NATIONAL RENEWABLE ENERGY LABORATORY

Comparing Effects of Feedstock and Run Conditions on Fast Pyrolysis Products Produced at the Pilot Scale: Solids Management from an Operational Perspective

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2017 ACS Spring Meeting

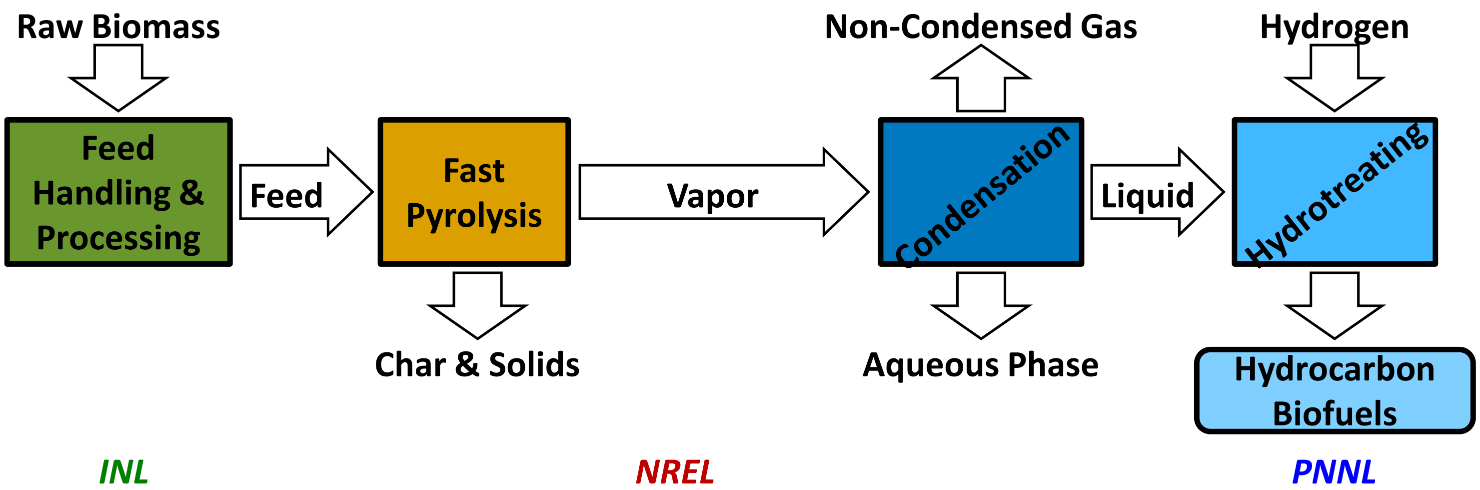
San Francisco, California

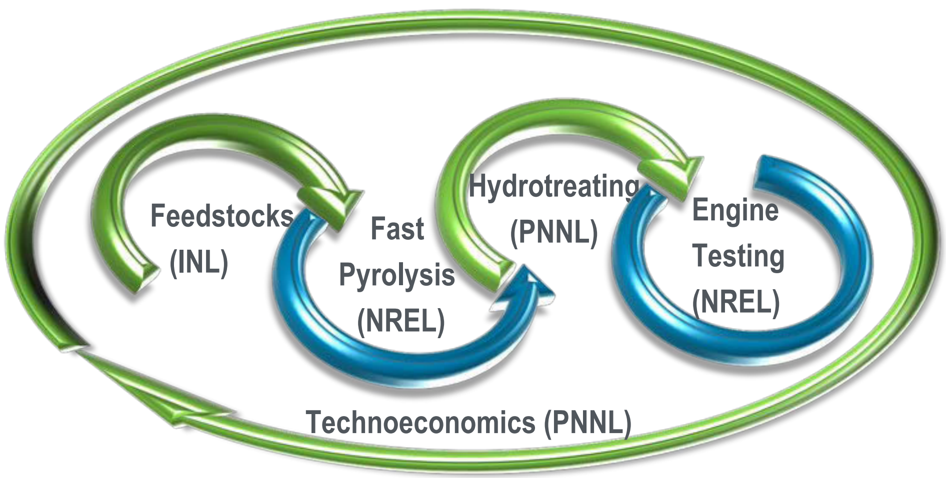
April 4th, 2017

NREL/PR-5100-70213

"Field to Fleet" Fast Pyrolysis Verification

Objective: Conduct preliminary pilot-scale tests to down select feedstock and operating conditions for the verification run.





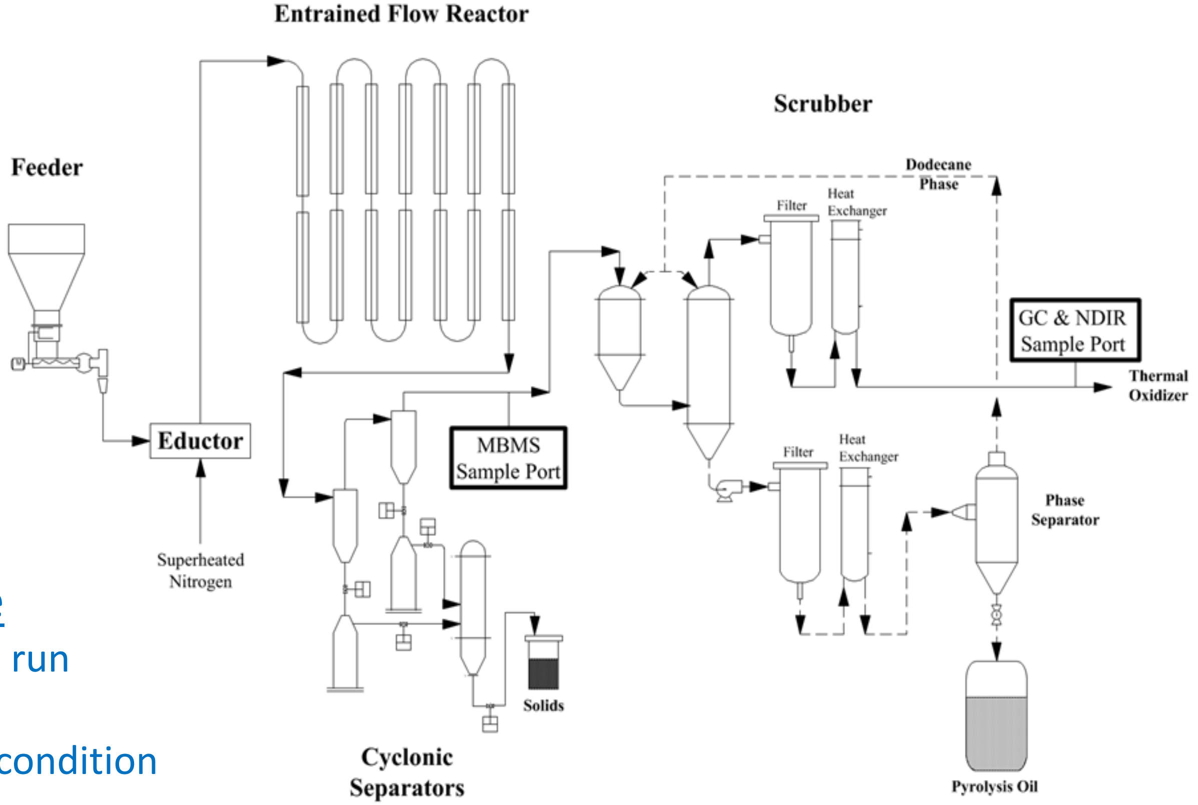
BETO FY17 Performance Goal:

"Validate at a pilot scale at least one technology pathway for hydrocarbon biofuel production at a mature modeled price of $3/GGE with GHG emissions reduction of 50% or more compared to petroleum fuel."

-BETO MYPP 2016

TCPDU Flow Diagram – Configured for Fast Pyrolysis

½ Ton/Day
Continuous feed plant
Variable Residence Time
Variable Temperature
Variable Flowrate



Sample Procedure

- Pyrolyse feedstock at determined run conditions and steady state
- Collect 5 gallon sample of oil per condition
- Collect char throughout run
- Analyze light gasses and pyrolysis vapors during run
- Residual carbon oxidation 'burnout' performed between trials
- Quenching fluid changed between feedstocks

Fast Pyrolysis: Thermochemical decomposition of biomass in the absence of oxygen at elevated temperatures

Blended feedstocks tested for demonstration

- Delivered cost target <$90/dry ton (biomass)
- Conversion target ~$2.53/GGE (2014$)
- Industrially relevant

Benefits of Blends:

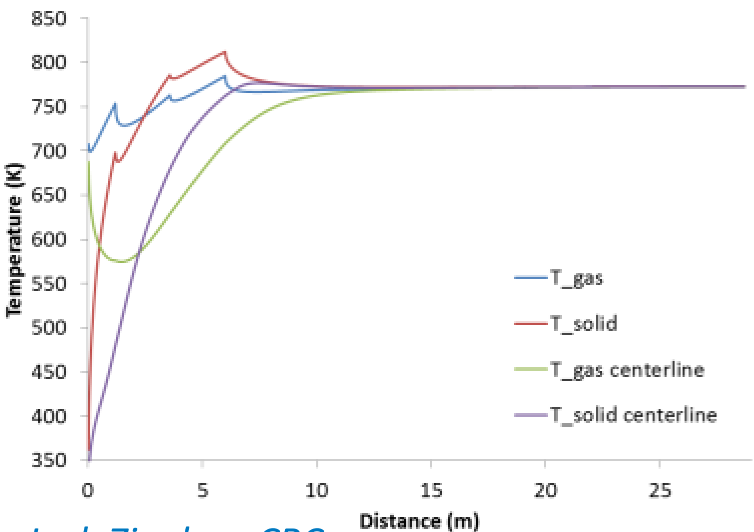
- Increase resources available
- Dilution of negative characteristics
- Enhancement of positive characteristics
- Lower feedstock cost

Feedstock	Oak	Clean Pine	$CP_{30}FR_{35}C\&D_{25}SW_{10}$	$CP_{45}FR_{25}C\&D_{30}$
Est. Feedstock Cost ($/dry ton)	>$100.00	$99.50	$75.10	$79.10
Other Notes	Baseline material used by TCPDU	Baseline material used by INL & PNNL.	PNNL design case blend	All-woody version of blend

CP = Clean Pine, FR = Forestry Residues, C&D = Construction and Demolition waste, SW = Switchgrass

Initial Operating Conditions Chosen Based on Modeling

Condition	1	2	3
Reactor Temp	500°C	500°C	480°C
# of reactor zones	12	4	4
Residence Time	~ 3.5 sec	~ 0.9 sec	~ 0.9 sec
Other Notes	Standard TCPDU operating condition	Slightly over time required for particle to get to temp based on model	Reaction temp oils PNNL uses



Jack Ziegler - CPC

Modeling & operational data show that solids in the entrained flow reactor reach temperature in less than 3 zones.

Initial Run Conditions Not Viable

- Plant shut downs necessary within 15 minutes of starting feed due to char plugging cyclones or continuing to condensation chain
- Unable to run consistently enough to perform 5 gallon runs

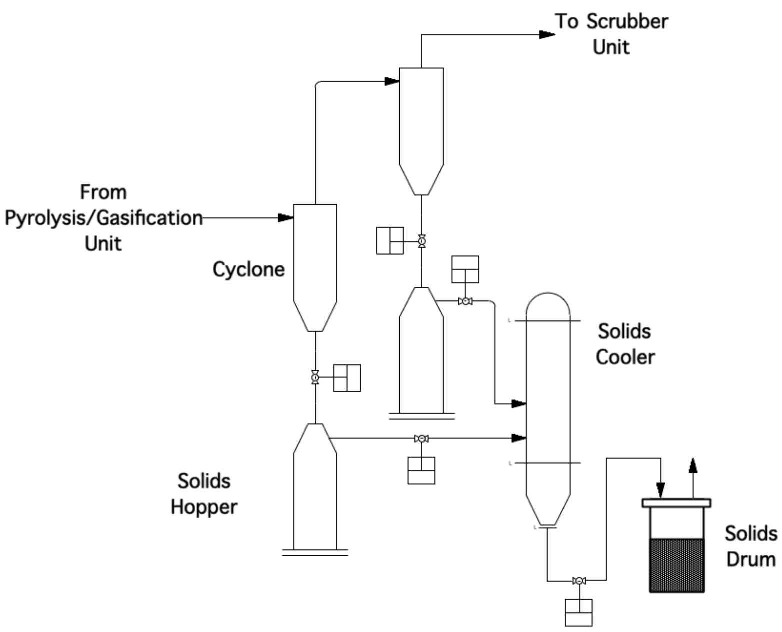
https://blogs.psychcentral.com/observations/files/2012/12/iStock_000014047443XSmall.jpg

Char collection problems presented in two ways

- Char not flowing through collection system
  - Required immediate on the fly plant maintenance
  - Resulted in loss of char
- Sending char to the scrubber
  - Requires shut down of feed for significant plant maintenance
  - Resulted in loss of char and oil used in mass balance

Further characterization required!

TCPDU Cyclonic Separator System



Additional Experiments Performed to Characterize Problems

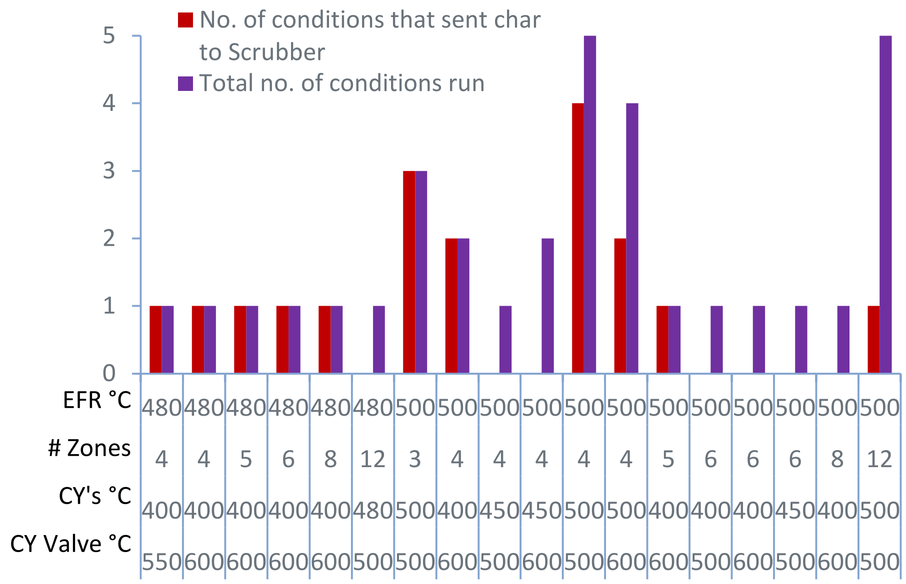
Hypotheses

- Sticky char caused by under-cracking (Under-pyrolyzing)
- Sticky char caused by over-cracking (Polymerizing)
- Non-ideal char particle size distribution (PSD)
- Cyclone build-up/obstruction

Lessons Learned

- Short residence times/less severe pyrolysis led to char in scrubber
- Longer residence times/more severe pyrolysis decreased operational difficulties

Trials conducted with Pine Feedstock to characterize char collection problems

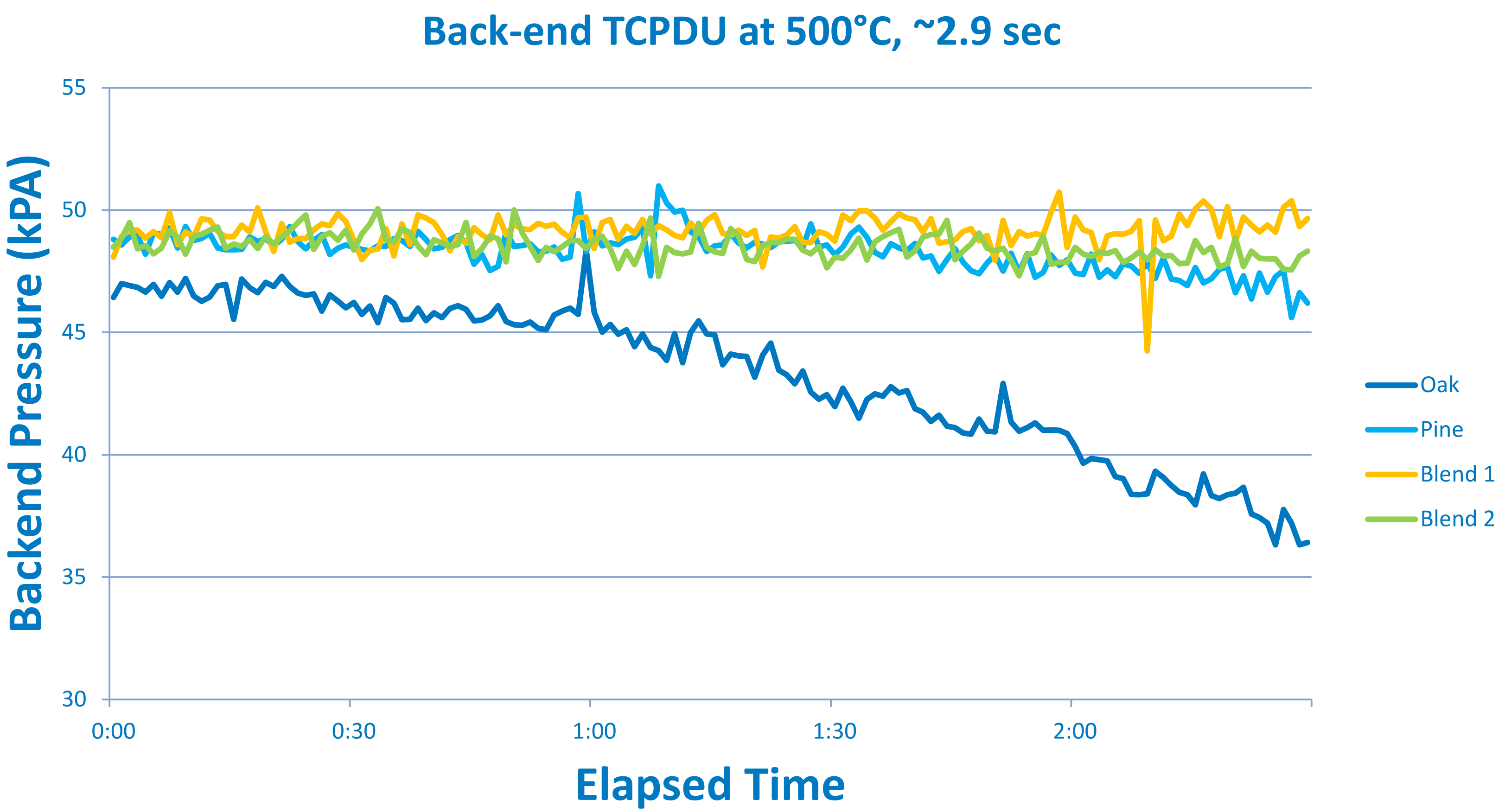


New operating conditions chosen

Condition	1	2	3
Reactor Temp	500°C	500°C	480°C
# of reactor zones	12	9	12
Residence Time	~ 3.5 sec	~ 2.6 sec	~ 3.5 sec
Other Notes	Standard TCPDU operating condition	Slightly over time required for particle to get to temp based on model	Reaction temp oils PNNL uses

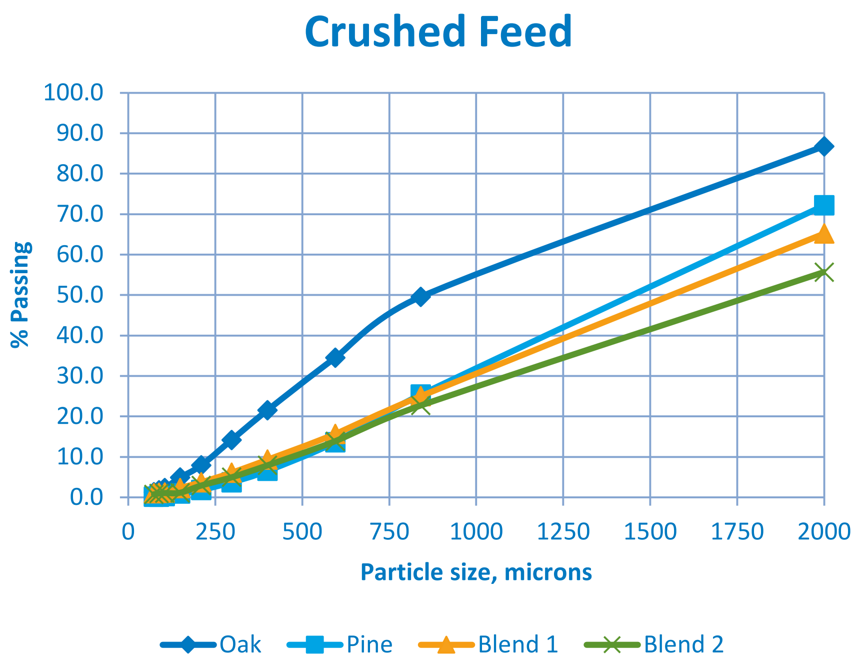
- Less severe conditions lead to increased operational problems
- Smaller native particle size of oak feed presumed to aid in plant operations

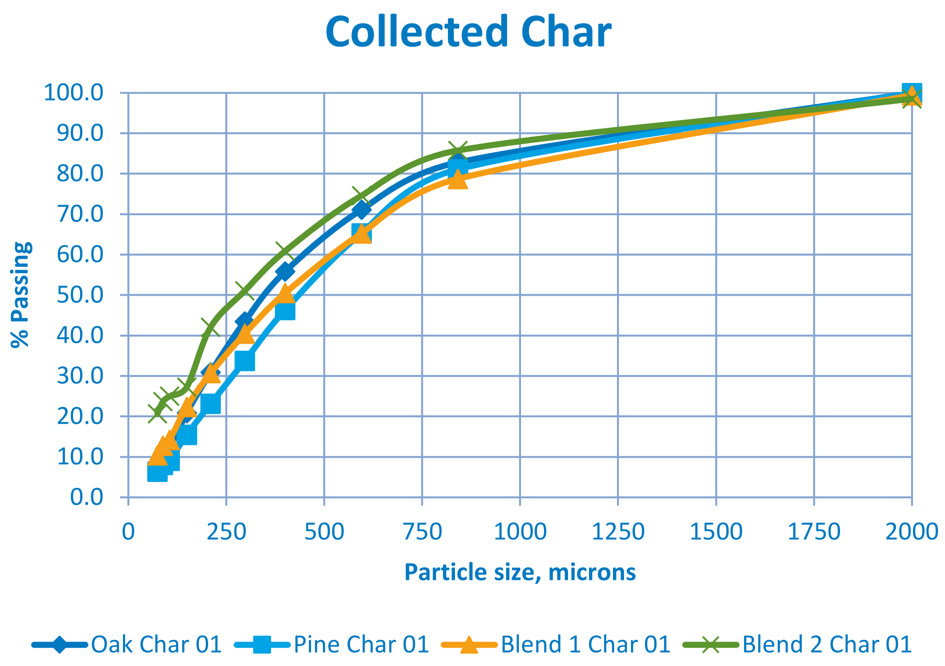
Pressure effects observed running different feedstocks



- Pressure drop due to build up of carbon/oil deposits at condensation chain inlet

Feedstock particle size relation to system pressure drop





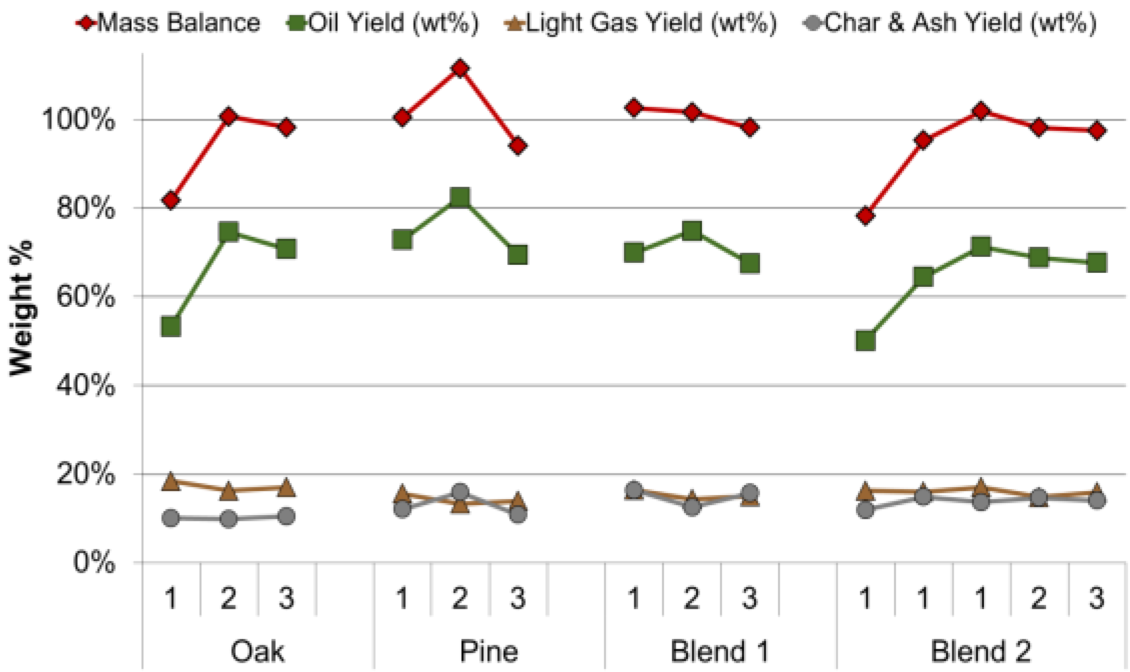
- Crushed Oak feed contained larger distribution of smaller particles
- Collected char samples contained similar size distribution regardless of feedstock
- Small particles in oak feed thought to volatilize more completely, though fine solids likely carried through cyclones and into condensation chain inlet, causing system pressure drop
- Oak pellets made from sawdust, where pine pellets made from native wood milled to ~2mm.
- Pellets very similar in size

Mass Balances Difficult to Obtain with Short run times

Lesson Learned:

- Mass lost due to char plugging complicates mass balance
- TCPDU optimized for larger runs-5 gallon runs at operational fringe for data resolution
- Scrubber requires ~8 hours to equilibrate in order to achieve consistent oil yields

Mass Balance & Product Yield Results



- Replicates of Blend 2, condition 1 run to verify reproducibility of results
- Trials run 12131

System brought to steady state operation conditions prior to collection of 5 gallon samples

Conclusions

- Essential to run tests prior to large demonstrations
- Optimum operating conditions depend on feedstock
- Under pyrolyzed material difficult to manage operationally
- Solids management is difficult but very important
- Pilot scale demonstration is critical to verify chemistry and operational scalability

Acknowledgements

Thermochemical Process R&D Section:

- Tim Dunning
- Katie Gaston
- Chris Golubieski
- Ray Hansen
- Matt Oliver
- Marc Pomeroy
- Kristin Smith
- Esther Wilcox (PI)

Collaborators:

Idaho National Laboratory

Pacific Northwest NATIONAL LABORATORY

Funding:

DOE BETO

Thank you!

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This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Bioenergy Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government.

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