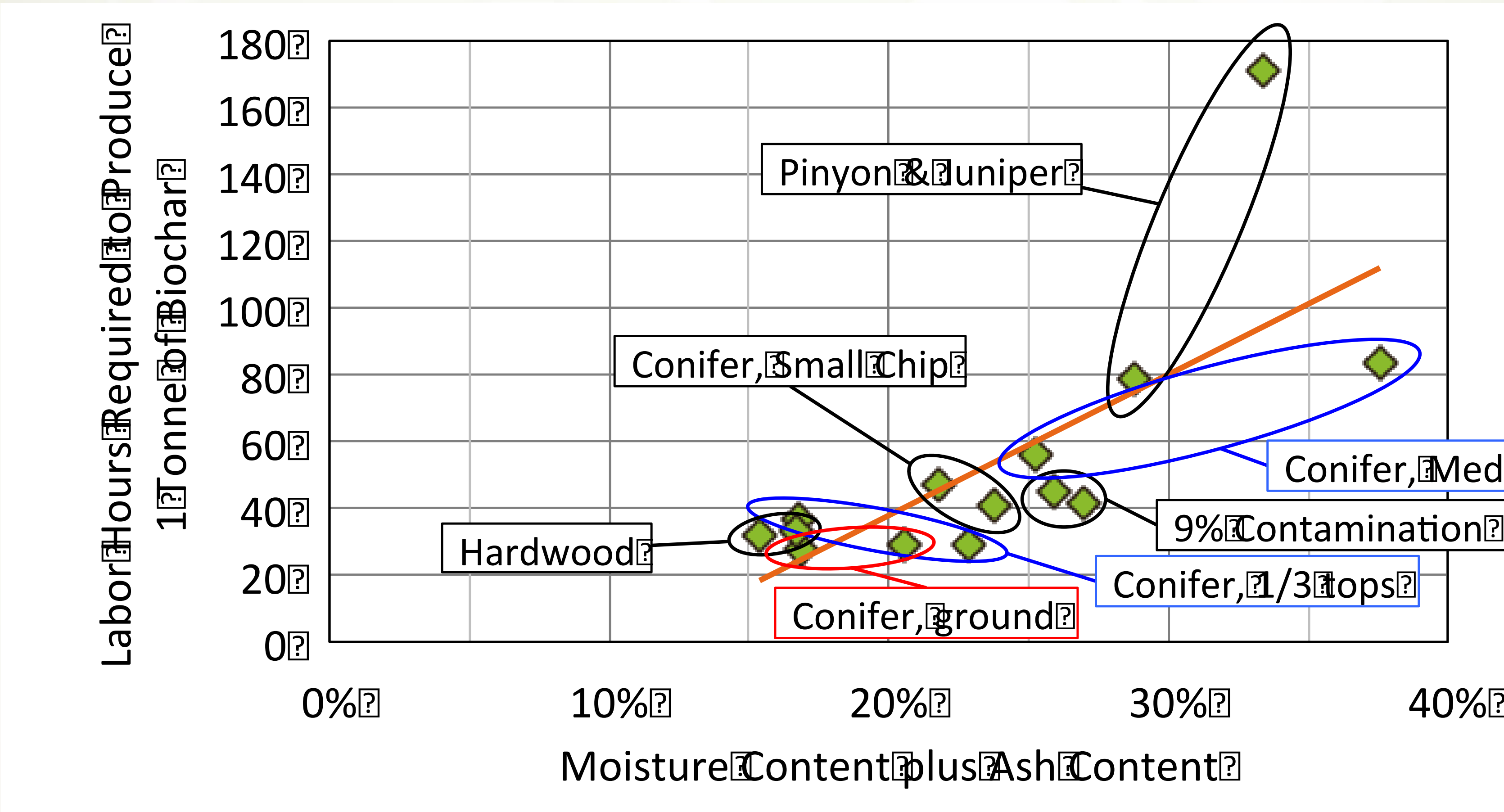


Feedstock	AR Yield	DAF Yield
Conifer ground	13%	15%
Conifer, ground, 2/3 bole, 1/3 tops	13%	13%
Conifer, ground, 9% contamination	11%	12%
Conifer, chip, medium	8%	11%
Conifer, chip, small	14%	15%
Hardwood, ground	8%	9%
Pinyon/Juniper, ground	15%	7%

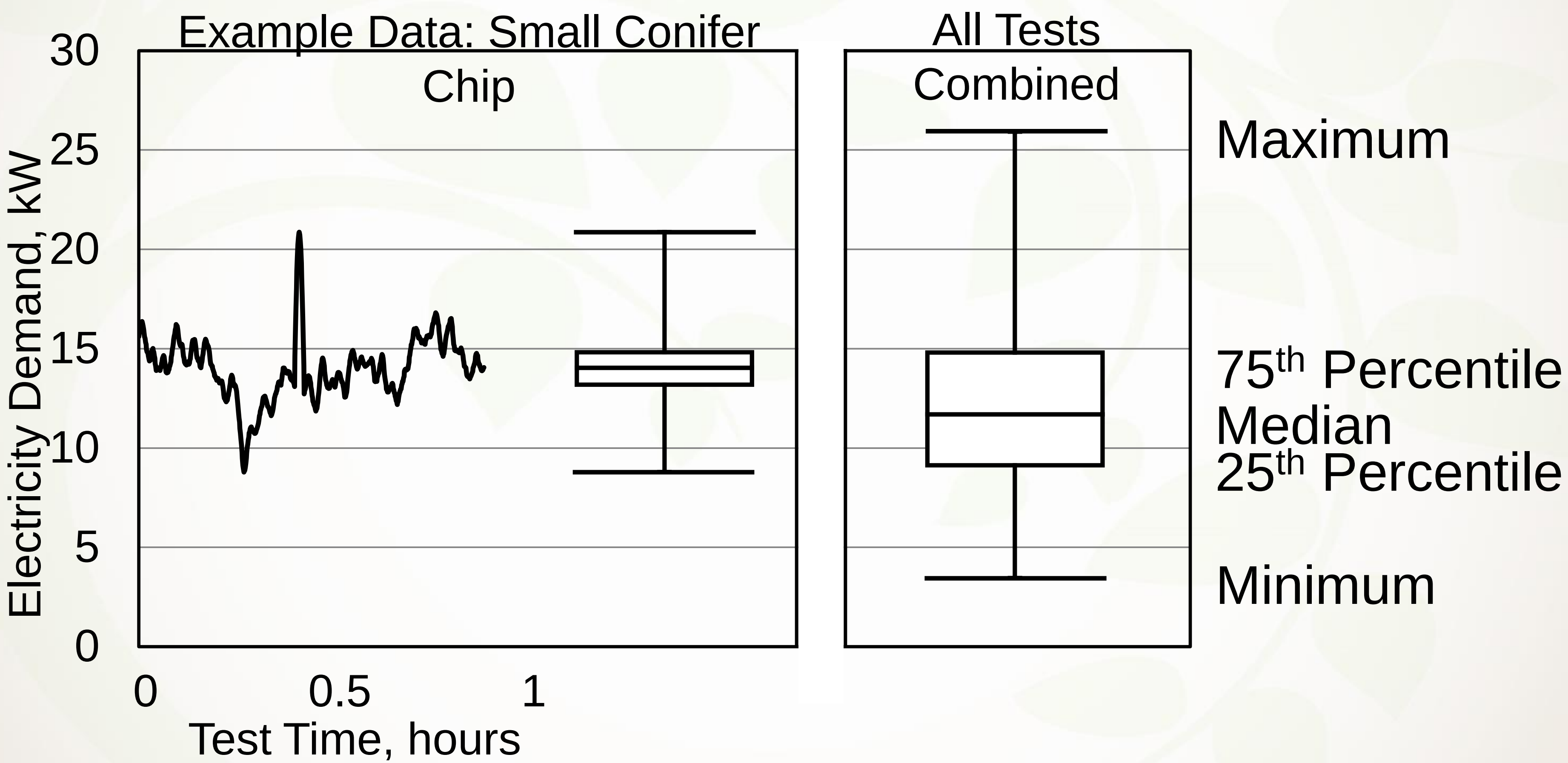
Operational Hours

The amount of labor required for each test is a function of the moisture and ash content.



Electrical Demand

Average electricity demand was 12 kW, but can vary significantly



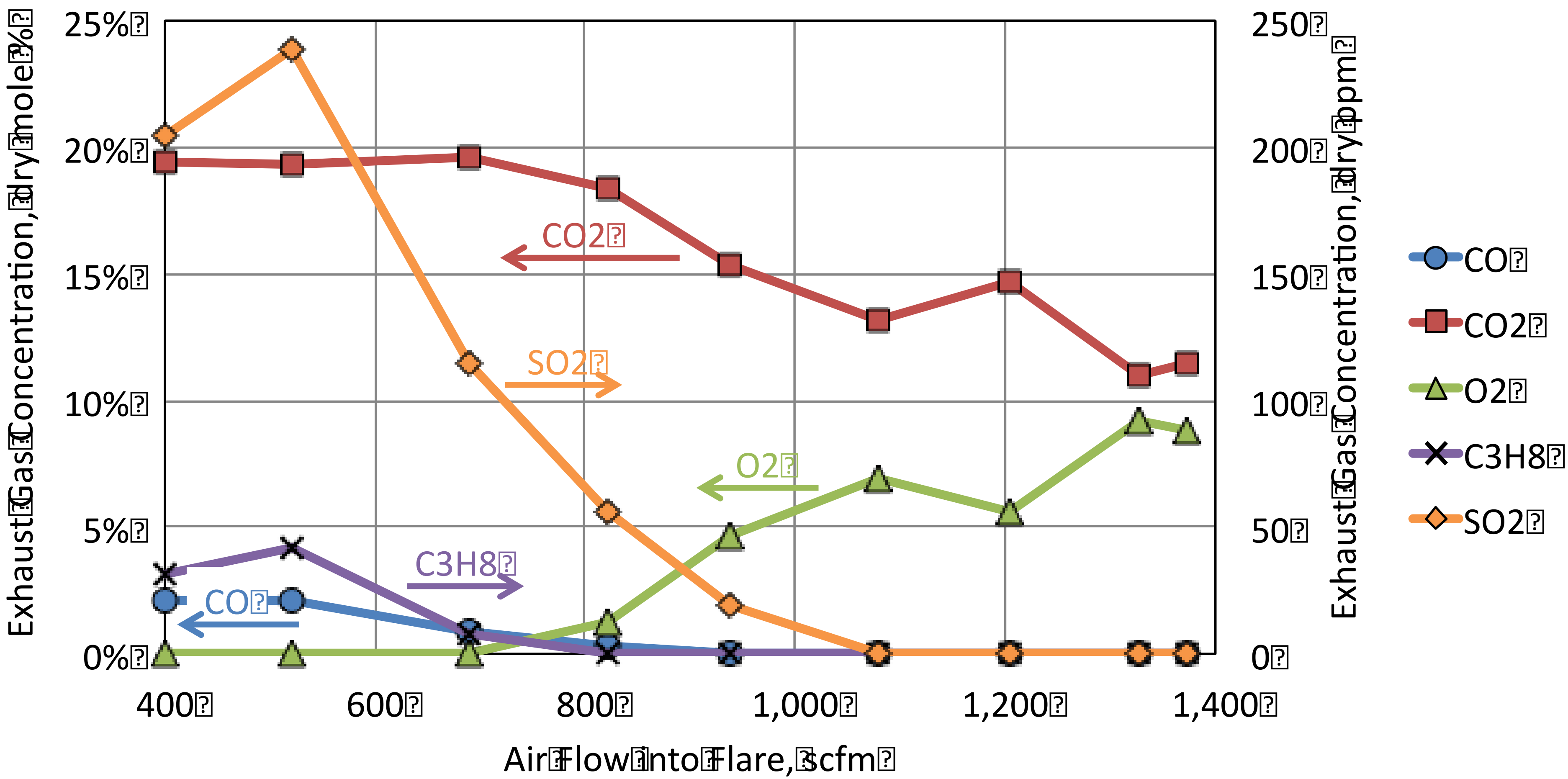
Emissions

Average exhaust gas emissions on a dry gas basis

	Test #	CO, mole %	CO_2, mole %	Propane, ppm	O_2, mole %
Conifer, ground	1	4.8%	17.0%	401	0.3%
	2	2.9%	16.0%	254	2.6%
Conifer, ground, 1/3 tops	1	5.5%	16.6%	547	0.4%
	2	4.7%	17.2%	360	0.1%
Conifer, ground, 9% contaminant	1	3.2%	16.7%	213	1.1%
	2	1.7%	15.6%	102	2.9%
Conifer, chip, medium	1	2.8%	11.2%	634	7.3%
	2	1.4%	17.7%	101	1.1%
Conifer, chip, small	1	1.2%	14.2%	127	0.3%
	2	1.7%	17.2%	163	2.6%
Hardwood, ground	1	9.6%	15.9%	1150	0.8%
	2	3.0%	17.8%	188	0.3%
Pinyon & Juniper, ground	1	0.51%	11.5%	207	8.4%
	2	1.1%	17.3%	60	2.1%

Emissions

Stack Emissions were reduced by increasing combustion air into the flare



Lessons Learned

The testing in Pueblo CO resulted in several important conclusions for scale up:

» An effective spark arrestor is necessary to reduce the risk of spot fires to acceptable levels.

»The combustion air flow rate was generally too low resulting in incomplete syngas combustion.

» Operator effort can be reduced significantly by automating the feed system and rejecting feedstock with high moisture or ash content

»Original feedstock drying system was not effective

Design Changes

Several design changes have been implemented:

» Larger combustion air blower reduces emissions

» Larger outlet airlock increases capacity

» Effective spark arrestor reduces fire hazard

»Improved feedstock drying system:

- » Max input MC specification was ~20%, now 35% or higher.

» Feedstock conveyor automated reducing operator effort

Design Changes Continued

- »Improved biochar cooling system
- »Control panel capacity increased for greater flexibility
- »Control panel moved further away from hot machine
- »Additional heat exchanger added to dropbox for flexibility
- »Various heat shields added to protect motors etc.

Recent Progress: Branscomb CA- 2015

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Recent Progress: Branscomb CA- 2016

Conclusions

» SERC and BSI have used experimental data used to make various improvements on the biochar machine and feedstock drying system

  » Lower emissions due to improved combustion stoichiometry, effective spark arrestor, automated feed system, improved biochar cooling effectiveness, increased capacity

»SERC and RFFI have successfully demonstrated a feedstock moisture management system using process heat from the biochar machine in a belt dryer from Norris Thermal Technologies

» SERC has successfully demonstrated that a small gasification generator set (All Power Labs Power Pallet) can be used to power the biochar machine and the moisture management system for remote operations without diesel.

» Lessons learned are being incorporated into the scaled up version of the biochar machine.

Thank you!

Contact:

David Carter PE, Sr. Research Engineer, Schatz Energy Research Center

Humboldt State University, david.carter@humboldt.edu, (707) 826-4345