U.S., Department of Energy (DOE)
Bioenergy Technologies Office (BETO)
2017 Project Peer Review

Catalytic Upgrading of Thermochemical Intermediates to Hydrocarbons

(WBS 2.4.1.403)

March 9, 2017

Thermochemical Conversion

David C. Dayton, PI

RTI International

This presentation does not contain any proprietary, confidential, or otherwise restricted information

Goal Statement

Demonstrate an advanced biofuels technology at the pilot scale that integrates a catalytic biomass pyrolysis step to produce a low oxygen-content, thermally stable bio-crude intermediate that can be upgraded in a hydroprocessing unit to produce infrastructure compatible biofuels.

Technical goals:

1) Operate a catalytic biomass pyrolysis process (1 tonne/day -1TPD))
    a. Investigate the effect of process conditions, catalyst, and feedstock on bio-crude yield to achieve high degree of deoxygenation (< 20 wt%) while maximizing the bio-crude yield (> 40 C%)
    b. Produce at least 25 gallons of bio-crude for upgrading from different feedstocks for upgrading
    c. Improve bio-crude thermal stability (< 80% residual losses in SIMDIST)
2) Evaluate the impact of bio-crude quality in the hydroprocessing step
    a. Investigate steady-state deoxygenation activity, hydrogen demand, and process severity with loblolly pine bio-crude of various quality (wt%O)
    b. Investigate impact of biomass feedstock on bio-crude upgrading
    c. Evaluate opportunities for co-processing bio-crude and upgraded bio-crude with refinery intermediates
3) Update techno-economic analysis of integrated process and conduct life-cycle assessment of the integrated advanced biofuels process

Target: nth plant modeled MFSP of $3/GGE (2014$) via CFP with hydroprocessing to produce hydrocarbon biofuel with GHG emissions reduction of 50% or more compared to petroleum-derived fuel.

- Update bio-crude and biofuel yields
- Verify CAPEX for upgrading step (single vs. multi-stage hydroprocessing)
- Update hydrogen demand and hydroprocessing conditions with experimental results

Quad Chart Overview

Timeline

- Award date: 10/1/2011
- Contract award date: 8/16/2012
- Project end date: 3/31/2017
- ~99% complete

Barriers

- Ct-F. Efficient High-Temperature Deconstruction to Intermediates
- Ct-H. Efficient Catalytic Upgrading of Bio-Oil Intermediates to Fuels and Chemicals

Partners

- RTI – project lead, CFP technology development, Hydroprocessing, project management
- Haldor Topsøe A/S (HTAS) - Hydroprocessing Development and Process Modeling

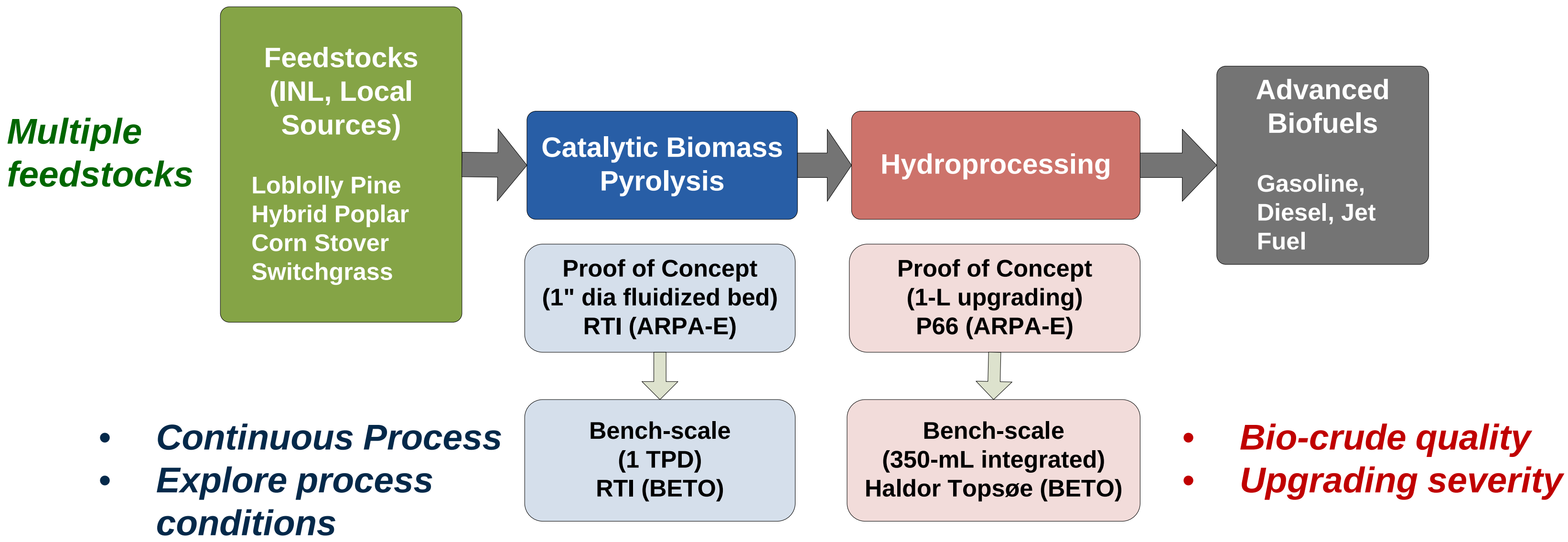
<u>High impact feedstock providers</u>

- Idaho National Laboratory
- Local NC wood products suppliers
- Iowa State University

	FY12 - FY14 Costs	FY15 Costs	FY16 Costs	FY17 - Project End Date Cost
DOE Funded	$1,946,214	$1,140,215	$1,056,193	$207,307
Cost Share - Haldor Topsoe	$240,765	$171,880	$445,393	$141,962
Cost Share - State of NC	$100,000	$0	$0	$0
Total	**$2,286,979**	**$1,312,095**	**$1,501,586**	**$349,269**

1- Project Overview

Build on previous development efforts (ARPA-e) that identified a suitable solid acid catalyst for catalytic biomass pyrolysis to demonstrate an advanced biofuels technology that integrates a catalytic biomass pyrolysis step and a hydroprocessing step to produce infrastructure compatible biofuels.



Scale-up CFP process to pilot-scale to validate catalyst performance and bio-crude yields and quality

1) optimize the catalytic biomass pyrolysis process (1TPD) to maximize high-quality bio-crude production (< 20 wt% O and > 40% carbon recovery)
2) improve bio-crude thermal stability

Design, build and operate a pilot-scale hydroprocessing unit to upgrade bio-crude intermediates

1) evaluate the impact of bio-crude quality on the hydroprocessing step
2) evaluate co-processing opportunities
3) evaluate hydrogen demand of the integrated process
4) maximize biofuels yield

2 – Approach (Management)

Detailed project plan with quarterly milestones and deliverables and annual Go/NoGo decision points

Task 1.0: Pilot-scale Catalytic Biomass Pyrolysis (RTI, INL)

Key Milestones: Complete 1TPD unit commissioning; catalyst and feedstock procurement, bio-crude production

Task 2.0: Hydroprocessing Evaluation and Optimization (Haldor Topsoe)

Key Milestones: Develop upgrading strategy for RTI bio-crude samples; Develop optimized process conditions for bio-crude upgrading; Bio-crude/refinery intermediate co-processing

Task 3.0: Hydroprocessing Reactor Design and Fabrication for Integrated Process Development (RTI, Haldor Topsoe)

Go/NoGo Decision Point *– Technical review of hydroprocessing unit design and cost analysis prior to start of fabrication. (April 2014)*

Go/NoGo Decision Point *– Commissioning hydroprocessing unit. (March 2015)*

Task 4.0: Integrated Bio-crude Upgrading and Process Operation (RTI)

Key Milestones: Complete up to 1000 hours of upgrading with loblolly pine bio-crude, 500 hours of upgrading with two other bio-crudes.

Task 5.0: Process Modeling and Refinery Integration (RTI, Haldor Topsoe)

Key Milestones: 2000 TPD Integrated Process Design and Economics; Economic analysis of the technical feasibility of co-processing bio-crude and hydrocarbon intermediate streams

Task 6.0: Project Management and Reporting (RTI)

2 – Approach (Technical)

Pilot-scale (1TPD) *in situ* Catalytic Fast Pyrolysis

- Continuous feed circulating fluidized bed reactor/regenerator – scaleable design
- Maximize carbon efficiency and deoxygenation to control bio-crude properties
- Verify long-term deoxygenation activity and attrition resistance
- Maximize bio-crude yield

Challenges: char/coke formation reduces bio-crude yields, bio-crude recovery efficiency, steady-state bio-crude yields, obtaining pilot-scale quantities of catalyst and feedstock

Bio-crude Upgrading

- Design, fabrication, and installation of a pilot-scale (dual 350-mL reactors) hydroprocessing unit that provides data for scale-up
- Benchmark operation to verify system performance and data reliability
- Long-term unattended operation to determine upgrading catalyst stability and lifetime (500-1000 hrs)
- Refinery integration and co-processing strategies

Challenges: Reactor plugging, process severity correlated to bio-crude composition

Critical Technical Goals

- Steady-state pilot plant operation to validate bio-crude yields
- Steady-state bio-crude upgrading to validate catalyst HDO activity
- Updated techno-economics to validate technology cost competitiveness

3 – Technical Accomplishments/Progress/Results

1 TPD unit operational for more than three years

- 4 catalysts tested; 5 feedstocks – loblolly pine, hybrid poplar, corn stover, hardwood pellets, red oak
- 12-h Parametric Studies
  - Temperature was the most influential factor.
    - Moderate temperatures ($450 \leq T < 500$) favored higher yields.
    - Anhydrosugars are cracked at higher temperature > 500 ^{o}C, and formation of simple phenols, catechols, and PAH increases.
  - Short residence times reduced biomass devolatilization
  - Overall material balances routinely 80%-100%
  - Gas Yield: 5-11 C%; Total Liquid Yield: 15-30 C%; Total Solid Yield: 48-70C%
  - Steady-state yield varied between 38 and 50 gallons/dry ton of biomass
- Over 200-gal of loblolly pine bio-crude and 20-gal of red oak bio-crude produced for upgrading.

3 – Technical Accomplishments/Progress/Results

Hydroprocessing Evaluation and Optimization

- Developed strategy for upgrading RTI bio-crude samples (catalyst selection and initial process conditions)
- Design, fabrication, and installation of hydroprocessing unit at RTI
- Commissioning (January 2015) and baseline testing (February 2015) to validate system performance
  - 3 baseline experiments with vacuum gas oil (VGO)
  - More than 300 hours time-on-stream and 30 gallons of VGO hydrotreated
  - Mass closures between 99-100 wt%
  - Hydrodesulfurization between 93.8 to 95.3% and hydrodenitrification between 84.1 to 89.7%.
- Over 1500 cumulative hours of bio-crude upgrading since April 2015.
  - High carbon yields (55% to 95%).
  - More stable hydrotreating catalyst activity (> 100-hrs) with lower oxygen containing bio-crudes (< 15 wt%)
  - The HDT product contained mostly naphthenic hydrocarbons. HDT product with greater than 5 wt% O contained more mono-phenols and aromatics hydrocarbons (Mono-, Di-, and Tri-)
  - HDT product carbon number distribution up to C27
- Comprehensive bio-crude and upgraded bio-crude sample analysis
- Co-processed bio-crude and refinery intermediate blends
  - 1180 hours total co-processing with 542-hrs 30%CPO/70%LG
  - 85% diesel-range product

Catalytic Biomass Pyrolysis Scale-up

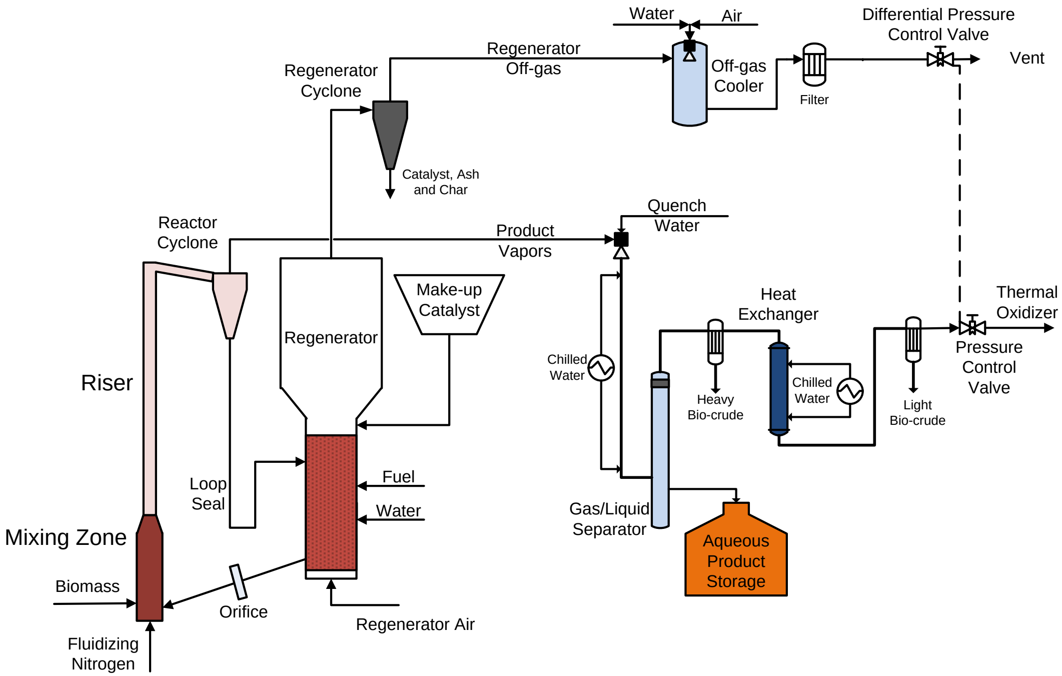
Understand the effect of operating parameters on product yields and quality

- Pyrolysis temperature (350-500 ºC)
- Residence time (0.5-1.0 s)
- Catalyst circulation rate (catalyst to biomass ratio)
- Type of biomass

Continuous, long-term operation

- Validate bio-crude yields and quality
- Demonstrate catalyst stability and durability
- Gain operational experience
- Collect engineering design data for scale-up

Produce bio-crude for Upgrading Technology Development



Pilot-Scale Studies: Methodology

Objective:

- Demonstrate steady-state operation for at least 12 consecutive hours to evaluate process conditions on biocrude yield and quality.

Catalyst:

- Non-zeolite alumina based catalyst with nominal 70 µm particle size

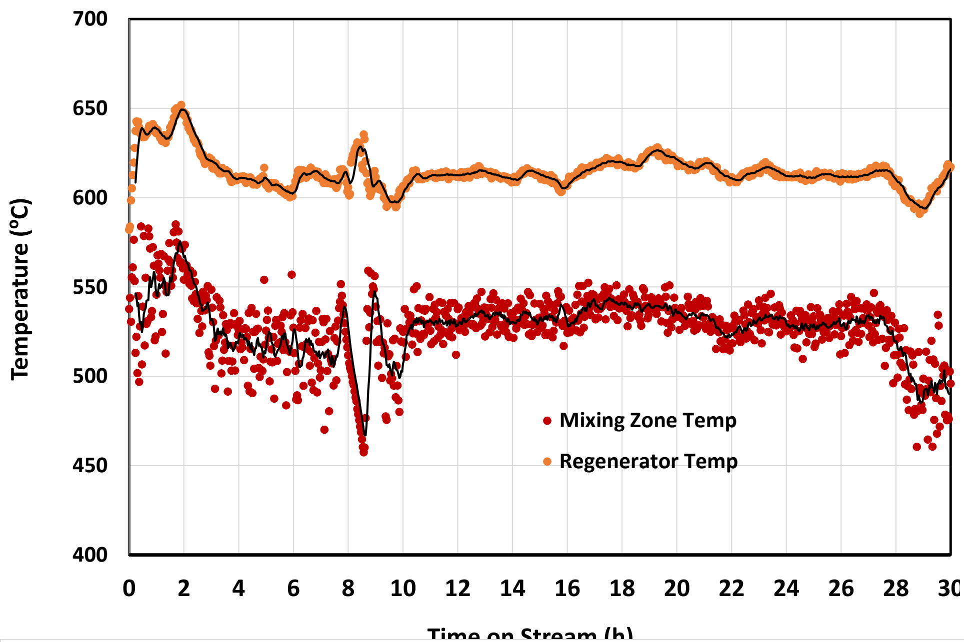
CFP Conditions:

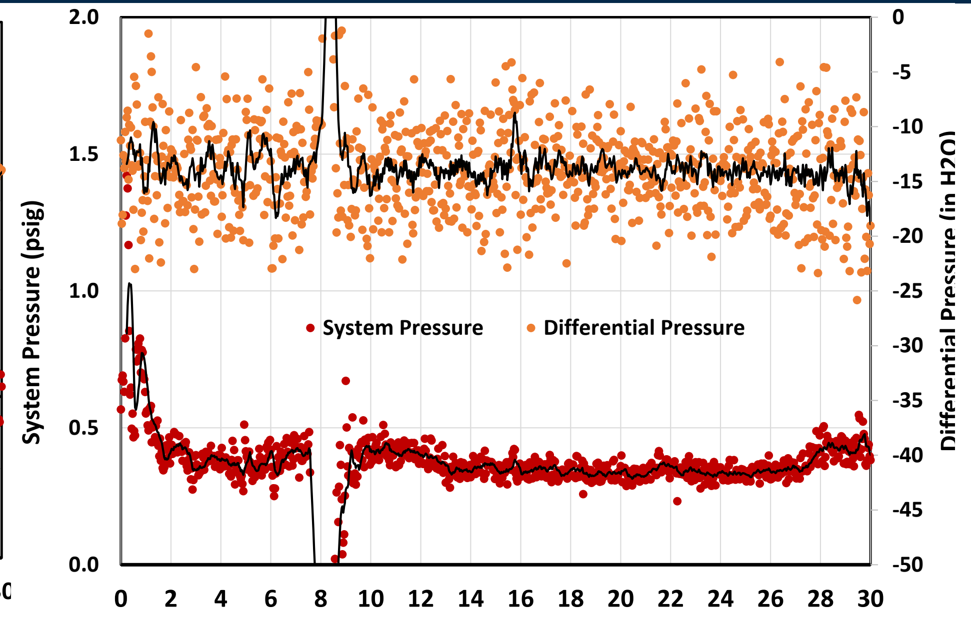
- Biomass Feed Rate: 35-70 kg/h
- Pyrolysis Temperature: 425-600 ºC
- Regenerator Temperature : 560 -640 ºC
- Mixing Zone N_2 flowrate : 75 – 550 scfh
- Mixing Zone Residence time : 0.5 – 2 s

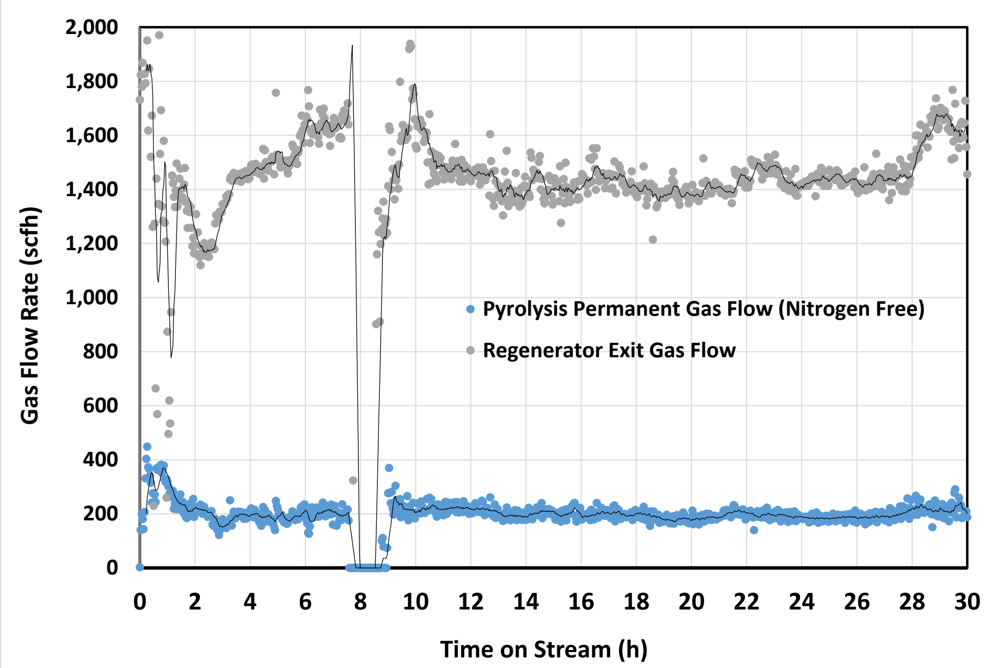
Feedstocks:

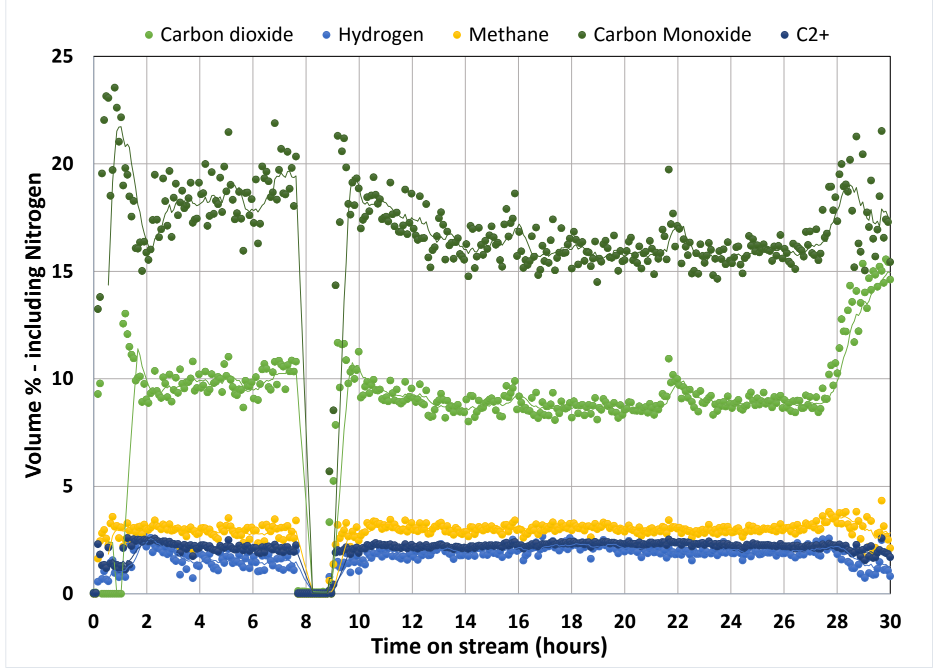
Biomass	Particle Size	Moisture wt%	Elemental composition (as-received), wt.%			
			Carbon	Hydrogen	Nitrogen	Oxygen
Loblolly pine	2 mm top size	15.0	47.4	6.5		46.2
Red Oak	< 2mm	10.0	45.5	6.4	0.4	47.7

Pilot Plant Operations



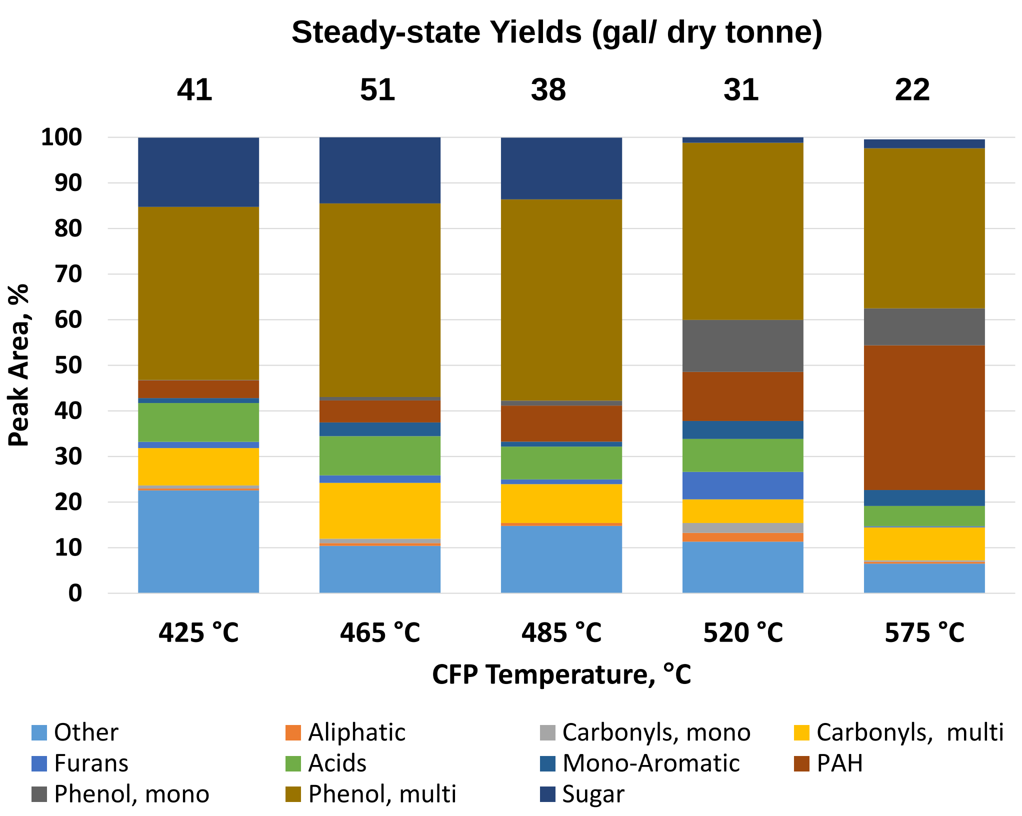


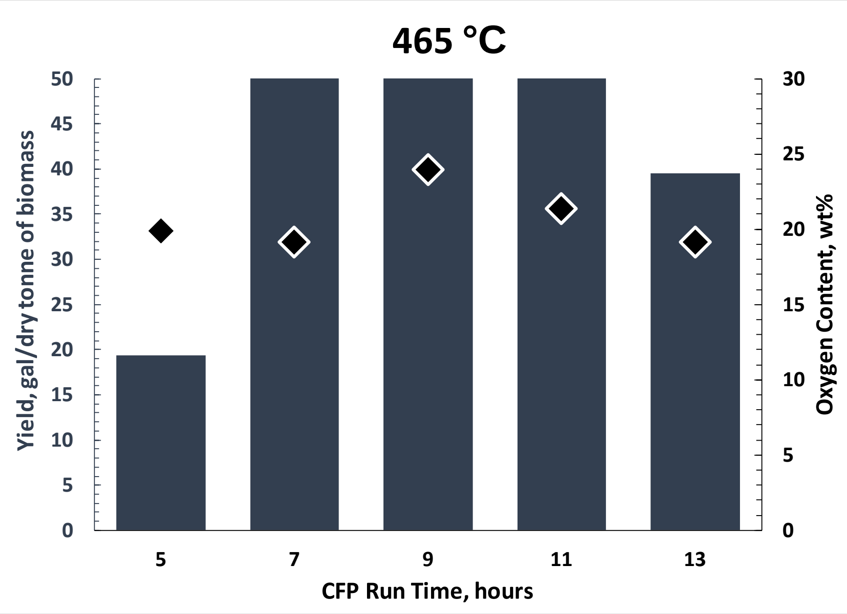




Results- Yield and Composition Summary

Steady-state yields of biocrude for CFP of loblolly pine using alumina catalyst at 465 ^oC was ~50 gal/ton.





Short residence times reduced biomass devolatilization

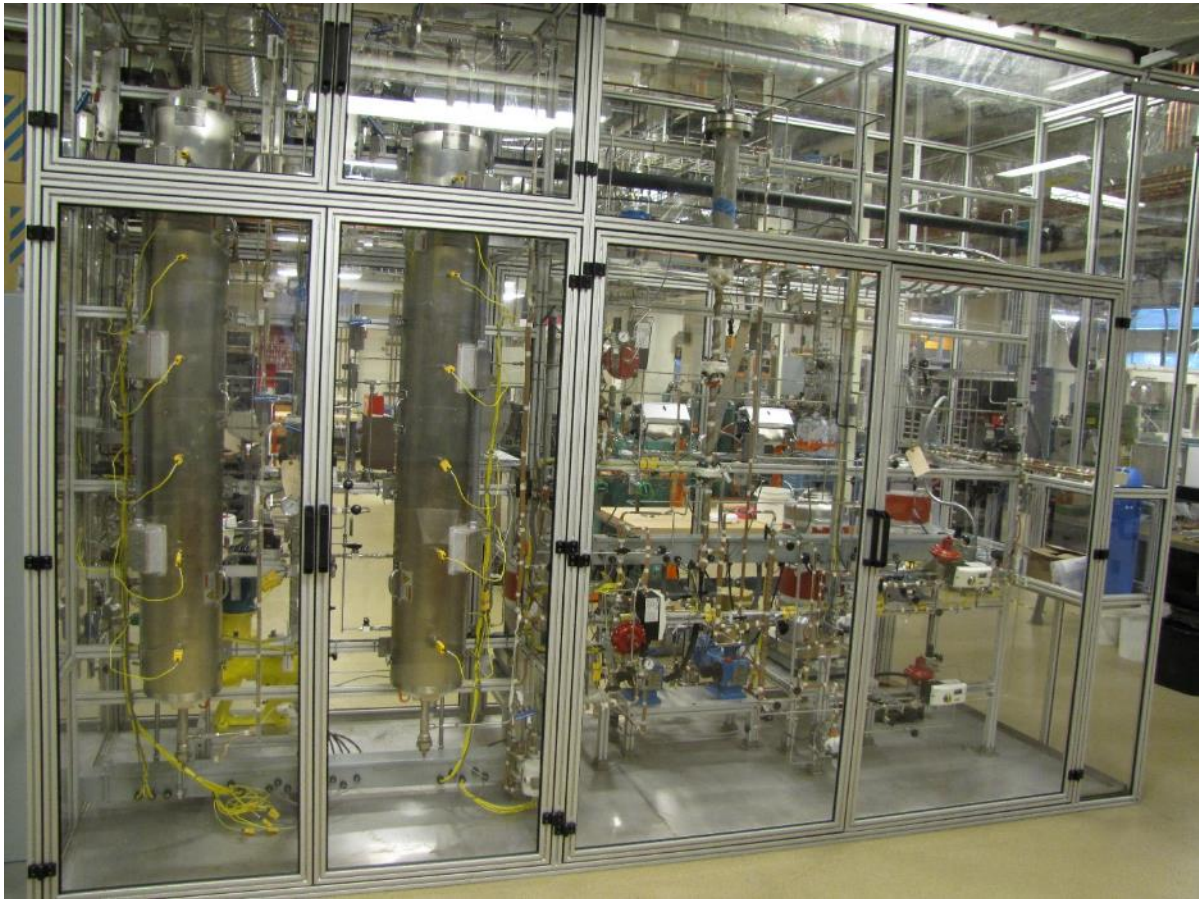
Temperature was the most influential factor

- Higher yields at T < 500
- Less anhydrosugars and more simple phenols, catechols, and PAH at > 500 ^oC

Steady-state yields varied between 22 and 51 gallons/dry tonne of biomass

Process Development Hydroprocessing Unit

UNIT OPERATIONS
- Oil feed system including pumps and flow control
- Gas feed system
- Reactor system
- Separator system
- Gas and liquid sampling system

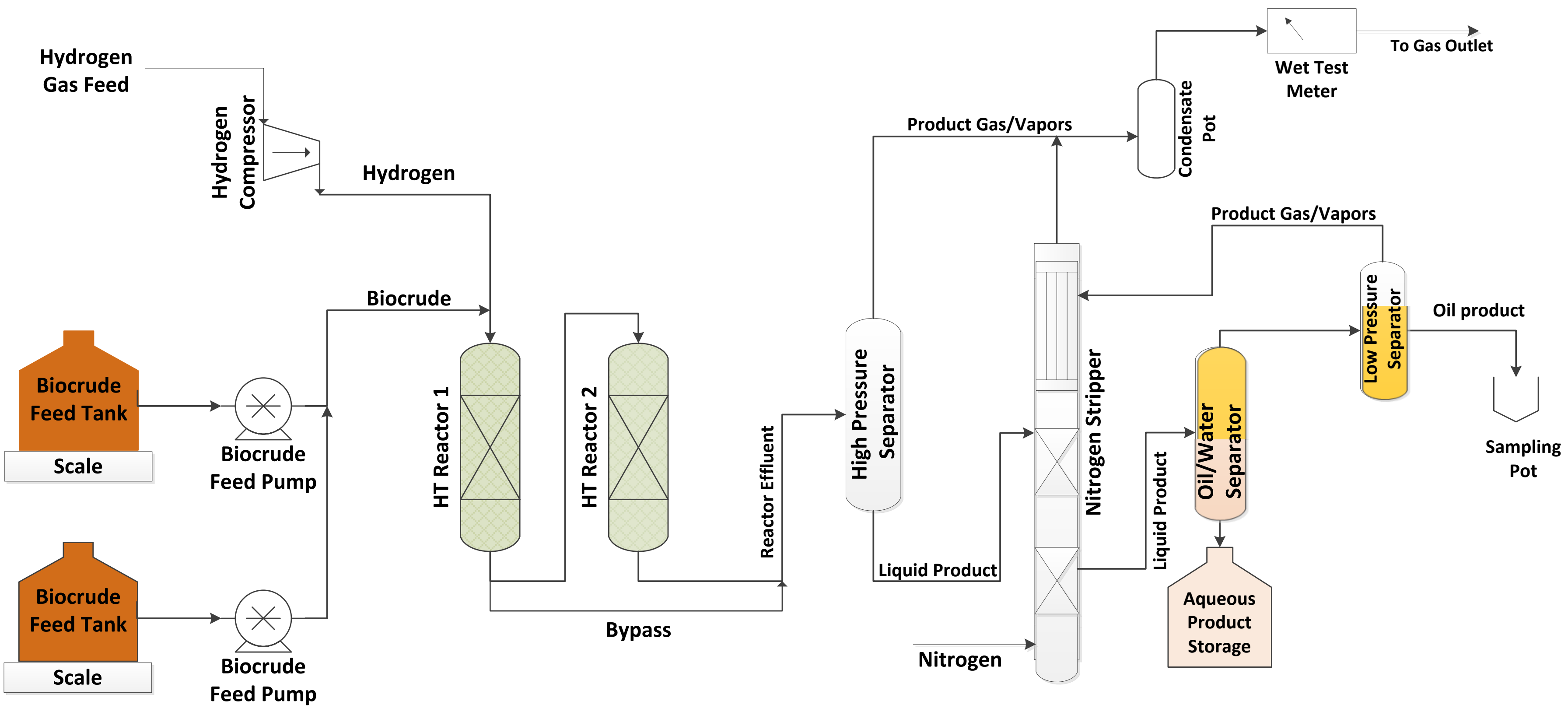


Hydroprocessing Reactor Unit Development

Design Basis

- Reactor volume - 350 mL
- Catalyst volume - 20 to 250 mL
- LHSV - 0.1 to 1.0
- Flow rates - 50 to 250 mL/h

- N_2 is used as the stripping agent
- Maximum design pressure of 3000 psig
- Maximum design temperature of 450 ° C



Simplified HDT Unit Process flow Diagram

Bio-crude Hydrotreating

Catalyst Loading, Sulfidation, and HDT Process Conditions

- HDT Catalyst: HaldorTopsøe Bio-Cat
- Catalyst Sulfidation: In-situ with H_2S in H_2 balance.
- Bio-crude flow rate: 50-250 ml/h
- Mass Balance Protocol: Allow at least 48 hours of run time prior to performing mass balance.
- Experiments continue until pressure drop across reactor > 60-100 psig

Parameters	Typical Test Conditions
Temperature	290 – 350 °C
Pressure	1450-2000 psig
LHSV	0.125 - 0.5 1/h
H_2/oil	2000-3300 Nl/l
TOS	16-396

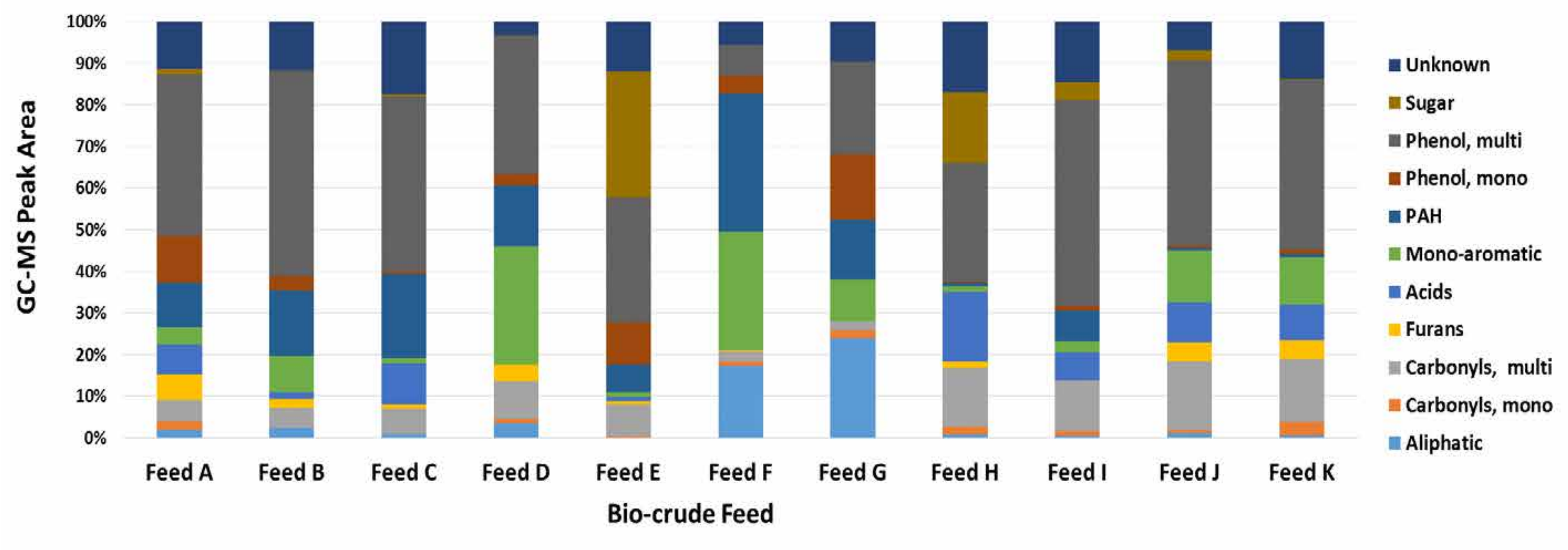
Analysis of Bio-crude and HDT products include:

Elemental Analysis(CHNSO), GC-MS, FTIR, NMR, Carbon Number Distribution, Distillation by ASTM D1160, SG 60/60 by ASTM D4052, Kinematic Viscosity by D445, and Karl Fischer Titration.

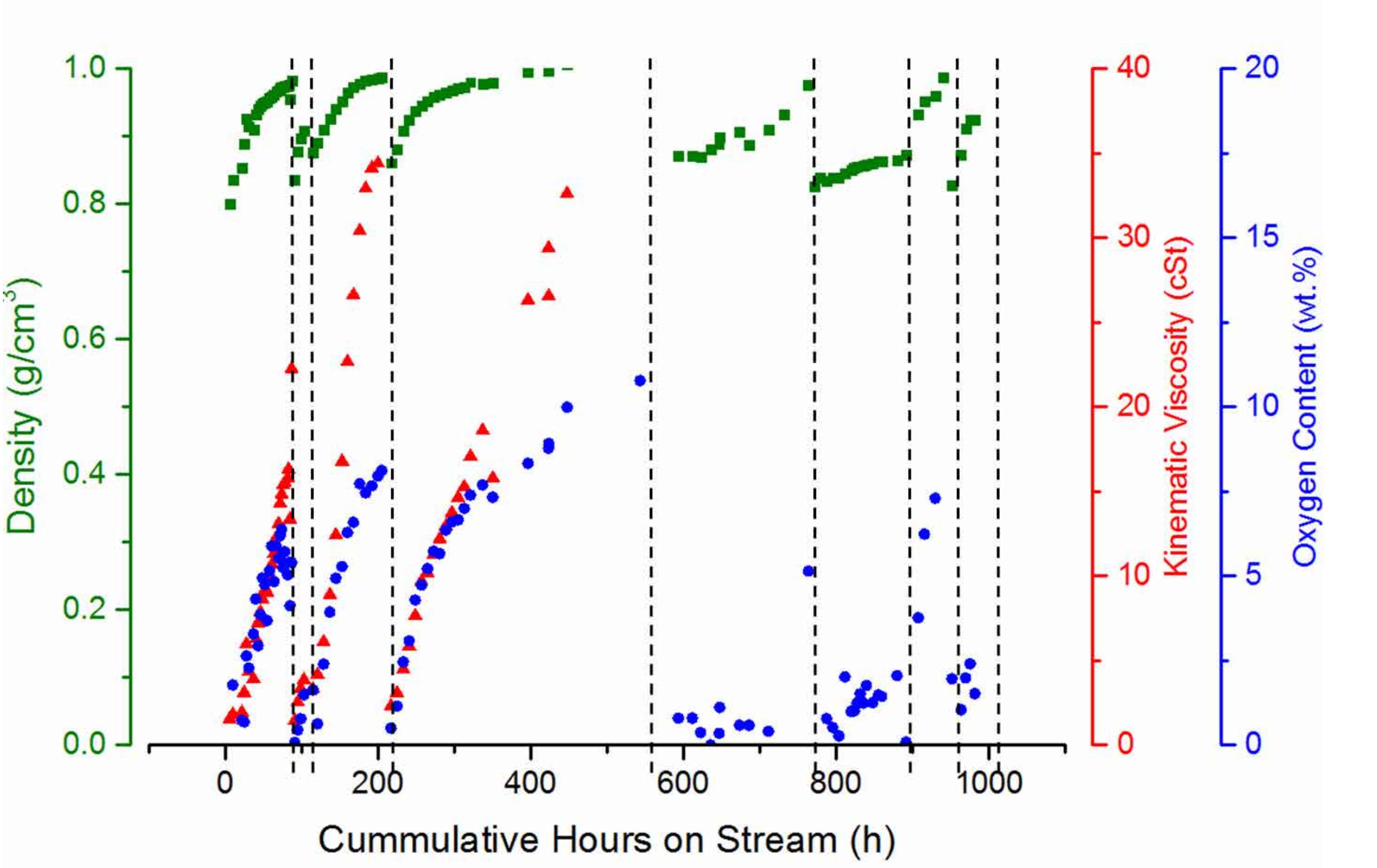
Biocrude Feedstocks

Biocrude Chemical Characteristics

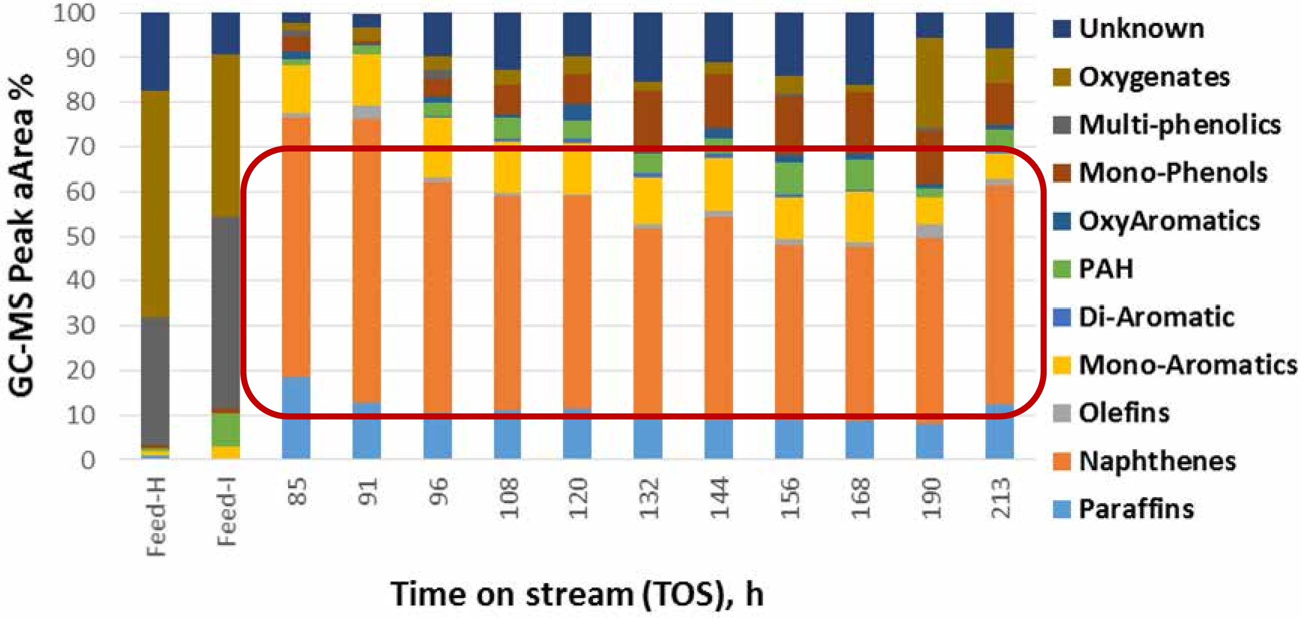
Elemental (wt.%) dry basis	A	B	C	D	E	F	G	H	I	J	K	L
C	72.7	73.1	69.7	76.6	63.7	84.1	84.0	64.9	70.5	70.5	68.8	64.9
H	7.1	7.1	7.2	7.9	6.7	9.0	10.1	6.1	7.0	7.0	6.6	6.2
N	0.6	0.3	0.3	0.5	0.5	1.0	0.3	0.7	0.1	0.1	0.2	0.4
O	19.6	19.5	22.8	15.0	29.6	5.9	5.6	28.3	22.4	22.3	24.5	28.5
H/C	1.17	1.17	1.24	1.24	1.26	1.28	1.44	1.12	1.19	1.19	1.15	1.14



Hydrotreating of Biocrude: Physico-chemical Properties

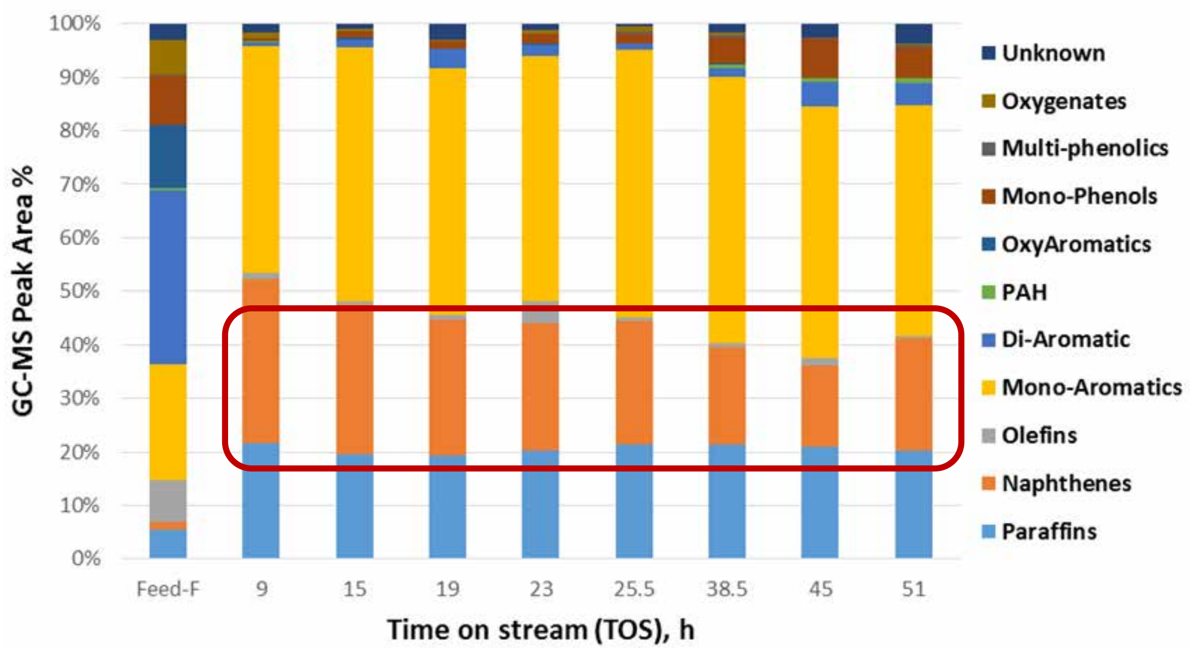


Hydrotreating of Biocrude: Chemical Composition of HDT oils

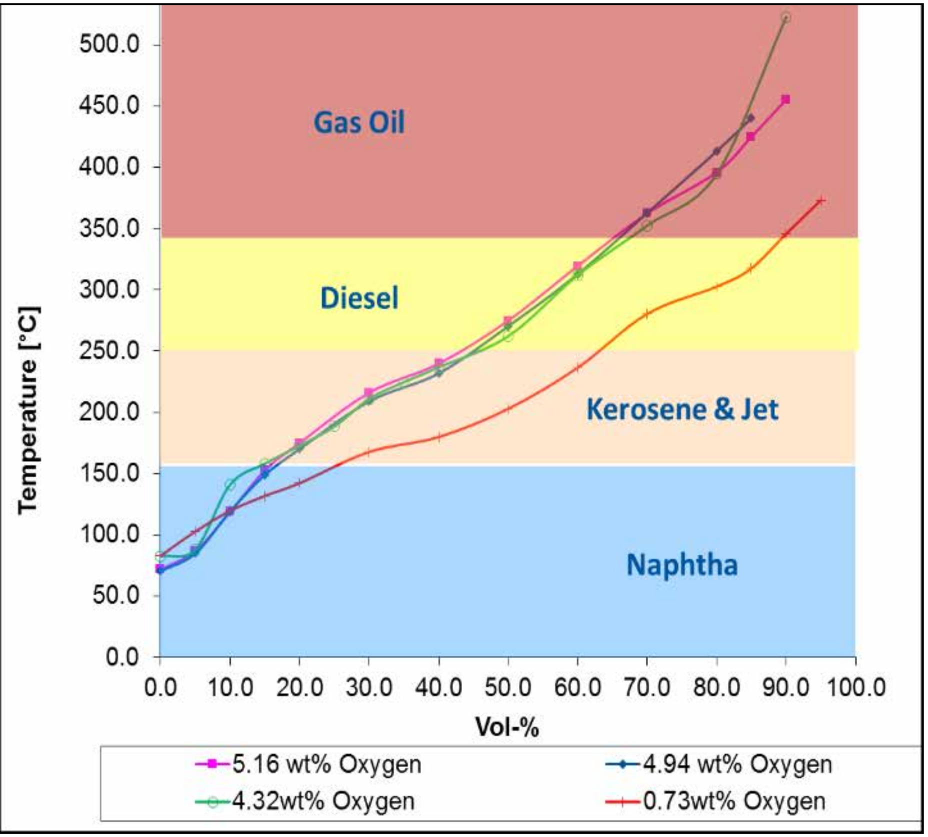


High yield of cyclic alkanes are produced from phenolic-rich feedstocks.

Less cyclic alkanes are produced from aromatic, hydrocarbon-rich feedstocks.



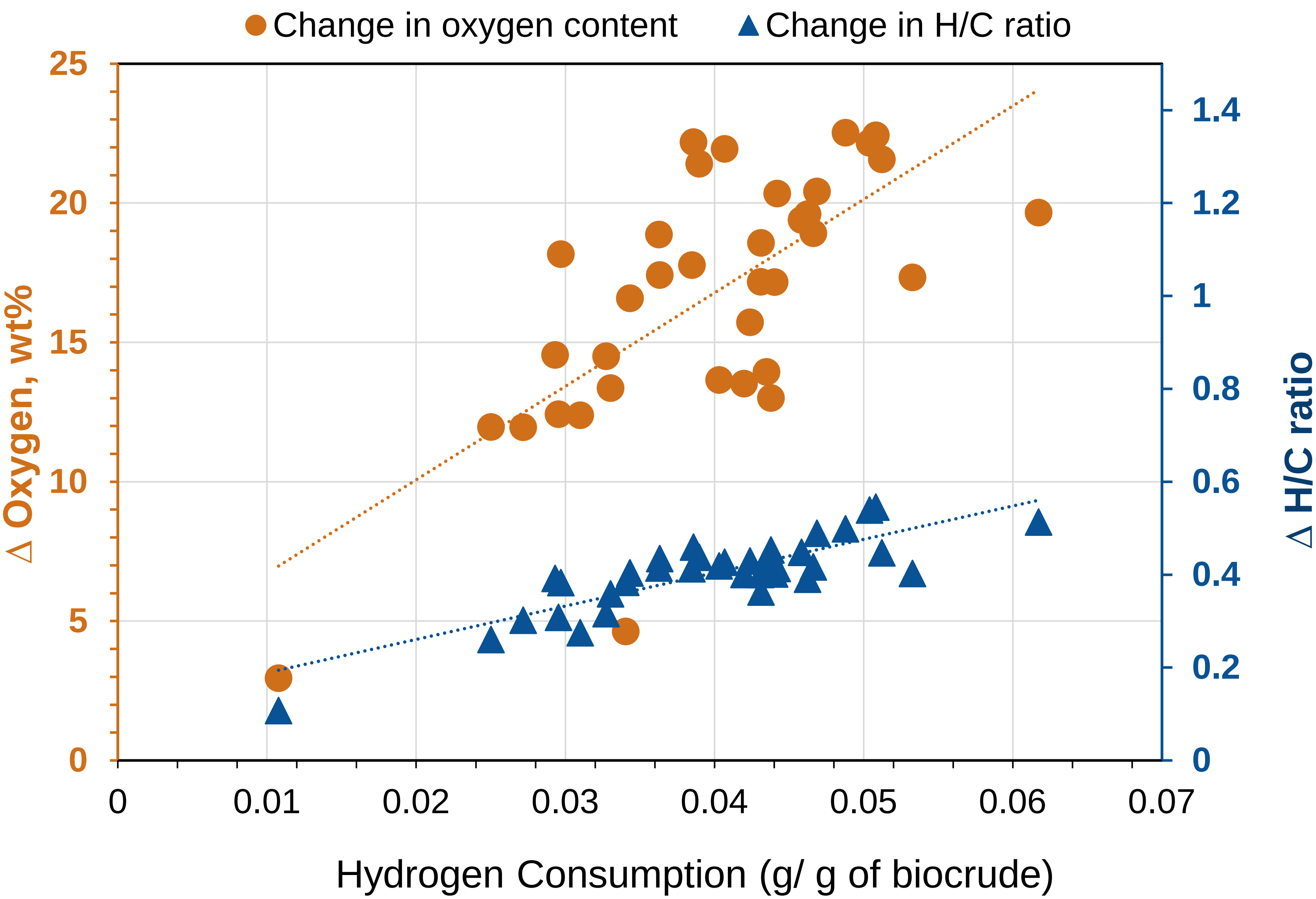
Hydrotreating of Biocrude: Physico-chemical Properties



~2:1 Diesel/Gasoline Range Products

Fractions	HDT Product Oxygen Content, wt%			
	0.73	4.32	4.94	5.16
Naphtha/Gasoline IBP-165 °C	30.1%	22.9%	24.8%	22.3%
Kerosene/Jet Fuel 165-250 °C	34.8%	26.2%	25.2	25.5%
Heavy Diesel/Heating 250-340 °C	23.6%	17.2%	17.8%	15.9%
Diesel (Total)	58.4%	43.4%	43.0%	41.4%
Gas oils 340-550 °C	6.5%	24.7%	19.3%	31.4%

Hydrotreating of Biocrude: Hydrogen Consumption

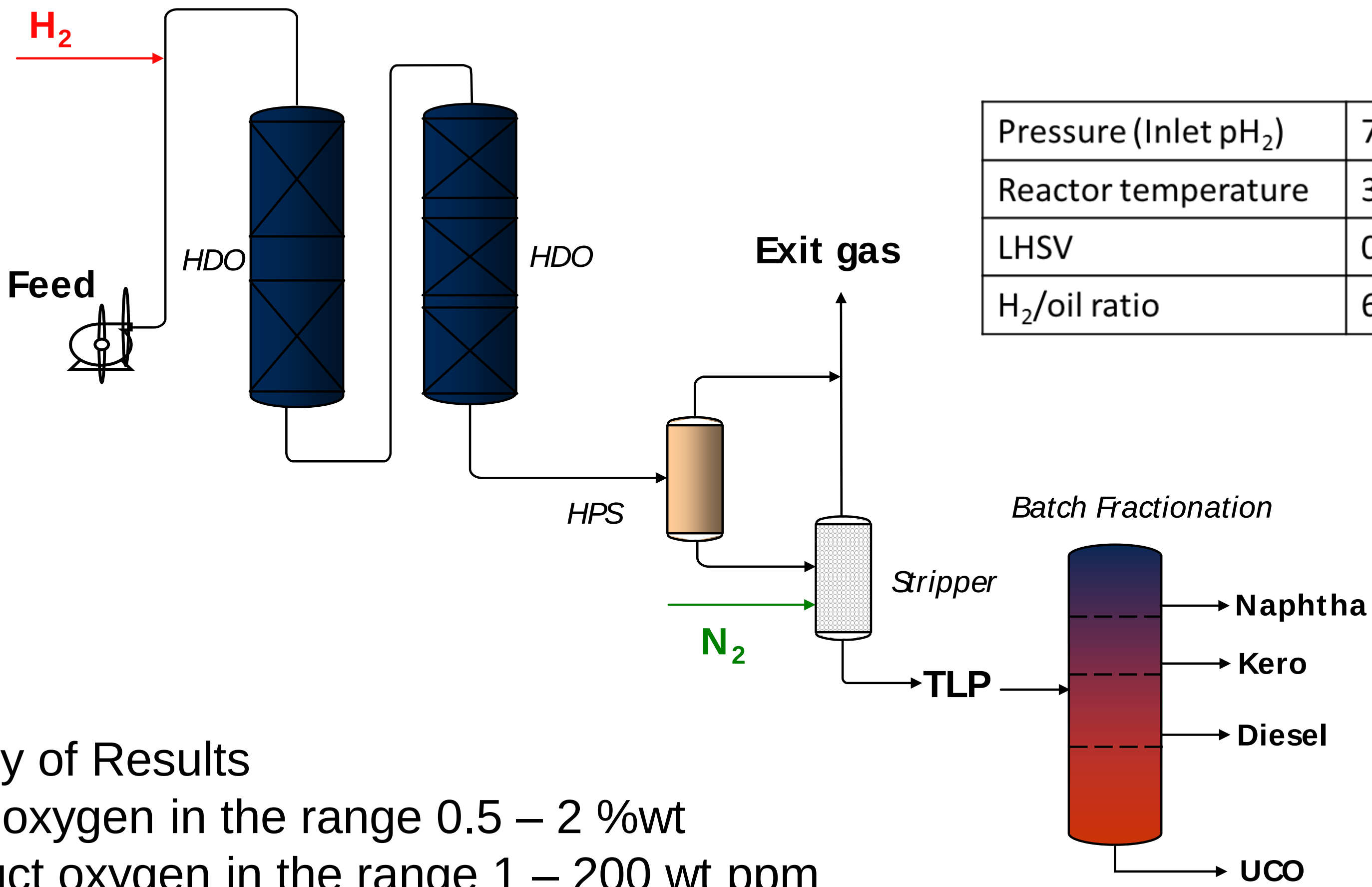


Factors: Biocrude oxygen content, Biocrude aromaticity, and Process conditions

Co-processing studies (Haldor Topsoe)

Refinery Integration and co-processing

Compare co-processing of light cycle oil (LCO) blended with light gasoil (LG) with co-processing of 30% once through catalytic pyrolysis oil (CPO) blended with LG

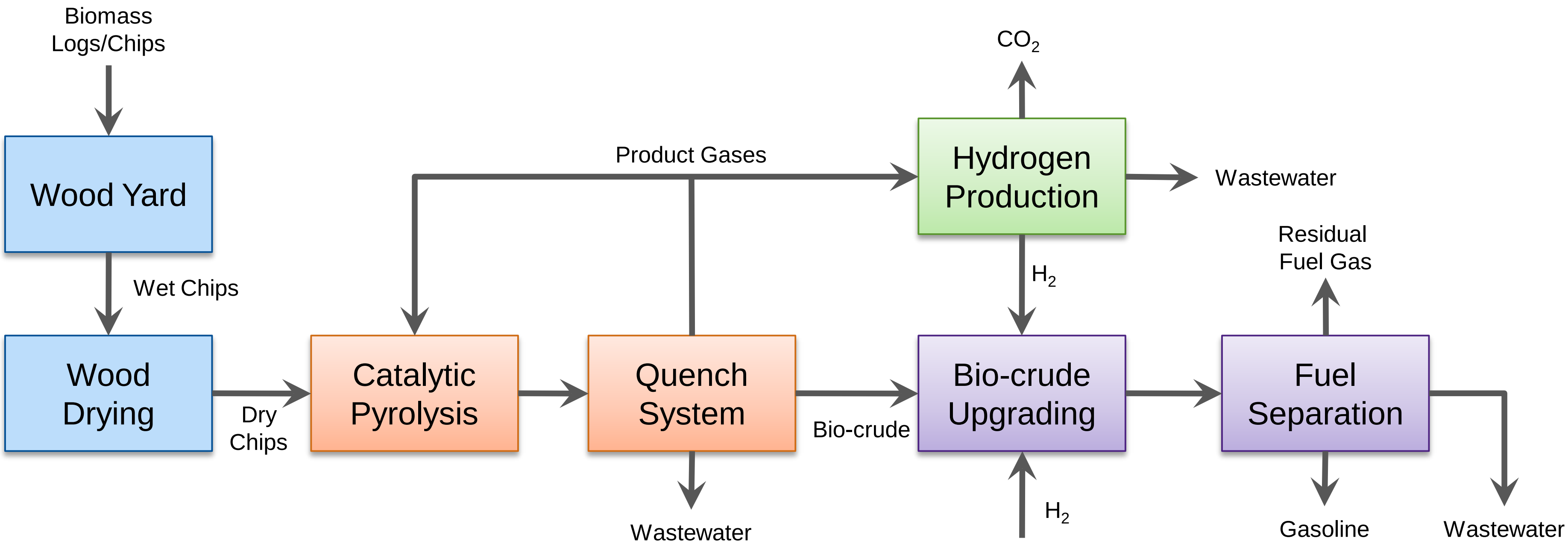


Pressure (Inlet pH_2)	70 Barg
Reactor temperature	330 – 345°C
LHSV	0.4 h^{-1}
H_2/oil ratio	625 Nl/l

Summary of Results

- Feed oxygen in the range 0.5 – 2 %wt
- Product oxygen in the range 1 – 200 wt ppm
- Diesel yields in the range of 85 %wt of FF
- Pilot test ran for 1180 hours where 542 were co-processing of CPO, no problems with pressure drop or extreme deactivation

Techno-economic Analysis: Detailed Block Flow Diagram



Wood Yard and Drying

- Logs and chips storage
- Wood chipping
- Wood chips drying
- Dry chips storage

Biomass to Bio-crude

- Catalytic pyrolysis reactor
- Coolers and quench column
- Electrostatic precipitator
- Bio-crude/water separation

Bio-crude Upgrading

- Bio-crude pump and heater
- Hydrotreater
- Multi-stage H_2 compressor
- Gasoline/water separation

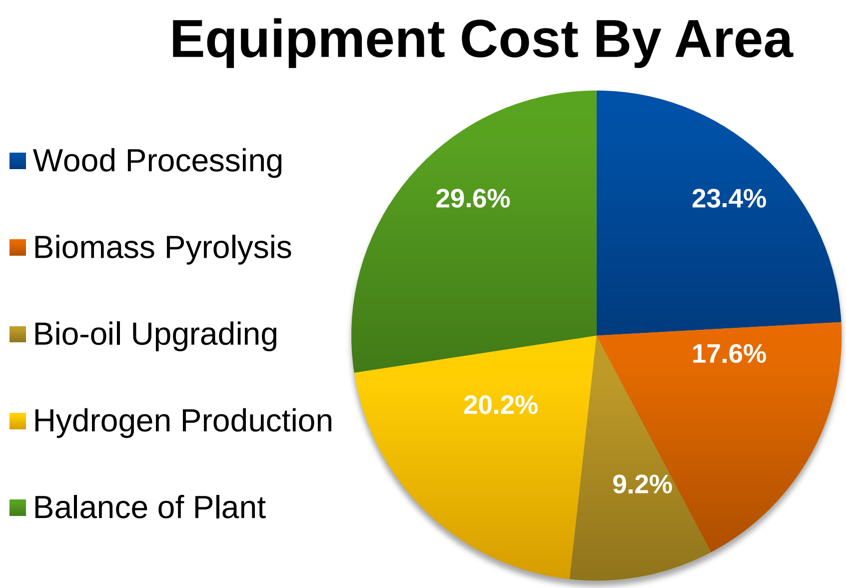
Hydrogen Production

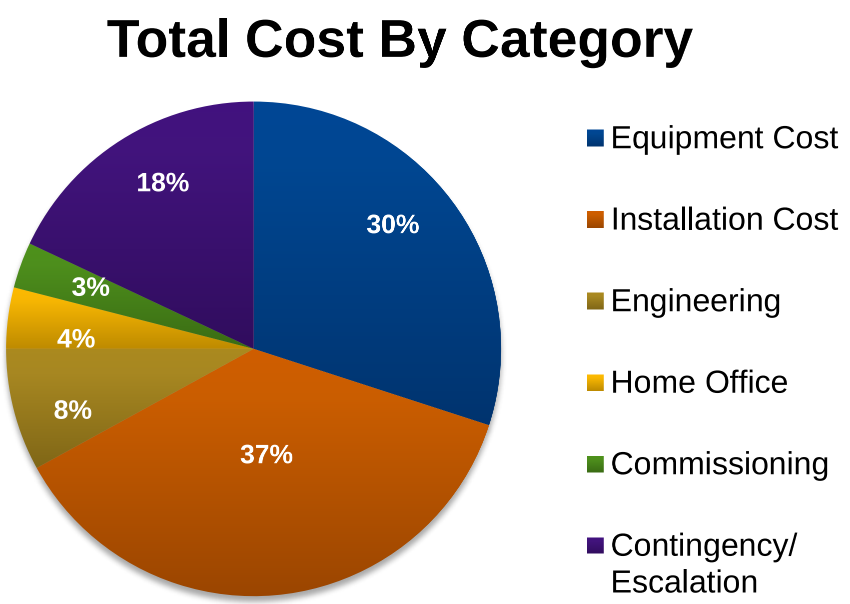
- Steam reformer
- Shift reactor
- Amine scrubber
- Gas furnace

- Process model developed in Aspen Plus with experimental results from1TPD pyrolysis unit
- Aspen Plus simulations for equipment sizing and heat and material balance calculations
- Equipment costs estimates from Aspen Process Economic Analyzer based on $2014
- Installed cost estimates based on equipment-specific installation factors from industrial experience.

Cost Summary

Process Details and Costs	
Feedstock Type	Loblolly Pine
Envisioned Commercial Feed Rate (dry tonne/day)	2000
Biofuel Yield (gallons/dry ton)	79.6
Annual Biofuel Production (MM gallons)	49.4
Carbon Conversion(%) - C_{in}(fuel)/C in feedstock	28.9%
Total Installed Capital ($MM)	471
Net Operating Costs ($MM)	93
Total Production costs, $/GGE	$3.21





4 - Relevance

Integrated pilot-scale process development to validate material balances and catalyst performance to provide data for scale-up

- ❑ Supports the strategic goal of Conversion R&D to develop commercially viable technologies for converting feedstocks into energy-dense, fungible, finished liquid transportation fuels
- ❑ Provides technical data that can be used to estimate mature technology processing cost of converting lignocellulosic biomass to hydrocarbon fuels
  - Correlation between laboratory-scale and pilot-scale studies
  - Balance between deoxygenation during CFP and hydrotreating catalyst performance
  - Balance between the amount and quality of bio-crude produced and the impact on downstream catalytic hydroprocessing steps
  - Opportunities for co-processing bio-crudes with refinery intermediates

Performance Milestone for Thermochemical Pathways

- By 2017, validate an nth plant modeled minimum fuel selling price (MFSP) of $3/GGE (2014$) via a conversion pathway to hydrocarbon biofuel with GHG emissions reduction of 50% or more compared to petroleum-derived fuel.

5 - Future Work

- Project end date – 3/31/2017
- All technical work complete; complete data analysis, report writing, and manuscripts
- Complete Final Report
- Project closeout

Summary

Integrated catalytic biomass pyrolysis and bio-crude hydroprocessing for advanced hydrocarbon biofuels production

Directly supports BETO Thermochemical Conversion R&D Objectives

- 1 TPD pilot-scale bio-crude production
  - Continuous feed circulating fluidized bed reactor/regenerator – scaleable design
  - Maximize carbon efficiency and deoxygenation to control bio-crude properties
  - Over 200-gal of loblolly pine bio-crude and 20-gal of red oak bio-crude produced for upgrading
- Leverage extensive refining expertise at Haldor Topsøe A/S for bio-crude upgrading
  - Catalyst selection and process optimization
  - Experimental results scale to commercial systems
  - Co-processing upgraded bio-crude with refinery intermediates (LG)
- Design, installation, and commissioning of hydroprocessing unit for bio-crude upgrading
  - Benchmark operation to verify system performance and data reliability
  - Long-term unattended operation to determine upgrading catalyst stability and lifetime
  - Over 1500 cumulative hours on stream of bio-crude hydrotreating since April 2015.

Project accomplishments

- Parametric CFP studies to understand the effects of operating conditions (mainly temperature) on bio-crude yield and oxygen content
- Studied the impact of bio-crude composition on hydroprocessing performance
- Stable hydrotreating catalyst activity (> 100-hrs) with lower oxygen containing bio-crude (< 15 wt%)
- Minimal pressure drop increase and no severe deactivation during 542-hrs co-processing 30%CPO/70%LG
- Updated techno-economic analysis with pilot-scale experimental data

Acknowledgements

BETO Project Officer: Liz Moore

Idaho National Laboratory

- Tyler Westover

RTI Contributors

- David C. Dayton (PI)
- John Carpenter
- Jonathan Peters
- Gary Howe
- Atish Kataria
- David Barbee
- Kelly Amato
- Ofei Mante
- Michael Carpenter
- Kaige Wang
- Nandita Akunuri

Haldor Topsoe

- Kim Knudsen
- Glen Hytoft
- Jostein Gabrielsen
- Nadia Luciw Ammitzboll
- Jeppe Kristensen
- Sylvain Verdier

HALDOR TOPSØE
CATALYSING YOUR BUSINESS

Additional Information - Publications

Publications

- Wang, K.; Mante, O. D.; Peters, J. E.; Dayton, D. C., Influence of the Feedstock on Catalytic Fast Pyrolysis with a Solid Acid Catalyst. Energy Technology 2017, 5 (1), 183-188.
- Mante, O. D.; Dayton, D. C.; Soukri, M., Production and distillative recovery of valuable lignin-derived products from biocrude. RSC Advances 2016, 6 (96), 94247-94255
- Mante, O. D.; Dayton, D. C.; Gabrielsen, J.; Ammitzboll, N. L.; Barbee, D.; Verdier, S.; Wang, K. G., Integration of catalytic fast pyrolysis and hydroprocessing: a pathway to refinery intermediates and "drop-in" fuels from biomass. Green Chemistry 2016, 18 (22), 6123-6135
- Mahadevan, R.; Adhikari, S.; Shakya, R.; Wang, K.; Dayton, D.; Lehrich, M.; Taylor, S. E., Effect of Alkali and Alkaline Earth Metals on in-Situ Catalytic Fast Pyrolysis of Lignocellulosic Biomass: A Microreactor Study. Energy & Fuels 2016, 30 (4), 3045-3056
- Dayton, D. C.; Carpenter, J. R.; Kataria, A.; Peters, J. E.; Barbee, D.; Mante, O. D.; Gupta, R., Design and operation of a pilot-scale catalytic biomass pyrolysis unit. Green Chemistry 2015, 17 (9), 4680-4689

Additional Information - Presentations

Presentations

- D.C. Dayton. “Catalytic biomass pyrolysis and bio-crude upgrading for advanced biofuels production.” Oral Presentation, in Challenges in Second Generation Biofuels: Processing, Stability, and Usage at Pacifichem 2015. December 15-20, 2015 Honolulu, HI.
- D.C. Dayton, “Catalytic Biomass Pyrolysis and Bio-crude Upgrading for Advanced Biofuels Production.” Oral Presentation, TCBiomass 2015 November 2-5, 2015 Chicago, IL.
- O.D. Mante, “Bio-crude Hydroprocessing: A Pathway to Refinery Intermediates and “Drop-in” Fuels.” Oral Presentation, TCBiomass 2015 November 2-5, 2015 Chicago, IL.
- D.C. Dayton, “Catalytic Biomass Pyrolysis in a 1 ton/day Pilot Plant.” Symposium on Thermal and Catalytic Sciences for Biofuels and Biobased Products, Denver, CO, 2-5 September 2014.
- J.C. Carpenter, D.C. Dayton, and J. Gabrielsen, “Hydroprocessing of Catalytic Fast Pyrolysis Bio-crude.” Symposium on Thermal and Catalytic Sciences for Biofuels and Biobased Products, Denver, CO, 2-5 September 2014.
- D.C. Dayton, “Catalytic Biomass Pyrolysis Technology Development for Advanced Biofuels.” Oral Presentation, TCBiomass 2013 September 3-6, 2013 Chicago, IL.
- M. Von Holle, “Small Scale Catalyst Testing with Biomass for Advanced Biofuels Technology Development.” Poster Presentation, TCBiomass 2013 September 3-6, 2013 Chicago, IL.
- J. Carpenter, “Low Oxygen-Content Bio-Crude via Single Step Hydropyrolysis.” Poster Presentation, TCBiomass 2013 September 3-6, 2013 Chicago, IL.
- J. Hlebak, “Experimental Capabilities at RTI International to Support R&D for Direct Biomass Liquefaction Pathways.” Poster Presentation, TCBiomass 2013 September 3-6, 2013 Chicago, IL.
- J. Peters, “Deoxygenation Chemistry of Bio-oil Model Compounds with Selected Catalysts.” Poster Presentation, TCBiomass 2013 September 3-6, 2013 Chicago, IL.

Responses to Previous Reviewers' Comments

Overall Impressions

- This is a good project, but it is possible that the project team has not planned enough time and money to get the integrated system running reliably. Other integrated startups have had to spend much more than expected time and money to get over this hump. It does not appear they have this included in their plan.
- This project is nearing the completion date, and seeking a six-month, no-cost extension, but it is questionable whether or not stated project deliverables will actually be achieved.
- Assuming the no-cost time extension is approved, this project should successfully produce reasonable quantities of highly upgraded liquids. Successful completion would essentially serve as the "validation" of the ex-situ pyrolysis approach.
- Product from Haldor Topsoe hydrotreated at severe conditions of 0.5 LHSV (liquid hourly space velocity) still appears to contain oxygen based on specific gravity, and hydrotreating catalyst deactivation seems to be significant. Yield is low at 40 gallons/ton. Based on the experience at Kior (one being low carbon selectivity into liquid fuels), what technical hurdles must be overcome and will this project be able to address them?
- The large pyrolysis unit is an expensive asset that appears to be underutilized (equivalent of four full days in 18 months). This reviewer hopes that the Haldor Topsoe hydrotreater will see better utilization to justify its purchase and commissioning costs.

PI Response to Reviewer Comments

- At the current stage of development, the catalytic biomass pyrolysis process is being scaled-up in a 1 ton per day pilot plant based on a single-loop transport reactor design with continuous catalyst regeneration. RTI has discovered a novel catalyst that effectively deoxygenates biomass pyrolysis vapors in a catalytic biomass pyrolysis process. This produces a low oxygen-content, thermally stable bio-crude intermediate. To date, we have produced 60 gallons of loblolly pine biocrude for upgrading.
- A hydrotreating unit was designed, built, installed and commissioned to provide the capability of integrating bio-crude production and upgrading in a single facility. Since the Peer Review meeting in March 2015, we have successfully upgraded bio-crude for over 100 hours. The hydrotreating unit was designed with the intent of producing commercially relevant data. Highly reproducible operation for hundreds of hours of steady-state operation can be used to simulate the performance of commercial units. Long-term catalyst testing can be used to estimate catalyst deactivation rates and lifetime.
- By the end of the project, experimentally validated process conditions (temperatures, pressures, hydrogen demand, and catalyst performance) and yields (both bio-crude and upgraded products) will be input into a process model to verify the technical feasibility and economic viability of this specific thermochemical pathway using specific catalysts and feedstocks. The integrated catalytic biomass pyrolysis process with bio-crude upgrading is defined by BETO as the in-situ direct biomass liquefaction pathway and a Design Case based on this approach is scheduled for release in 2016. In principle, the data from this project can be used to support future design cases; however, they are typically based on publicly available information and proprietary technical details may need to be protected.