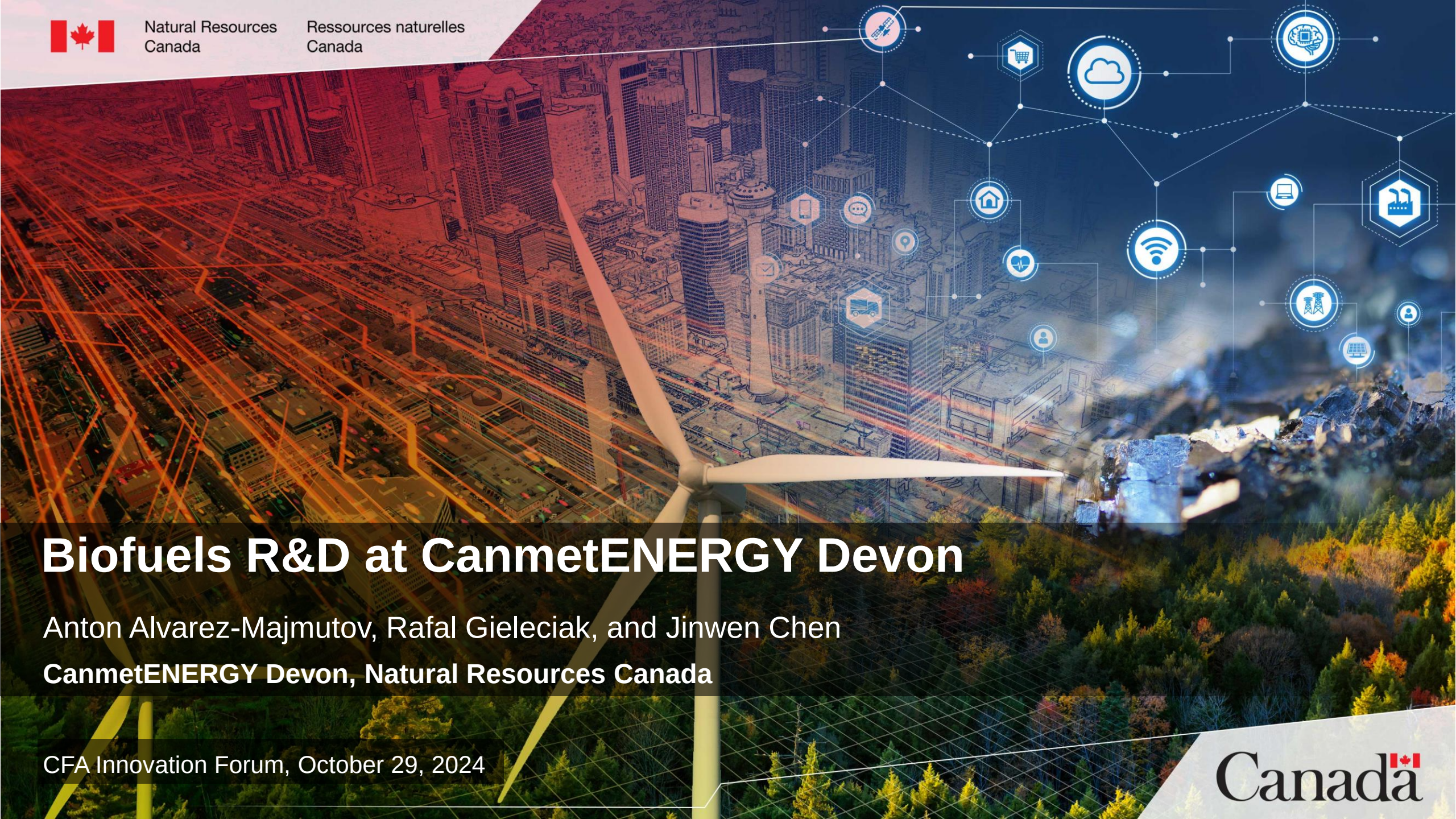

Natural Resources Canada | Ressources naturelles Canada

Biofuels R&D at CanmetENERGY Devon

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CanmetENERGY Devon, Natural Resources Canada

CFA Innovation Forum, October 29, 2024

Canada

NRCan's Canmet Labs

Expertise in 4 Canmet labs that support science and clean technology development

- Bioenergy
- CCUS, hydrogen
- Clean fuels
- Reducing environmental impacts
- Spill science
- Critical minerals

Devon, AB

- Buildings and communities
- Industrial processes
- Renewable and distributed energy
- RETScreen International

Varennes

- Bioenergy
- Built environment
- CCUS
- Industry
- Northern and remote energy
- Renewables, electrification, and transportation

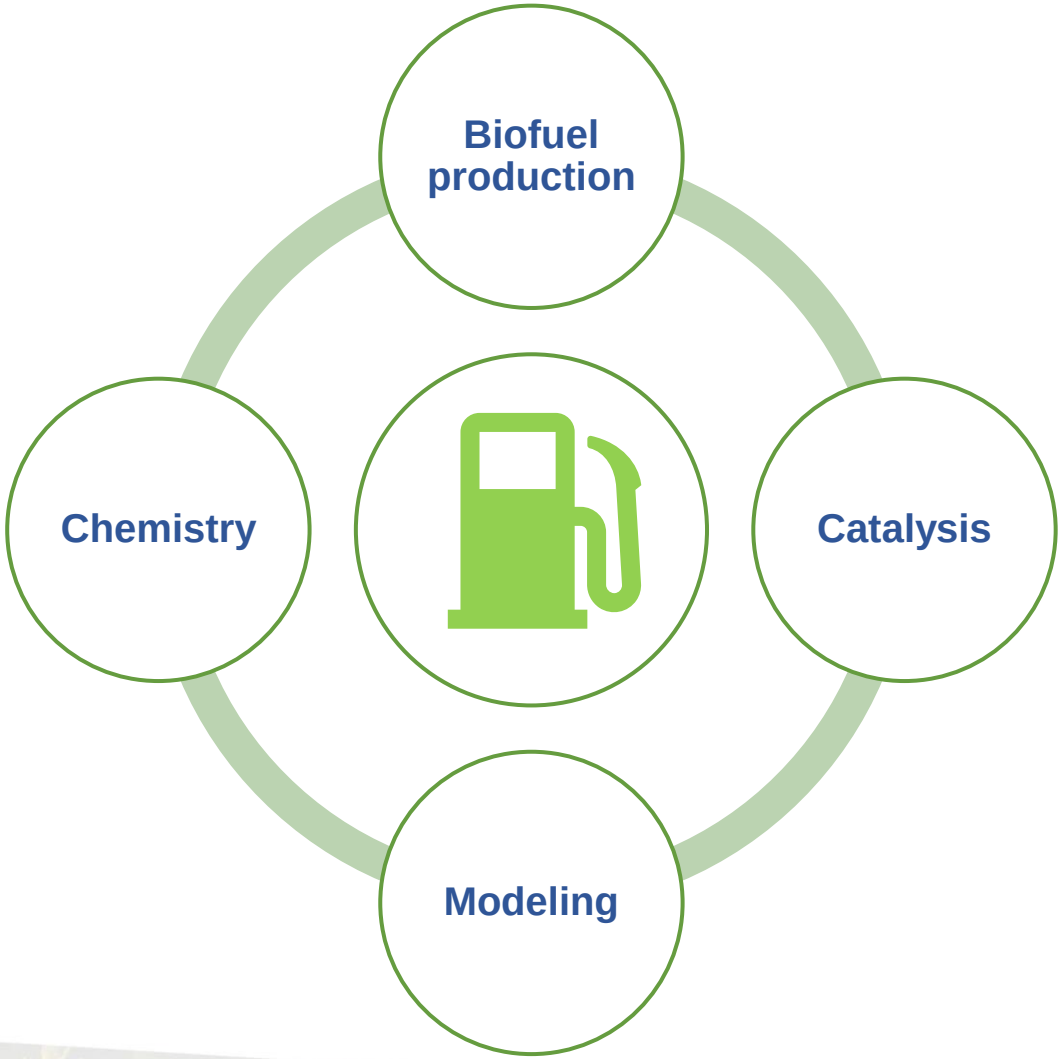
Ottawa

Advanced materials for:

- Energy end-use
- Energy production
- Energy distribution (pipelines)
- Safety and security

Hamilton and Calgary

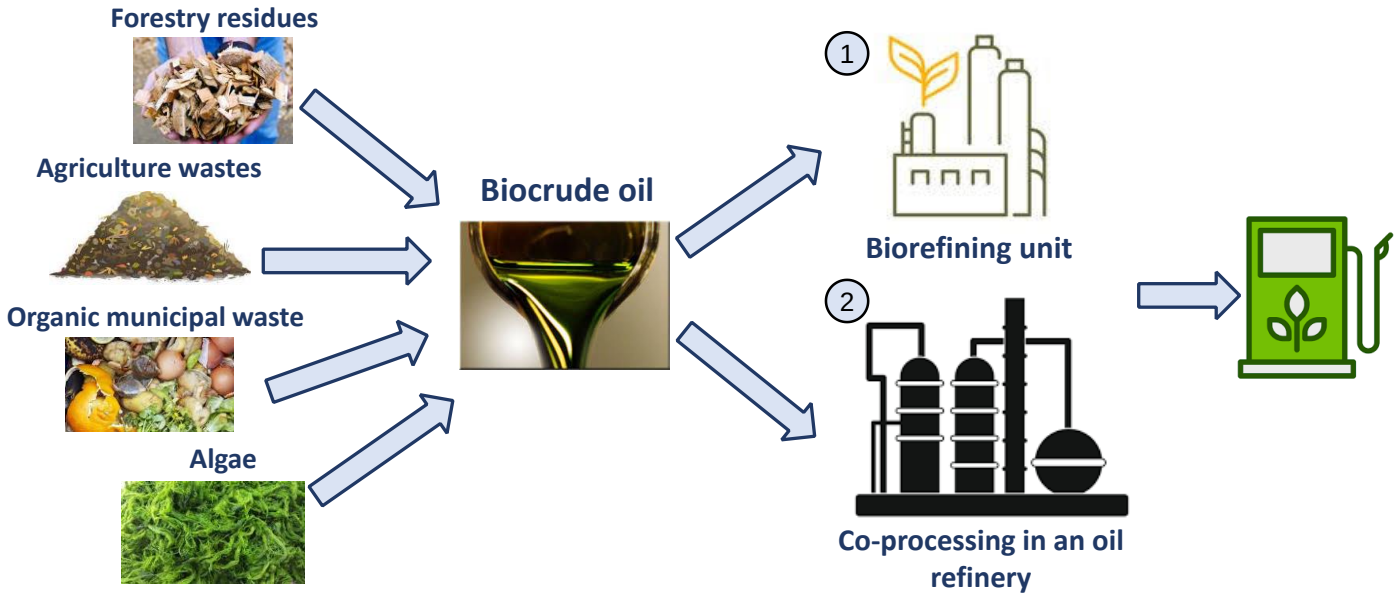
CanmetENERGY Devon's Biofuels R&D Program



- Focused on biofuels from advanced feedstocks
  - Industry wastes – forestry, agriculture, food processing
  - Municipal wastes – organic waste, sewage sludge, cooking oils
  - Algal biomass
- 3 major multi-year projects with a combined budget of ~$2.3M per year from federal R&D programs
  - Program of Energy Research and Development (PERD)
  - Forest Innovation Program (FIP)
- Broad collaboration network
  - Bioenergy companies and fuel producers
  - Universities in Canada, US, and other countries
  - Government organizations and labs (international, national, provincial, and municipal)

Focus Area 1: Biofuel production

- Developing biocrude upgrading solutions
- Piloting biorefining and co-processing technologies
- Supporting industry in technology development, demonstration, and scaling up

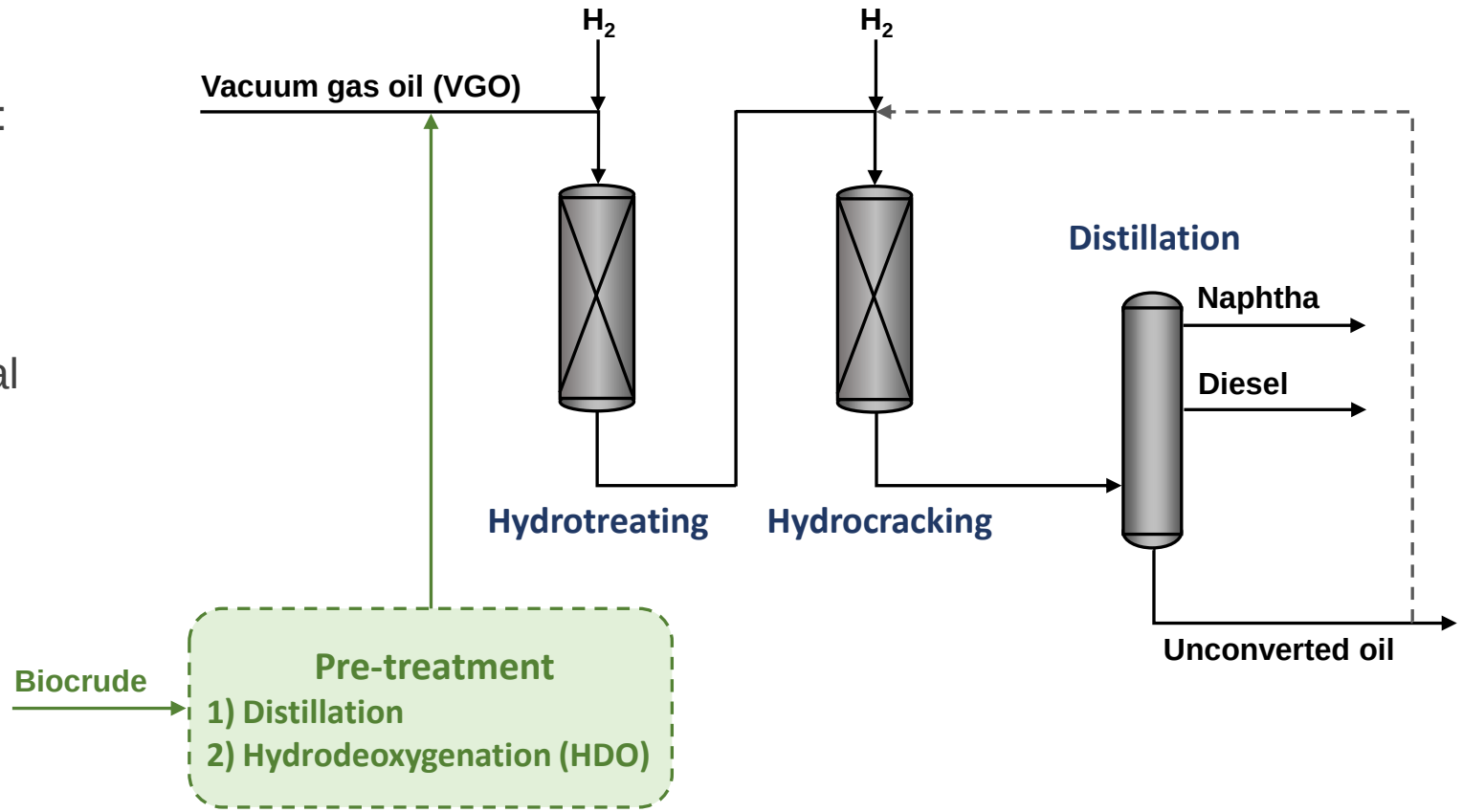


0.5 barrel (80 L)/day hydroprocessing unit with 2 reactors and on-line distillation

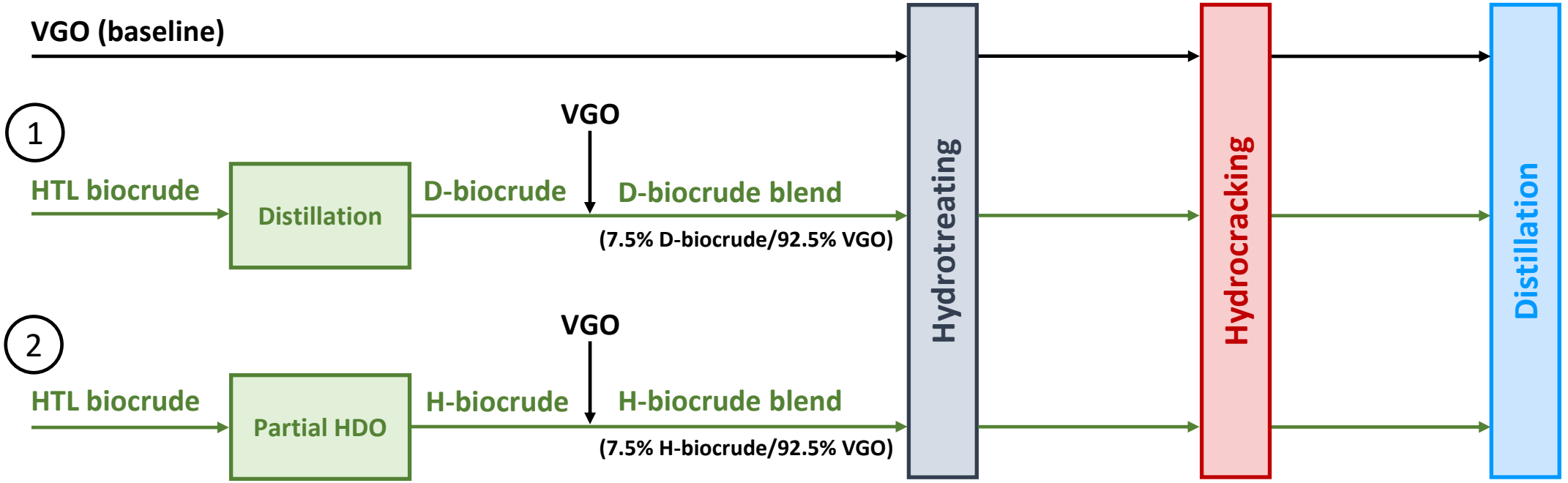
Biocrude co-processing

Goal: investigate the co-processing of pre-treated biocrude in the hydrocracking process

- Biocrude produced by hydrothermal liquefaction of woody biomass
- Biocrude pre-treatment needed to alleviate:
  - Poor miscibility with petroleum
  - Thermal instability
  - Catalyst poisoning
- Pilot plant study designed to emulate typical hydrocracking process
  - Hydrotreating
  - Hydrocracking
- Similar study done using fluid catalytic cracking (FCC) (not presented here)



Biocrude co-processing – experimental plan



Feed materials

- Petroleum feed: VGO (343-525ºC) from Canadian bitumen
- Biogenic feed: HTL biocrude from a mix of spruce and pine wood

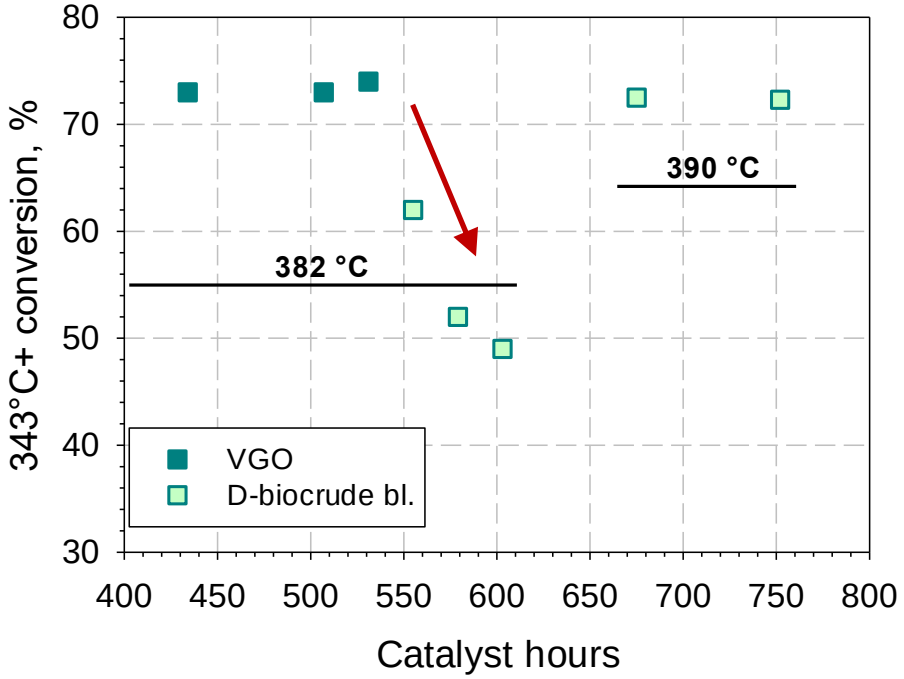
Biocrude co-processing – feed properties

Property	HTL biocrude (1)	D-biocrude	HTL biocrude (2)	H-biocrude	VGO
distillation yield, wt%	-	63.4	-	-	-
density at 15.6°C, g/mL	1.0536	0.9925	1.0880	0.9910	0.9759
carbon, wt%	80.0	79.5	79.7	84.8	84.8
hydrogen, wt%	9.4	10.0	8.6	10.5	11.1
sulfur, wt%	<0.1	<0.1	0.1	<0.1	3.6
nitrogen, wt%	<0.1	<0.1	0.3	0.1	0.3
oxygen, wt%	**10.5**	**10.6**	**11.3**	**3.6**	0.5
Fractional composition					
distillate (<343°C), wt%	27.7	47.1	17.1	42.8	4.5
vacuum gas oil (343-525°C), wt%	34.7	49.6	31.9	28.7	86.5
vacuum residue (>525°C), wt%	**37.6**	**2.7**	**51.0**	**28.5**	9.0

Biocrude co-processing – hydrocracking stage

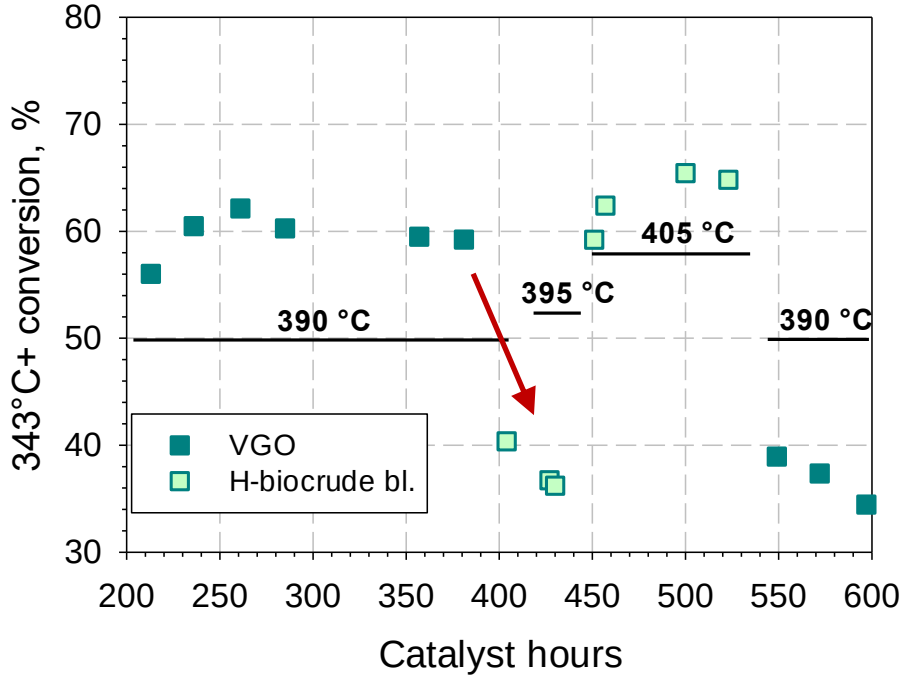
1 7.5% D-biocrude bl. hydrocracking activity

(D-biocrude 10.6 wt% oxygen)



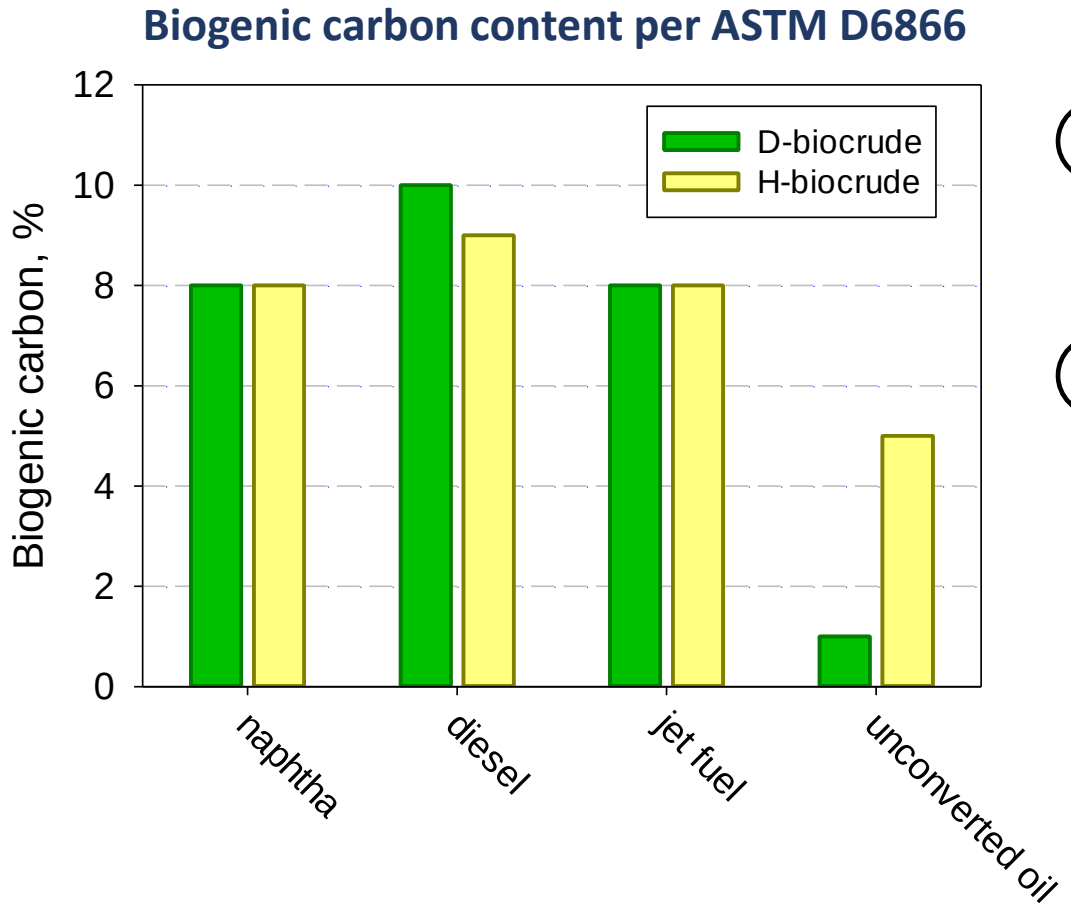
2 7.5% H-biocrude bl. hydrocracking activity

(H-biocrude 3.6 wt% oxygen)



Pressure = 1,600 psi; LHSV = 1.5 h^{-1}; H_2/oil ratio = 800 NL/L

Biocrude co-processing – biogenic carbon analysis



1 **D-biocrude co-processing:**

- 83.6% of the biogenic carbon ends up in the naphtha and diesel products
- 2.9% remains in the unconverted oil

2 **H-biocrude co-processing:**

- 70.7% of the biogenic carbon ends up in the naphtha and diesel products
- 14.7% remains in the unconverted oil

Focus Area 2: Catalysis

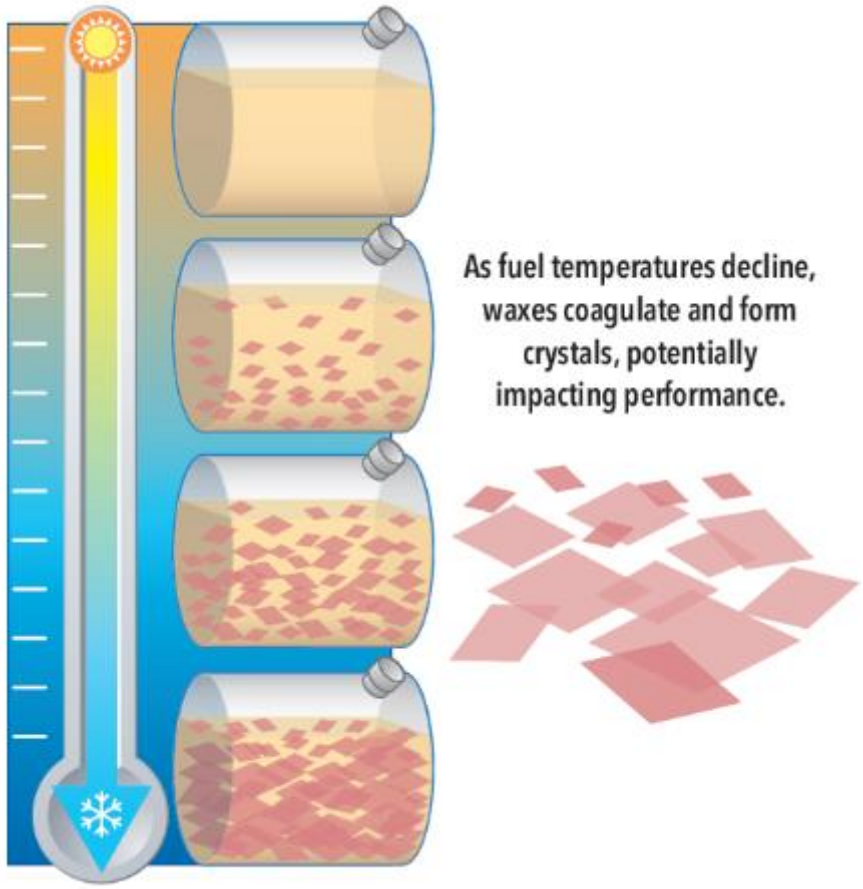
- Catalyst synthesis for biorefining applications
  - Biocrude deoxygenation and denitrogenation
  - Isomerization and hydrocracking
- Catalyst testing and characterization

250 mL batch reactor unit for catalyst evaluation studies

Isomerization of n-paraffins

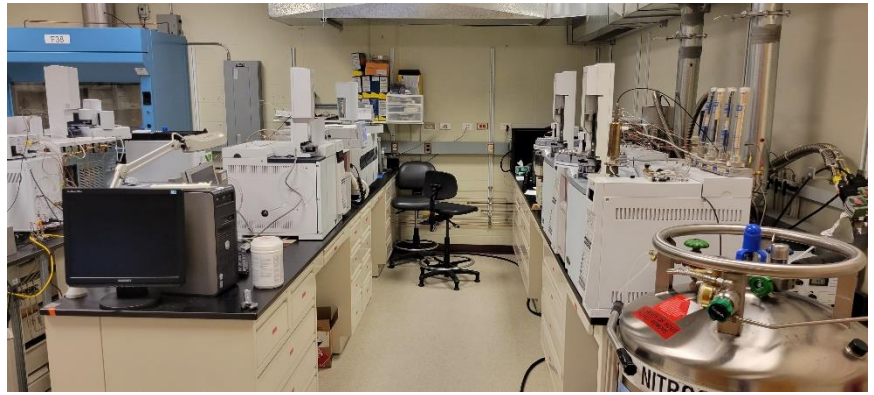
Goal: develop isomerization technology to upgrade a lipid-derived biofuel product into biojet

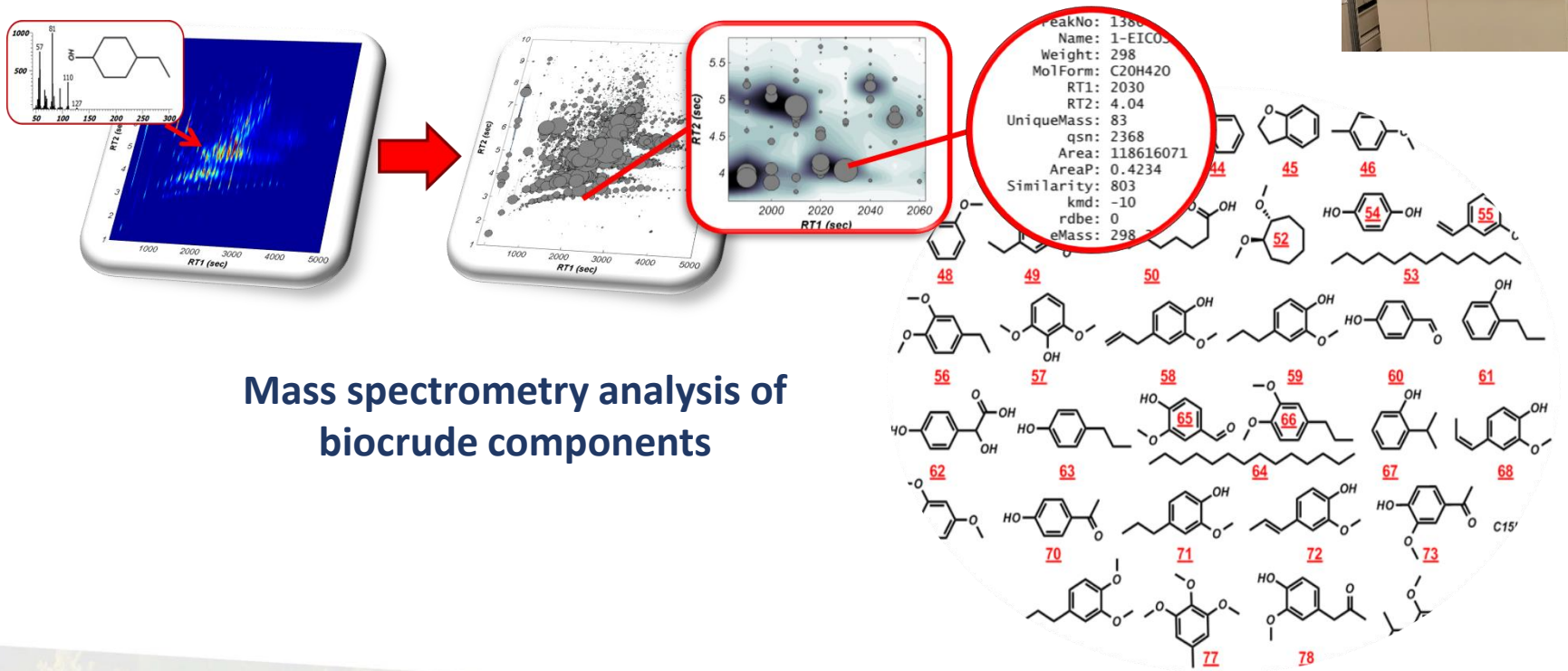
- Biofuel rich in n-paraffins and with a poor freezing point
- Synthesized, tested, and scaled-up isomerization catalysts for converting n-paraffins into isoparaffins
  - Several catalysts screened at different conditions in a batch reactor
  - ~2,700 h of continuous pilot testing
  - Product quality testing against standard specifications for Jet A and Jet A-1 grade aviation fuels



Focus Area 3: Chemistry

- Chemical analysis of biocrudes and biofuel products
- Elucidation of reaction pathways in biorefining processes
- Biogenic carbon content determination in co-processed fuels





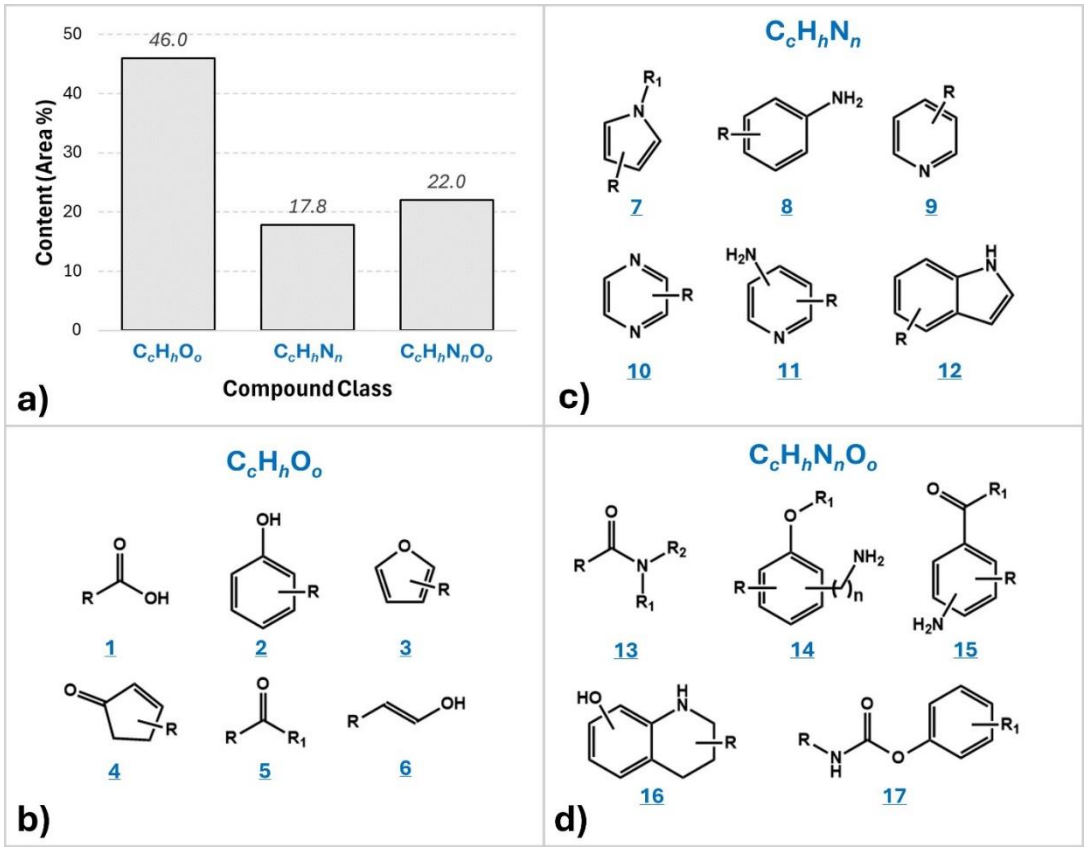
Mass spectrometry analysis of biocrude components

Algae biocrude analysis

Goal: understand the nature of the oxygen and nitrogen compounds in the biocrude

- Biocrude produced by hydrothermal liquefaction of algal biomass
  - 8.4 wt% oxygen
  - 3.8 wt% nitrogen
- Long-chain fatty acids, amides, and pyrroles were prevalent in the algae biocrude
- Amides and pyrroles were easily removed from the biocrude during its co-processing with gas oil

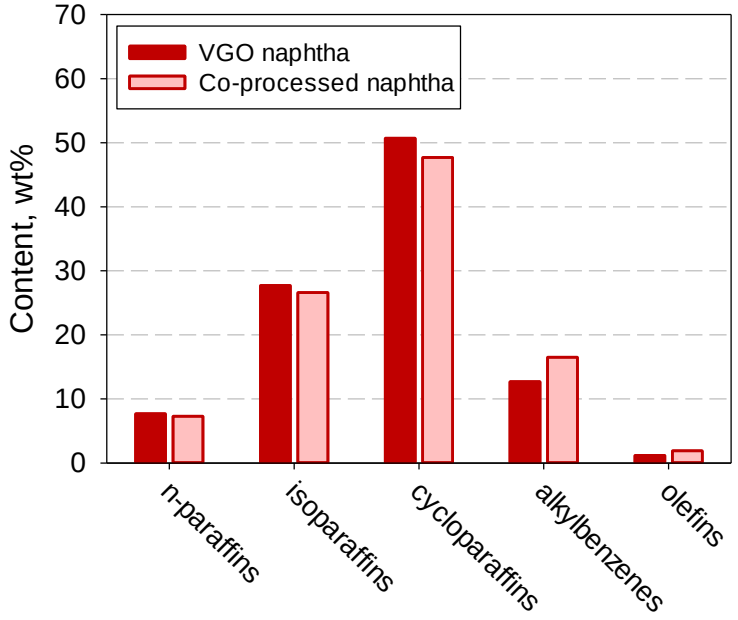
GC×GC-TOFMS analysis of the biocrude



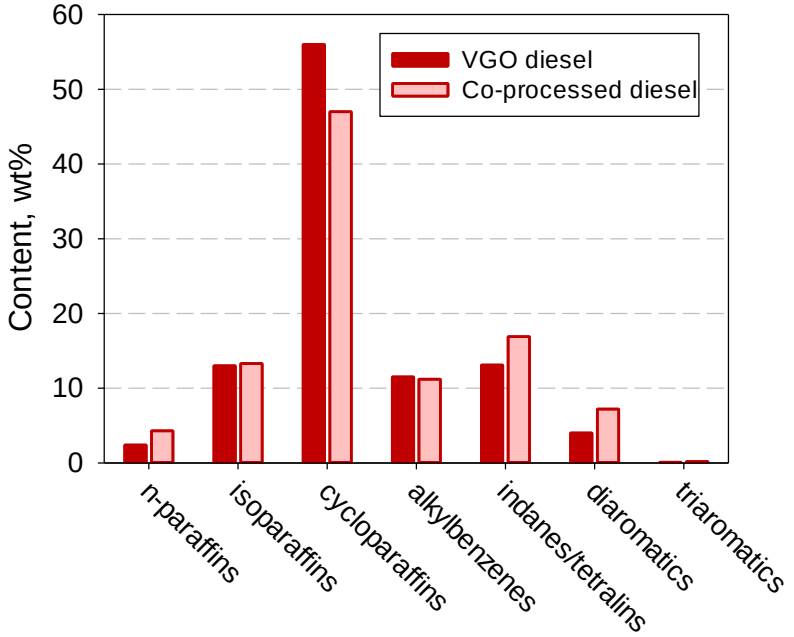
Co-processed fuel composition analysis

Goal: understand differences in hydrocarbon composition of co-processed fuels

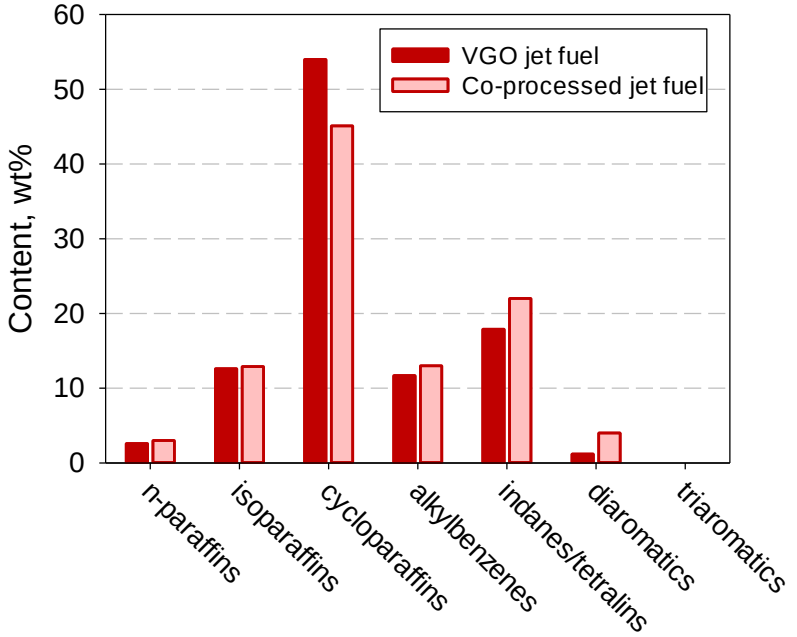
Hydrocracked naphtha



Hydrocracked diesel



Hydrocracked jet fuel



GC×GC-FID characterization of hydrocracked products

Biogenic carbon analysis

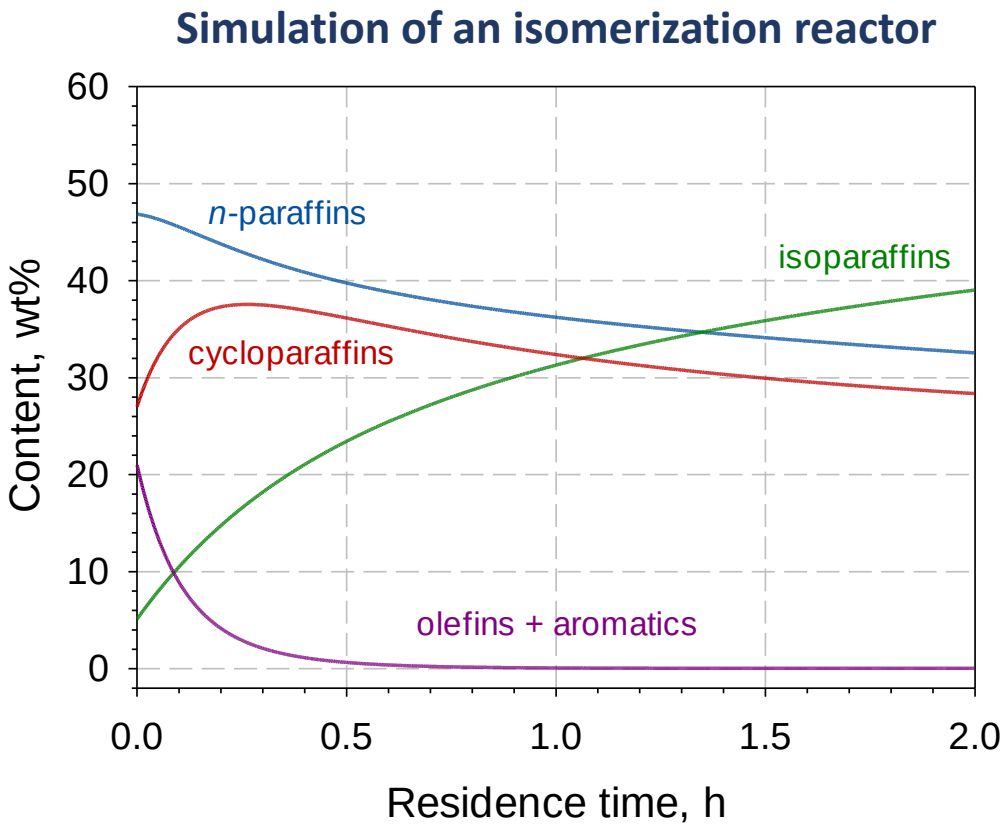
Goal: measure the biogenic carbon content in co-processed products

- Hidex 600 OX oxidizer and 300 SL super low-level liquid scintillation counter (LSC)
  - commissioned in October 2024
- The Hidex 600 OX is ideal for a variety of solid samples
- Determination of biogenic carbon content in liquid fuels is based on radiocarbon dating using the LSC

Oxidizer

Liquid scintillation counter (LSC)

Focus Area 4: Modeling



- Molecular modeling of biocrudes and their reaction chemistry
- Process modeling and simulation of biorefining units
  - Biocrude upgrading
  - Co-processing
  - Biorefining
- Techno-economic and life cycle assessment of biofuel pathways

Acknowledgement

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