Recent Progress in Catalytic Biomass Pyrolysis and Biocrude Upgrading

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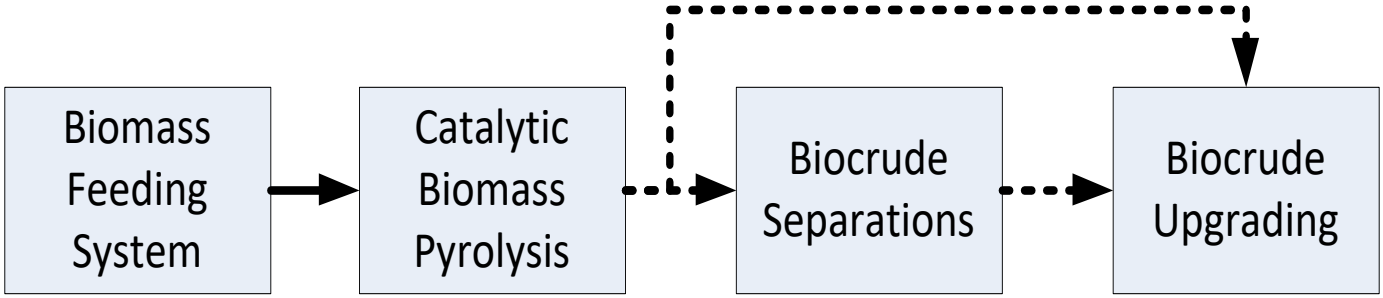
RTI is an independent, nonprofit institute that provides research, development, and technical services to government and commercial clients worldwide.

Our mission is to improve the human condition by turning knowledge into practice.

Overview

Goal: Improve the carbon efficiency and process economics for producing a renewable diesel blendstock

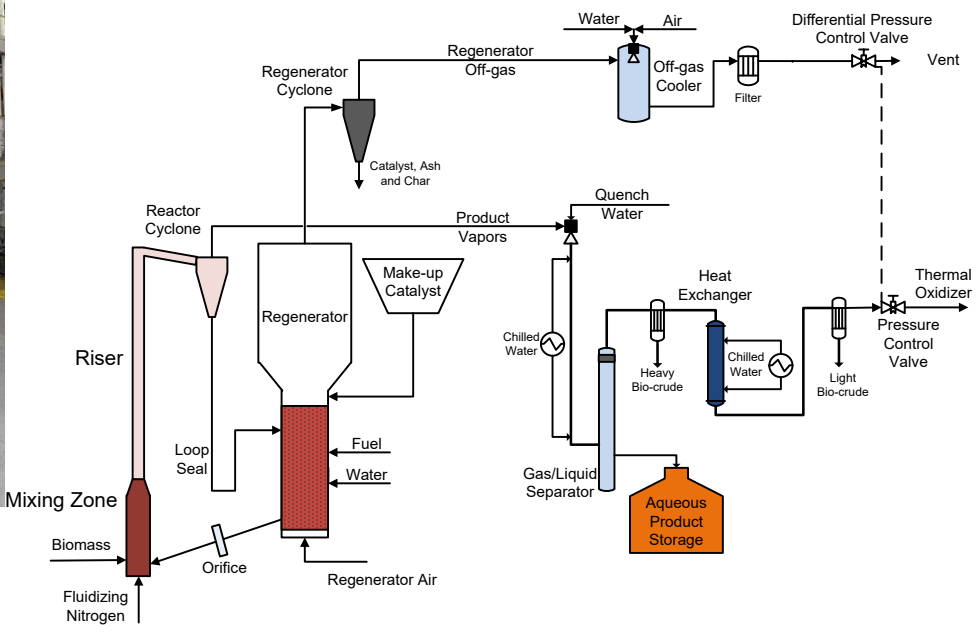


Objective: Explore synergies between innovative technology solutions:

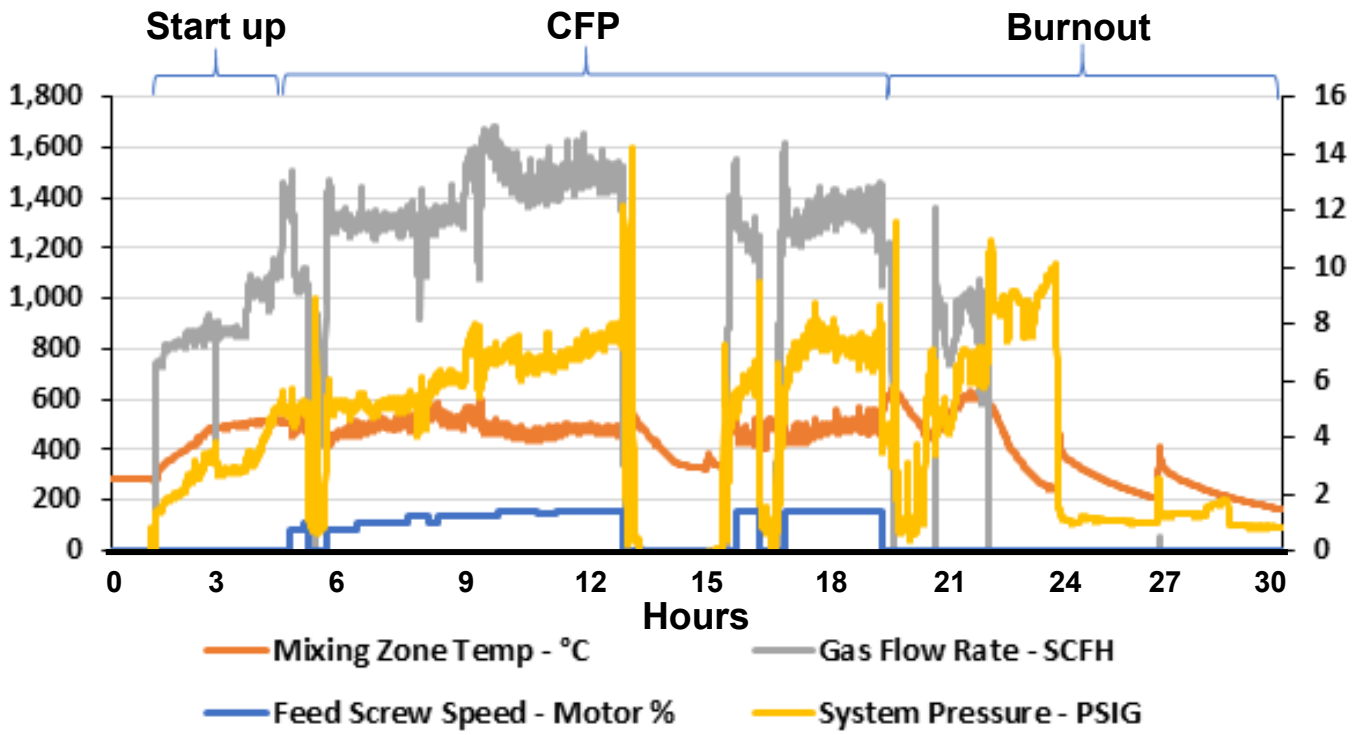
- biomass feedstock preparation
- pilot-scale catalytic pyrolysis
- biocrude separations
- biocrude hydroprocessing

1TPD CFP Biocrude Production – 2mm Douglas Fir Crumbles

Parameter	Design Basis	Operational Values (Avg.)
Pyrolysis temperature (°C)	500	464
Regenerator temperature (°C)	700	604
System pressure (psia)	20	19.7
Biomass feed rate (kg/hr)	45	49.5
Pyrolysis reaction residence time (s)	0.75	0.85

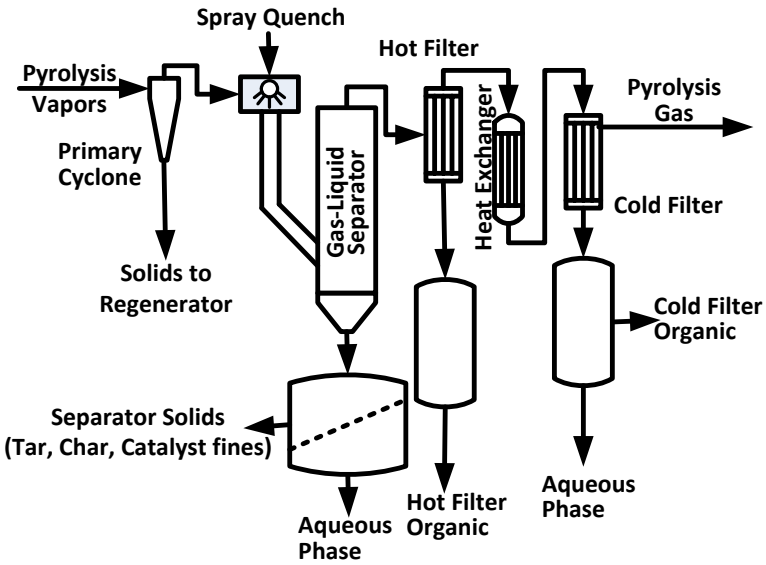


2mm Douglas Fir Crumbles CFP – Operations Summary



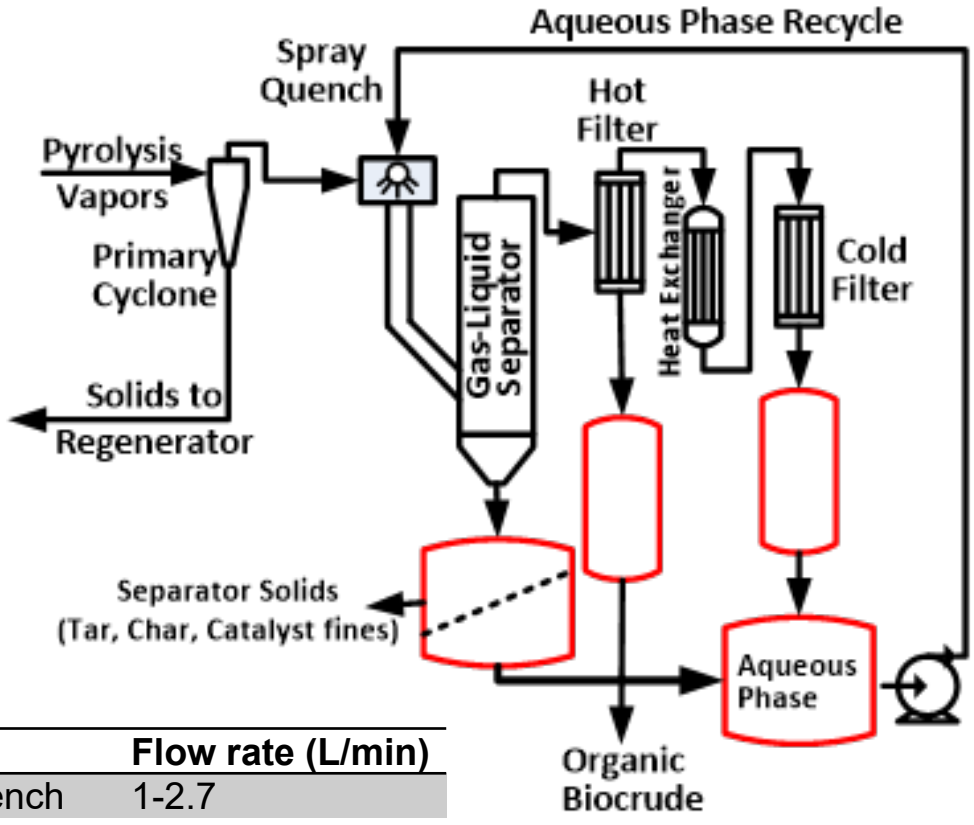
1TPD CFP Product Stream Recovery

Material ID	Mass Collection (kg)		Mass Yield (total)
	Input	Output	
Biomass, dry	562.23		
Biomass Moisture	81.50		
Water	350.95		
Py-Gas		61.29	4.4%
Regen-Gas		287.69	20.7%
Hot Filter		53.99	3.9%
Cold Filter		317.34	22.9%
Day Tank		288.62	20.8%
Ash Pot		36.44	2.6%
Separator Char/Tar		92.04	6.6%
Separator Catalyst		58.33	4.2%
Catalyst	150.00	55.08	4.0%
Oxygen	243.20	112.29	8.1%
Total	1387.9	1363.1	**98.2%**



1TPD CFP Biocrude Production – Aqueous Recycle

Saturate carbon in the aqueous phase to improve biocrude recovery and minimize waste



Water inlet	Flow rate (L/min)
Primary spray quench	1-2.7
Separator quench	0.27-0.73

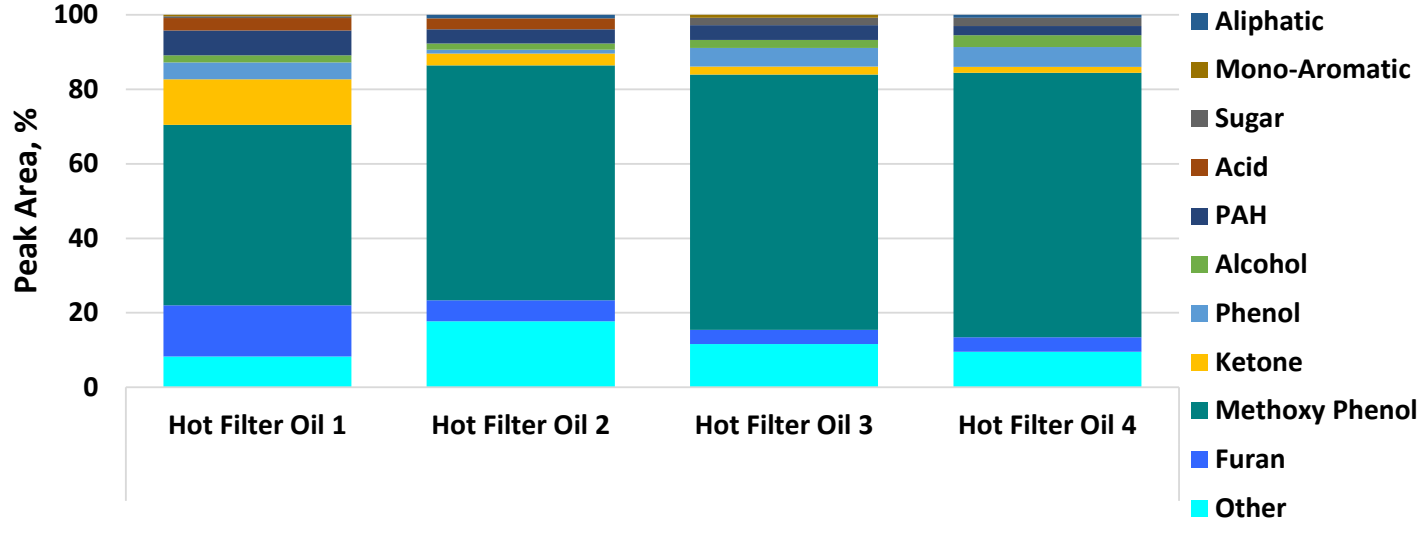
2mm Douglas Fir Crumbles - Aqueous Recycle Summary

	Average feeding rate – 103 lb/hr Total run time – 16.7 hr				Average feeding rate – 127.3 lbs/hr Total run time – 6.4 hr			
	Mass Balance (kg)			Carbon	Mass Balance (kg)			Carbon
	Input	Output	Δ	balance	Input	Output	Δ	balance
Totals	1635.8	1514.5	93%	99%	546.3	582.0	107%	98%
Biomass	762.6				370.5			
Ash pot		56.1	3.4%	11%		31.7	5.8%	12%
Separator Solids		146.3	8.9%	12%		66.7	12.2%	13%
Cold Filter Organic		10.0	0.6%	2%		1.8	0.3%	1%
Cold Filter Aqueous		178.5	10.9%	4%		96.8	17.7%	3%
Hot Filter Organic		77.7	4.8%	12%		33.8	6.2%	10%
Day Tank		963.9	58.9%	3%		82.6	15.1%	6%
Pyrolysis Gas		82.0	5.0%	9%		40.2	7.4%	9%
Regen Gas			0.0%	47%		164	30.0%	43%
Water	873.2							
Aqueous Recycle					56.8	64.43	11.8%	0.3%

Aqueous Recycle Summary – Liquid Analyses

Hot Filter Organic				
Sample	Sample Time	KF	pH	C wt%
HFO-1	12:06 PM	34.1%	3.33	59.0
HFO-2	1:45 PM	17.2%	3.11	49.8
HFO-3	3:00 PM	16.3%	3.11	48.9
HFO-4	4:35 PM	16.6%	3.08	48.4

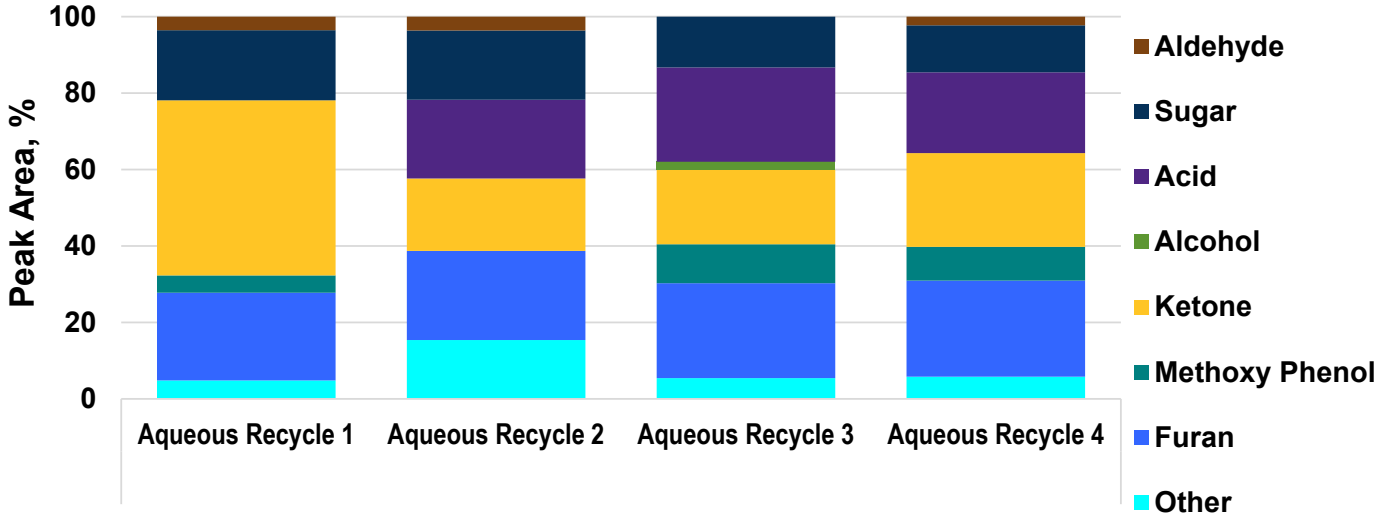
Aromatic biocrude product with decreasing acid and sugar content as a function of time on stream



Aqueous Recycle Summary – Liquid Analyses

Aqueous Recycle				
Sample	Sample Time	KF	pH	C wt%
AR-1	10:56 AM	93.8%	2.85	3.3
AR-2	12:24 PM	92.8%	2.88	3.8
AR-3	3:26 PM	90%	2.79	5.5
AR-4	5:00 PM	90.8%	2.83	5.3

- Ketones, acids and sugars concentrated in aqueous recycle
- Organic biocrude concentration increasing with time on stream



Forest Concepts Feedstock Preparation

- Tolerates high moisture variation
- Narrow particle size distribution
- Lower fines production
- Better flowability from lower aspect ratio
- Lower drying costs
- Less dust for most feedstocks

- Crumbles rotary-shear system to mill the biomass to a desired size
- Screen process biomass for size and length
- Deliver reactor-ready feedstock to project specifications

Crumbler® Rotary Shear

Forest Concepts Feedstock Preparation

Douglas Fir Crumbles	
1mm	1488-kg
2mm	1675-kg
4mm	730-kg

Sample	Ultimate Analysis					Proximate Analysis (wt%)			
	%N	%C	%H	%S	%O (by difference)	Moisture	Volatile Content	Fixed Carbon	Ash
Douglas fir 1mm	0.00	45.24	6.47	0.0	48.3	8	78	13	1
Douglas fir 2mm	0.00	45.85	6.26	0.0	47.9	8	78	13	1
Douglas fir 4mm	0.12	47.53	6.16	0.0	46.2	8	78	13	1

Biocrude Production – Selected Experiments

	1mm Douglas fir	2mm Douglas fir	4mm Douglas fir
Pyrolysis Temperature	***480***	***480***	***520***
Run Time (hours)	7.3	9.0	5.4
Total Fed (kg)	378	603	403
Stream	**Carbon Balance**		
Total	91%	91%	90%
Pyrolysis Gas	**9%**	**9%**	**14%**
Liquid	**27%**	**20%**	**27%**
Biocrude	**16.7**	**17.1**	**13.1**
Hot Filter	*12*	*10*	*7*
Cold Filter		*1*	
Separator Solids	*4.7*	*6.1*	*6.1*
Aqueous Phase	**15**	**9**	**20**
Cold Filter Aqueous	*5*	*3*	*8*
Aqueous Recycle	*10*	*6*	*12*
Char	**55%**	**62%**	**49%**
Ash Pot	*11*	*12*	*11*
Char in Separator Solids	*5.3*	*6.9*	*6.9*
Regen Off Gas	*39*	*43*	*31*

1TPD CFP Biocrude Production Summary

Douglas Fir Crumbles CFP

- 245-L of biocrude from CFP of 1mm, 2mm, and 4mm Douglas Fir Crumbles (1533-kg)
  - Biocrude yields ~17%C
  - Conversion efficiency with 4mm feedstock is lower than 1mm and 2mm feedstock
- Aqueous phase recycle eliminates freshwater consumption and improves biocrude collection efficiency
  - Reduces aqueous stream volume by 84%
  - Biocrude concentration in aqueous stream increases over time
- Overall, need to improve conversion efficiency and reduce char production
  - Increase residence time in mixing zone
  - Reduce feedrate/increase catalyst:biomass ratio

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