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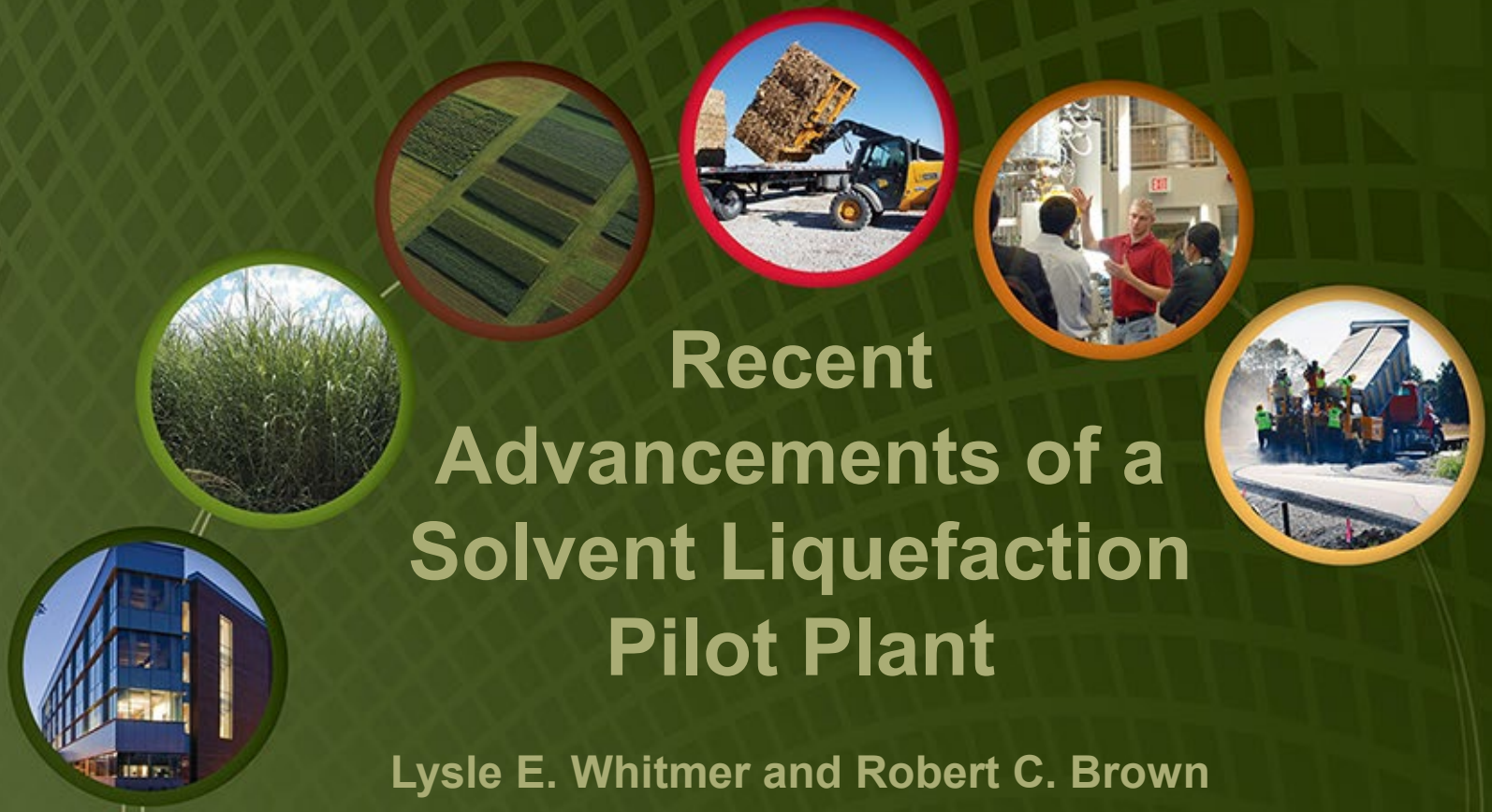
KVASIR TECHNOLOGIES



Recent Advancements of a Solvent Liquefaction Pilot Plant

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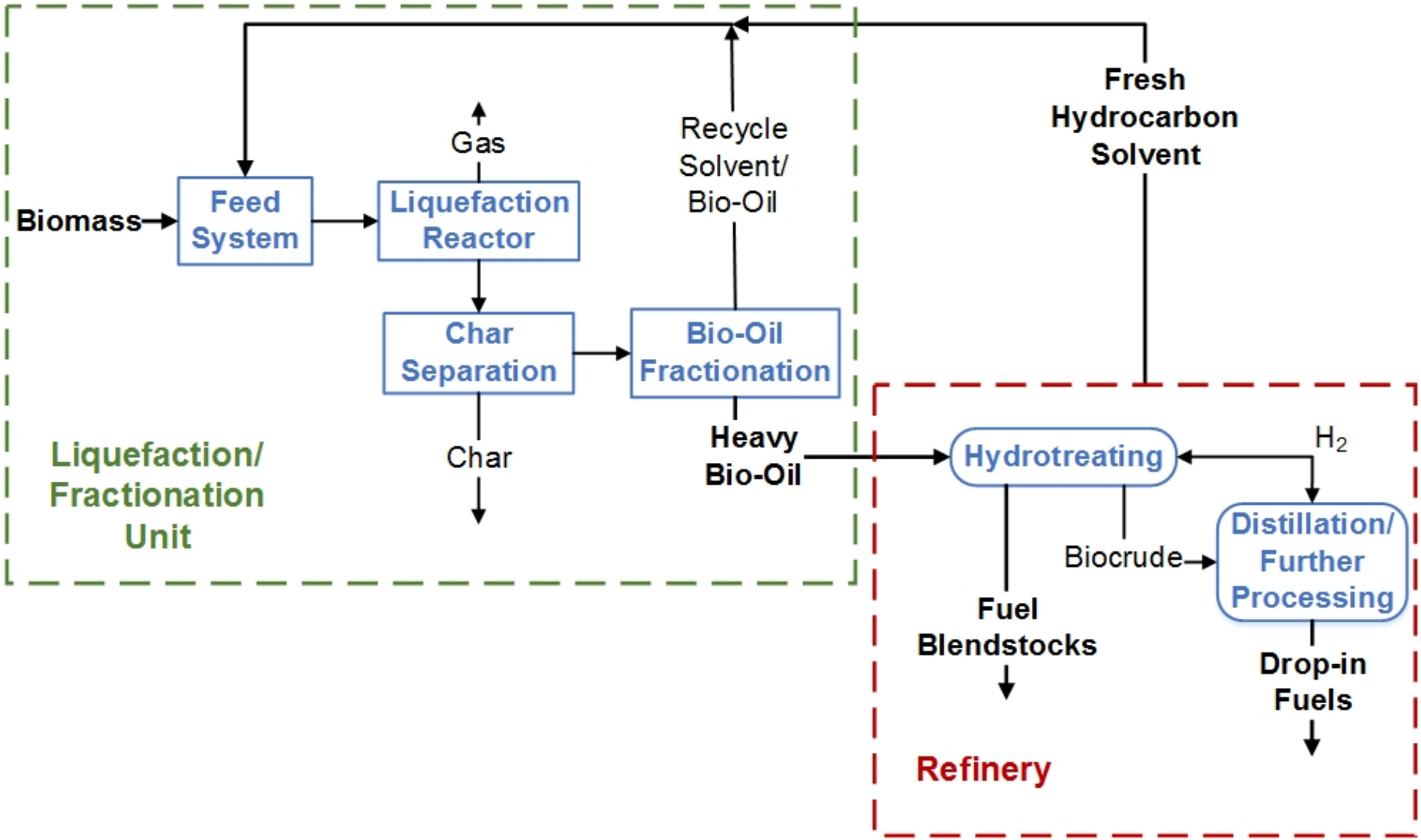
Project Background

- **Chevron & Iowa State University**
  - Department of Energy BRDI Grant: DE-EE0005974
  - Biomass to “green crude” to gasoline and diesel drop in fuels
  - Solvent Liquefaction in a hydrocarbon solvent
- **Project Benchmarks**
  - Convert biomass with 50% bio-oil yield
  - Generate bio-oil with oxygen content <20 wt. %
  - Recycle wood oil product for use as solvent, displacing initial hydrocarbon solvent
  - Bio-oil hydroprocessing to biocrude (<2 wt. % oxygen)

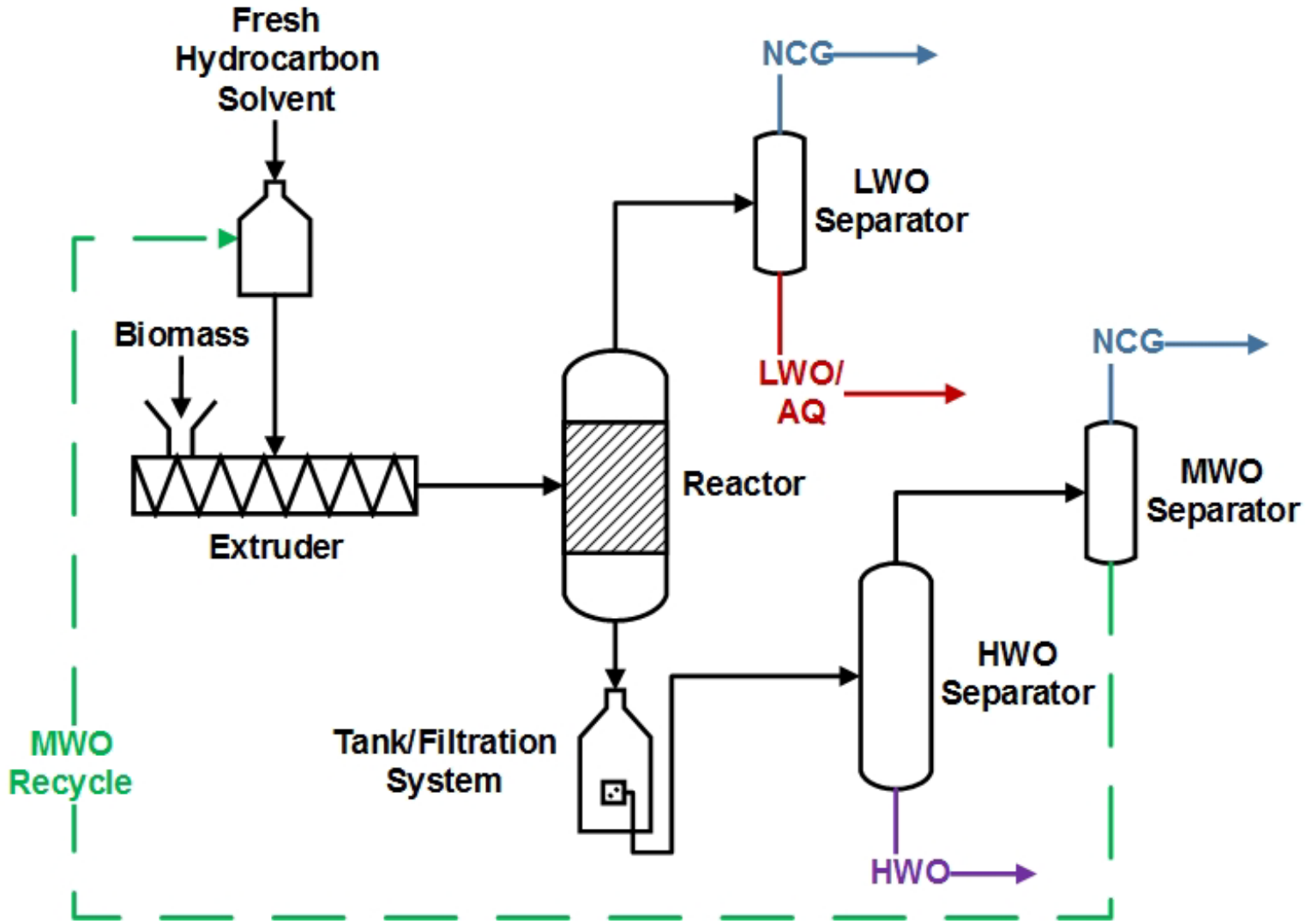
Project Overview



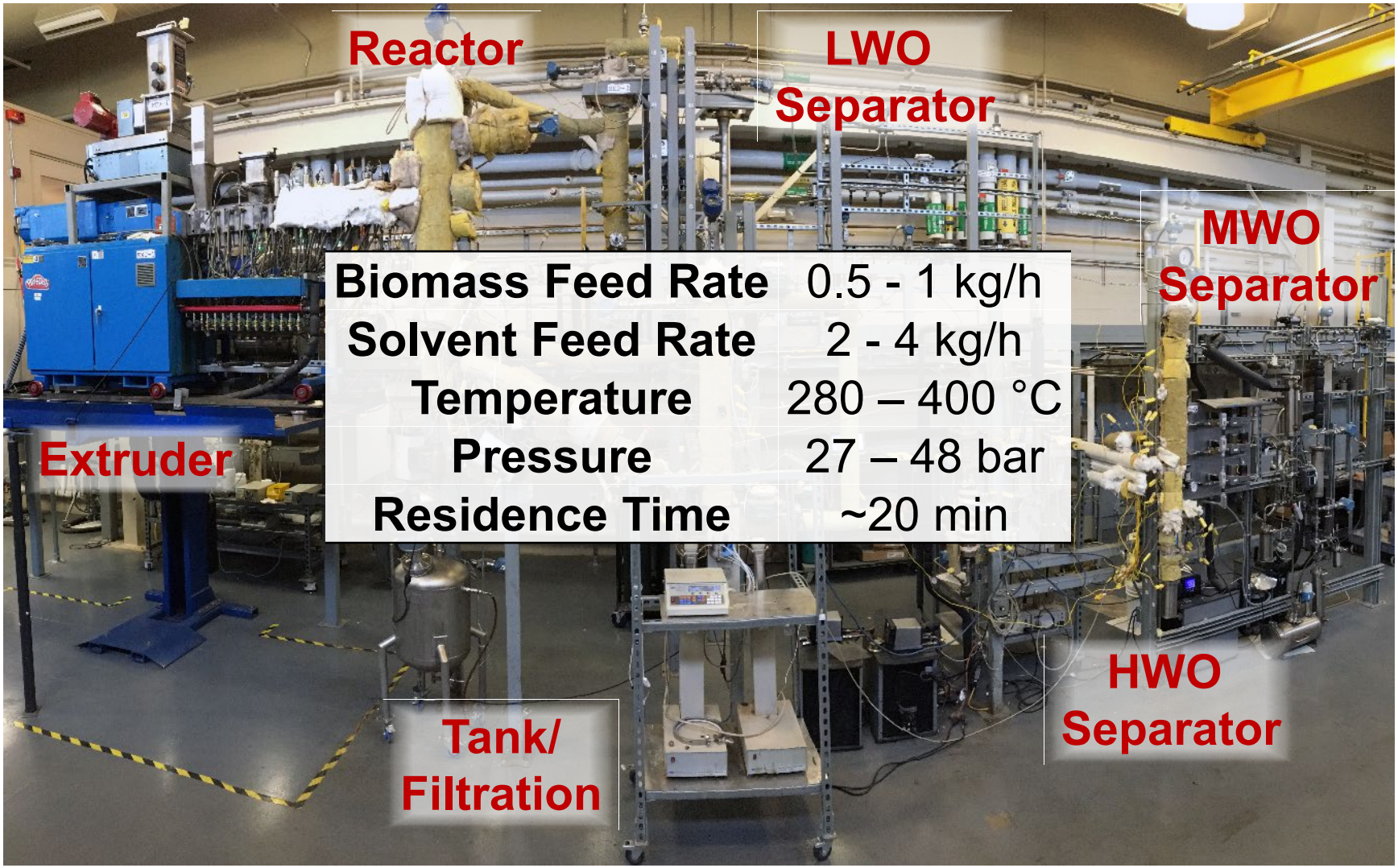
Definition of Terms

Initialism	Name	Primary Components
SCLU	*Small continuous liquefaction unit*	-
NCG	*Non-condensable gases*	CO, CO_2, CH_4
AQ	*Aqueous products*	Fed/product H_2O and light acids
LWO	*Light wood oil*	Lighter phenolic monomers and solvent components
MWO	*Medium wood oil*	Phenolic monomers and solvent
HWO	*Heavy wood oil*	Heavier solvent components and phenolic monomers, phenolic oligomers, sugars

SCLU Block Flow Diagram



SCLU and Process Conditions



Biomass Feed Rate	0.5 - 1 kg/h
Solvent Feed Rate	2 - 4 kg/h
Temperature	280 – 400 °C
Pressure	27 – 48 bar
Residence Time	~20 min

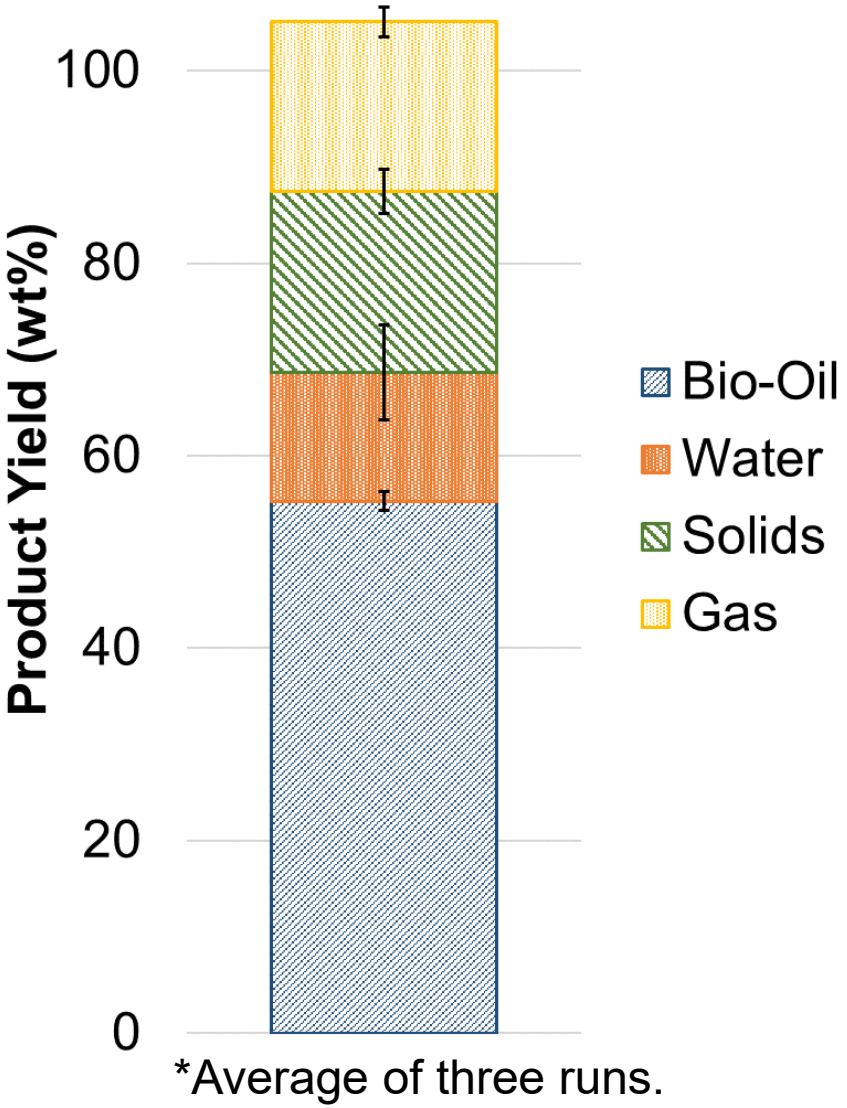
Biomass Characterization

¼” Loblolly Pine Chips

Proximate Analysis (wt. %)	
Moisture	~5
Volatiles (AF/MF)	84.4
Fixed Carbon (AF/MF)	15.6
Ash (MF)	3.71

Ultimate Analysis (wt. %, AF/MF)	
C	52.0
H	5.37
O	42.6
N	0.05
S	0.02

Hydrocarbon Solvent Processing



*Average of three runs.

- Three continuous liquefaction experiments with fractionation for >4 h
- Retention of char particles in mixing tank via barrier filtration
- Sufficient selectivity to MWO to close recycle loop at 25% makeup solvent – more expensive test case

Liquefaction Metrics	
Bio-Oil Yield (wt. %)[a]	55.3

[a]Solvent-less, dry biomass basis

Hydrocarbon Bio-Oil Analysis

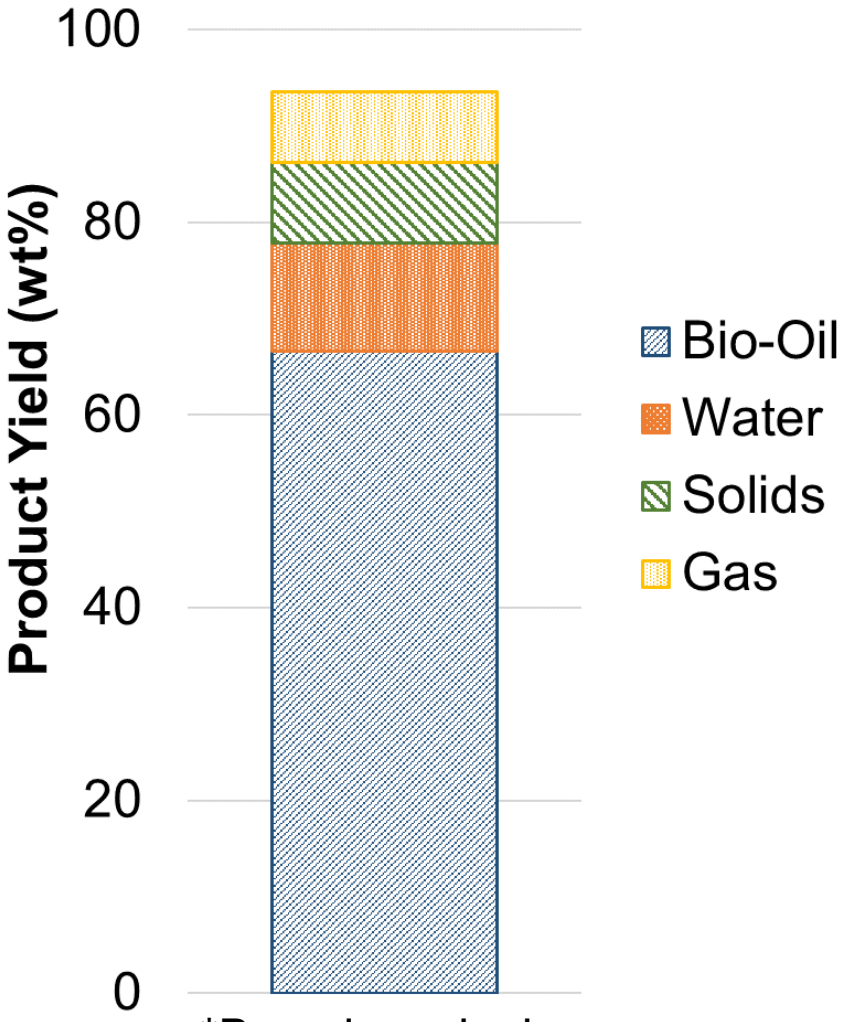
Sample	LWO	MWO	HWO
Moisture (wt. %)	1.08	0.76	0.914
Elemental Analysis (wt. %, MF/AF)			
C	86.4	86.7	88.0
H	7.80	7.25	6.93
O[a]	5.43	5.75	4.69

[a]Determined by difference

- MWO mix of hydrocarbon solvent, phenolic monomers/oligomers, and biopolymers
- HWO viscous liquid at room temperature

MWO Product **HWO Product**

Phenolic Solvent Processing



*Based on single run.

- Solvent mix simulates expected composition for full recycle operation with 5% makeup solvent
- Phenolic solvent generated smaller char particles requiring offline separation
- Insufficient selectivity to MWO to close recycle loop at these conditions

Liquefaction Metrics	
Bio-Oil Yield (wt. %)[a]	66.7

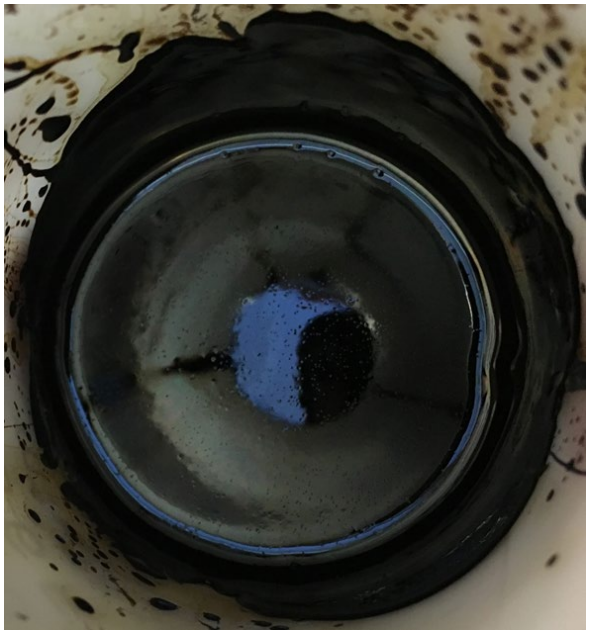
[a]Solvent-less, dry biomass basis

Phenolic Bio-Oil Analysis

Sample	LWO	MWO	HWO
Moisture (wt. %)	1.48	0.208	2.53
Elemental Analysis (wt. %, MF/AF)			
C	73.0	73.3	83.7
H	6.42	5.98	5.76
O[a]	20.2	20.3	10.3

[a]Determined by difference

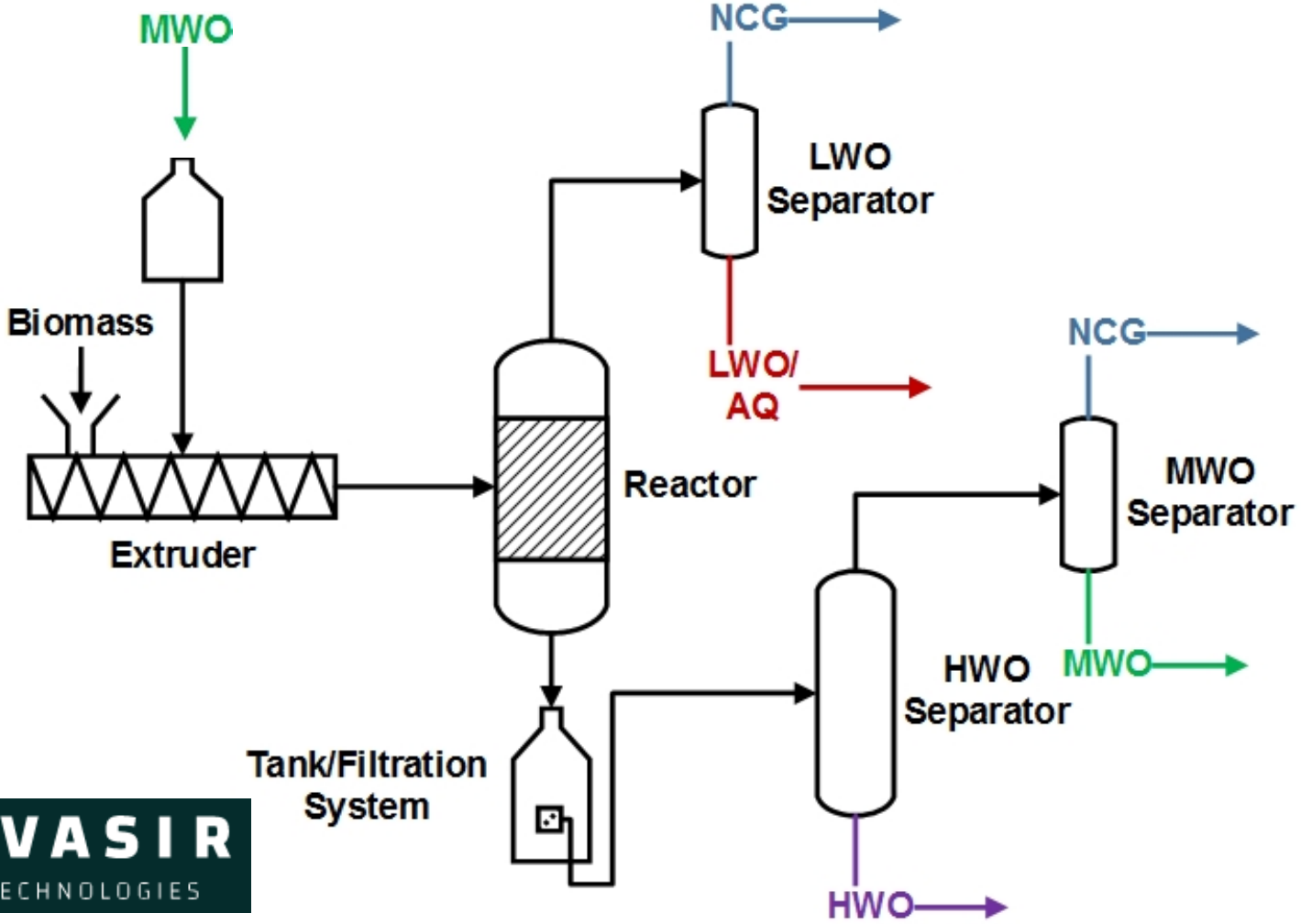
- MWO mix of phenolic monomers/oligomers and biopolymers, some hydrocarbon
- HWO solid at room temperature with melt point ~80 °C



HWO Product

Once-Through MWO Processing

Project conducted with Kvasir Technologies



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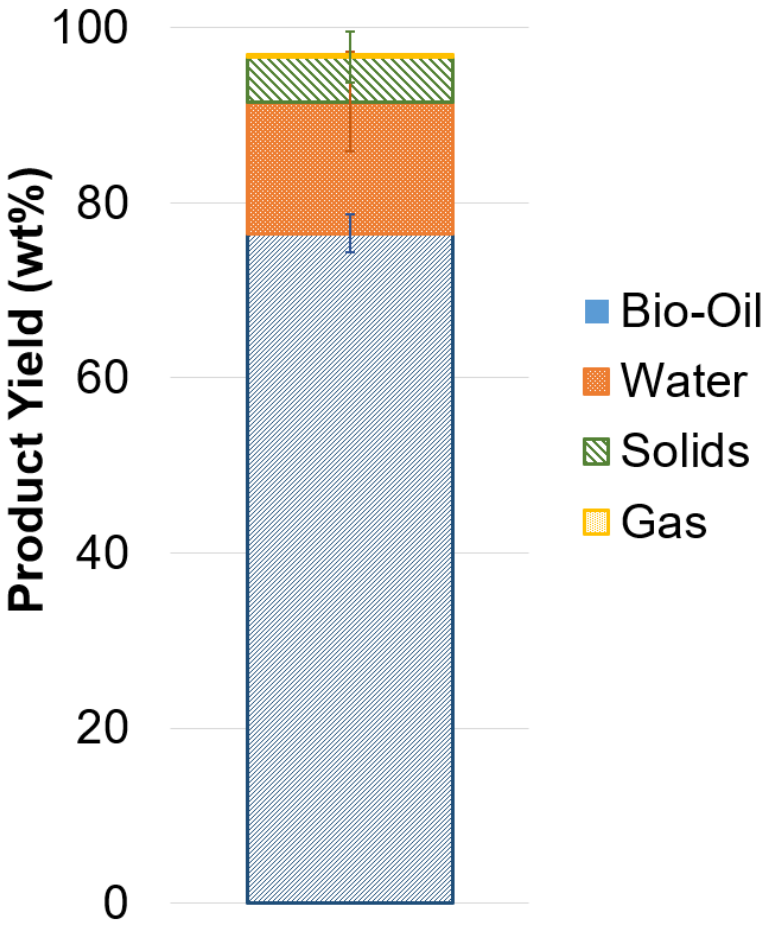
Neat Phenolic Solvent Processing



- Solvent mix simulates potential composition for full recycle operation with MWO
- Phenolic solvent generated low yields of very fine char particles with very little gas production
- Over 96% conversion to liquids and gases demonstrated

Liquefaction Metrics	
Bio-Oil Yield (wt. %)[a]	76.5

[a]Solvent-less, dry biomass basis

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Summary and Future Work

- **Summary**
  - Demonstrated increased conversion/yield with MWO solvent during continuous liquefaction of pine with high selectivity to liquid products
  - Achieved >96% biomass conversion and ~76.5 wt. % bio-oil yield
- **Future Work**
  - Conduct separation and product analysis
  - Contents intended to serve as subject matter for publication
  - Conduct additional trials using MWO obtained from separation process, implementation of MWO direct recycle

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  - Joachim Bachmann Nielsen
  - Nikos Montesantos
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Questions?