



ICARUS Final Webinar

25 September 2026

Innovation in biocrude oils to SAF

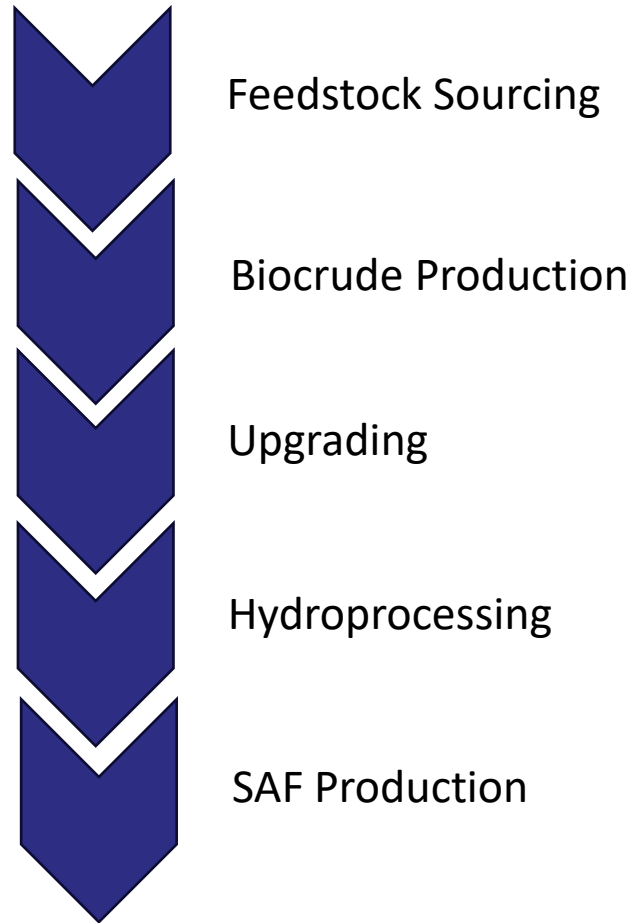
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Outline

- The HEFA Pathway: The path from biocrude oils to SAF
- ICARUS Technical challenges
- ICARUS concept
- Biocrude oil production by HTL and upgrading
- Conclusions

HEFA - Biocrude oils to SAF



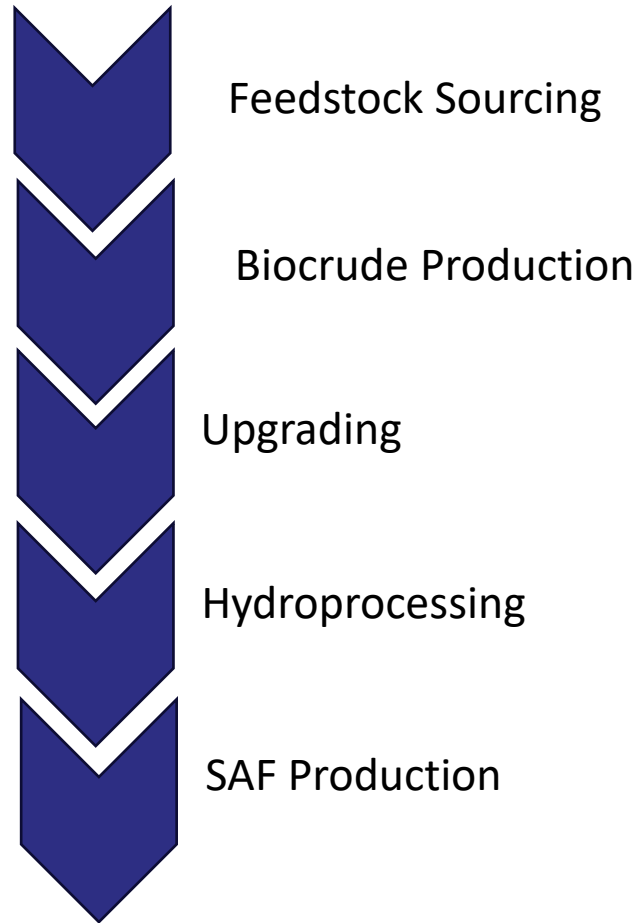
Feedstock sourcing

Current:

- ✓ Part B, Annex IX RED (UCO, animal fat)
- ✓ Part A, Annex IX RED (POME,...)

Beyond 2030:

- ✓ Microalgae oils (ICARUS Feedstock)
- ✓ Microbial oils
- ✓ Intermediary (oleaginous) crops
- ✓ ...



Technical Challenges

Biocrude Production & Upgrading (Hydroprocessing)

- ✓ Hydrothermal Liquefaction (HTL) biocrude contains high oxygen, nitrogen, and sulfur, requiring intensive hydrotreatment (HDO) to meet jet fuel specifications.
- ✓ Issues include high hydrogen consumption, catalyst deactivation, and operational complexity.

Process Efficiency

- ✓ Achieving optimal HTL yields (>36–55% dry weight) and refining efficiency (>16–24%) is critical for SAF compliance.
- ✓ Variability in feedstock composition complicates process control.

Integration with Existing Infrastructure

- ✓ While modular upgrading is possible, compatibility with refinery systems and blending limits remain technical hurdles.

Technical Challenges at ICARUS

MICROALGAE

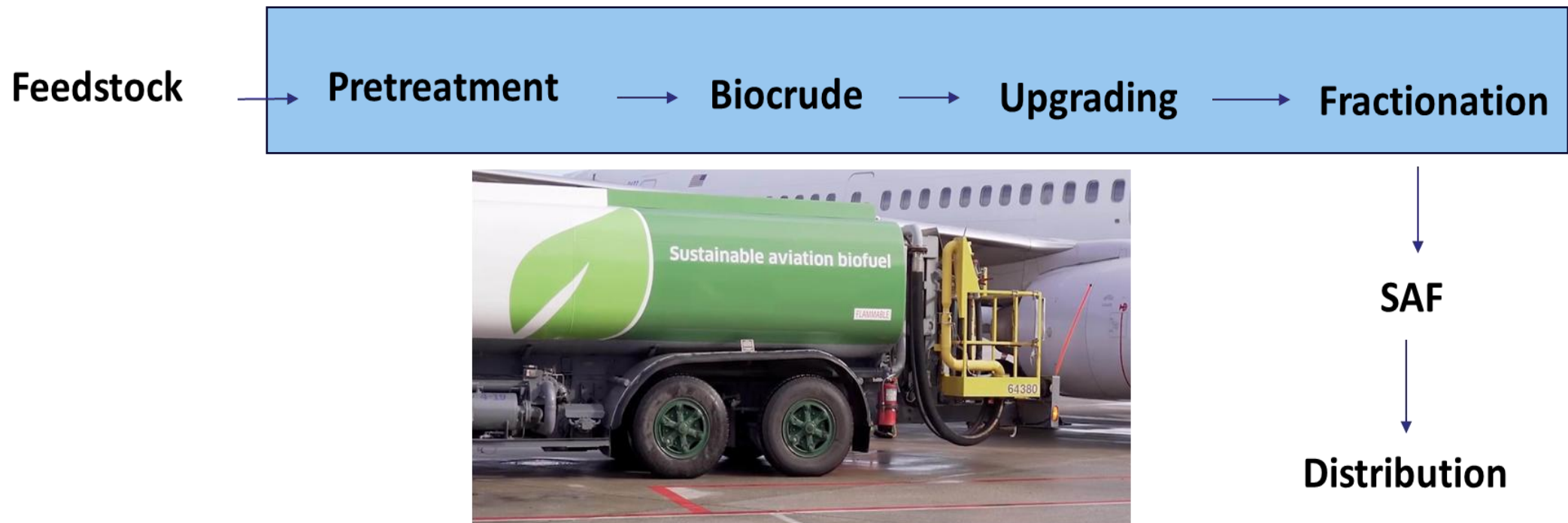


Proprieties	Light crude oil	Heavy crude oil	Jet fuel	Spirulina Biocrude	Chlorella Biocrude	Nannochloropsis Biocrude
HHV (MJ/kg)	47.0	42.5	46	36.8	35.1	34.5
C (% w/w)	84.0	85.0	85.0	73.3	70.7	68.1
H (% w/w)	14.0	11.0	13	9.2	6.8	8.8
O (% w/w)	1.0	1.0	<0.1	10.4	14.8	19.0
N (% w/w)	1.0	0.3	<0.01	7.0	5.9	4.1
Ashes (% w/w)	0.1	0.1	<0.01	-	-	-

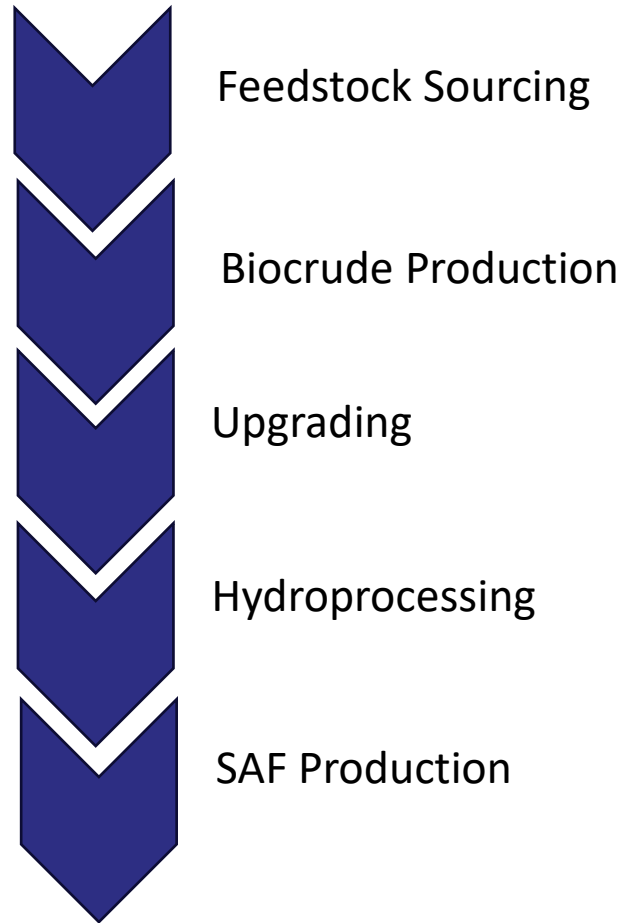
- High N-content
- High O-content
- High viscosity
- Chemical instability
- Low energy density
- High acidity and water content



ICARUS concept for high N-content Microalgae biomass



HEFA - Biocrude oils to SAF



Removal of particulate matter/solids from biocrude oils

Process	Advantages	Disadvantages	Source
Centrifugation & Filtration	- Capable of recovering high yields of bio-oil - Simple and scalable	- May not effectively remove the finest particles	(Mujahid et al., 2020b)
Microfiltration	- Can target specific sizes of particles for removal - Beneficial for improving bio-oil purity	- Lack of established technologies for particles <10µm - Potential for high operational costs	(Elliot et al., 2016; Javaid et al., 2010),
Two-step separations	- Enhances bio-oil purity by employing sequential refinement - Effective for complex feedstock bio-oils (microalgae)	- Potentially resource-intensive due to multiple processes	(Grigorenko et al., 2018)
Biomass filter aids	- Utilizes biomass-derived materials, enhancing sustainability - Efficient in aiding the filtration process	- Requirement for subsequent disposal or processing of spent filter aids	(Biller et al., 2018; Johannsen et al., 2019; Lin, 2015)
Advanced membranes technologies	- High effectiveness in particle and oil separation - Reduced fouling compared to other membranes	- Costs associated with ceramic membranes can be high - Potential for ceramic membrane fouling in long-term operations	(Sayegh et al., 2022)

HEFA - Biocrude oils to SAF

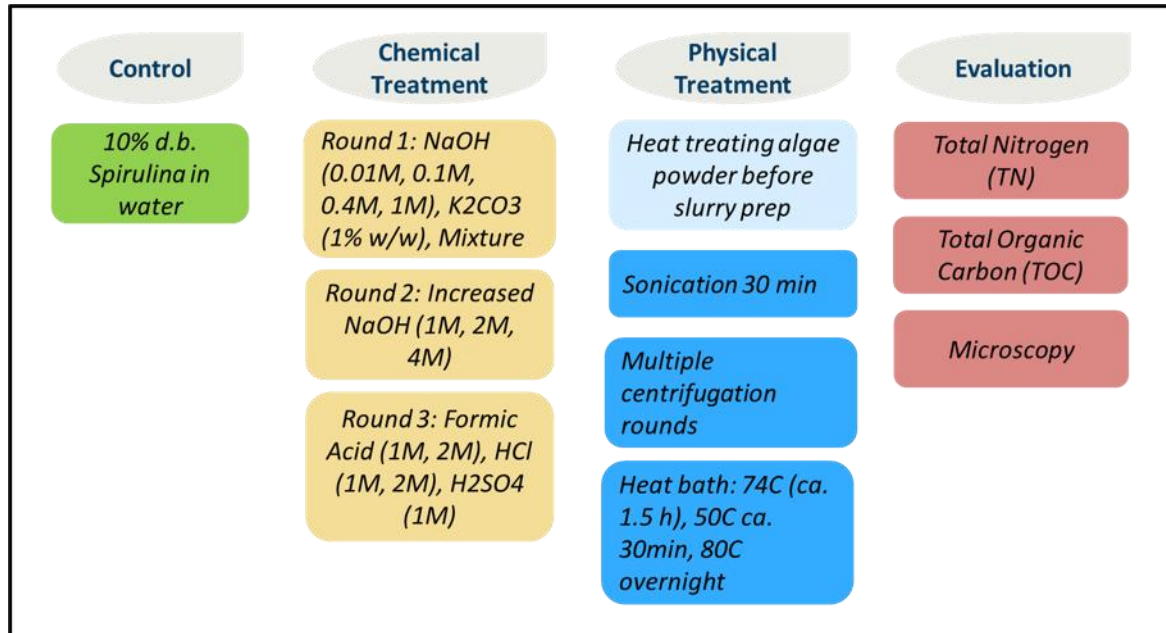


Main methods for N removal

Method	Advantages	Disadvantages	Technology readiness
Hydrotreating	- Industrially proven method for nitrogen removal - Effective in removing nitrogen as ammonia	- Not a selective nitrogen removal process - Other hydroprocessing reactions occur simultaneously	industrially proven and widely used
Liquid-Liquid Phase Partitioning	- Selective extraction of nitrogen-containing compounds based on solubility parameters - Potential for efficient separation of nitrogen compounds	- Limited by solubility parameters and selectivity of extracting liquid - Process complexity and solvent recovery challenges	requires further optimization for industrial application
Solvent Deasphalting	- Effective in removing heavier components like asphaltenes containing nitrogen - Can improve oil quality by reducing nitrogen content	- Not capable of deep nitrogen removal from oil - Process may not eliminate all nitrogen-containing compounds	requires further optimization for industrial application
Adsorption	- Selective adsorption of nitrogen-containing compounds based on interactions with adsorbent - Potential for high selectivity and capacity	- Regeneration of adsorbent for reuse can be challenging - Adsorbent capacity and selectivity may vary based on the type of adsorbent	requires further optimization for industrial application
Chemical Conversion and separation (2 step)	- Transformation of nitrogen compounds to facilitate separation - Potential for modifying chemical structure of nitrogen compounds	- Process complexity and optimization required for effective conversion and separation - May require specific catalysts and conditions	requires further optimization for industrial application
Microbial Conversion	- Potential for biological removal of nitrogen compounds from oils - Environmentally friendly approach	- Limited application and research compared to other methods - Effectiveness may vary based on microbial strains used	low

High N-content biomass Pre-treatment (before HTL) - ICARUS

Development of pre-treatment strategies to remove N/salts and improve feedstock quality.



Overview of experimental approach for pre-treatment methods.

HTL semi-continuous at 350°C, 300 bar, 0,9 L/h



Sample 1 – control

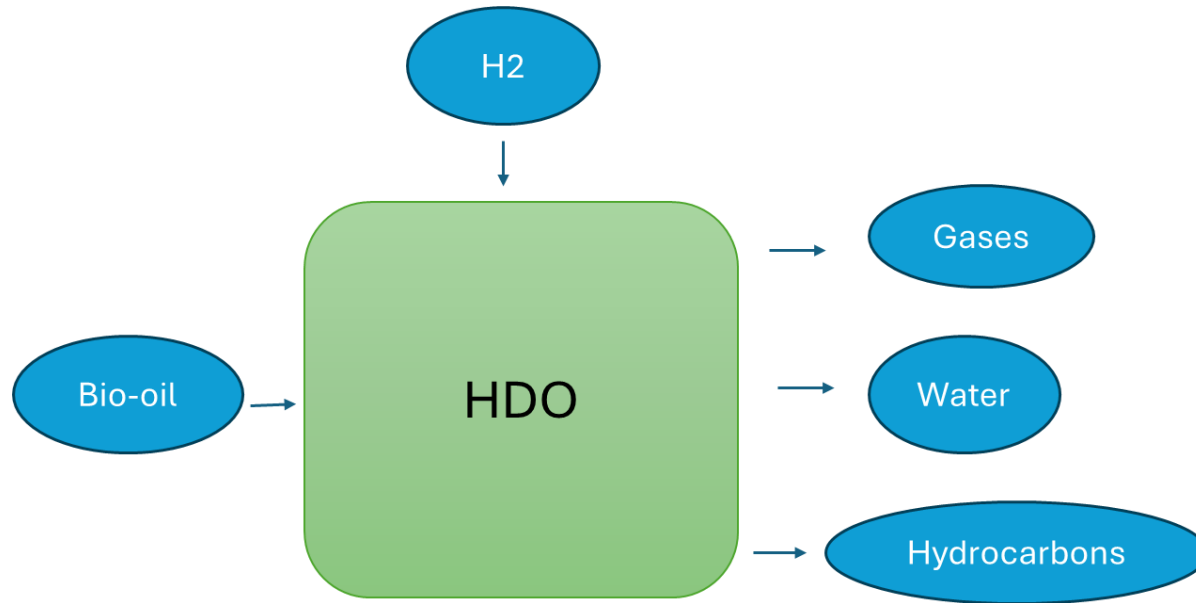
Sample 2 – Heat treated algae

Sample 3 – Sulfuric acid + heat treated algae

Sample 4 – Water-washed algae

Upgrading via Hydrodeoxygenation (HDO)

Objective : Improve the physical and chemical properties of bio-oil.



Operating conditions:

Temperature: 200°C and 400°C.

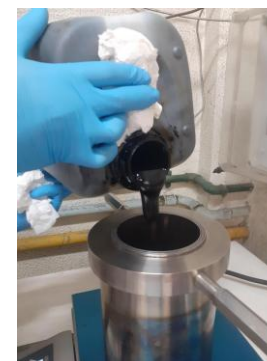
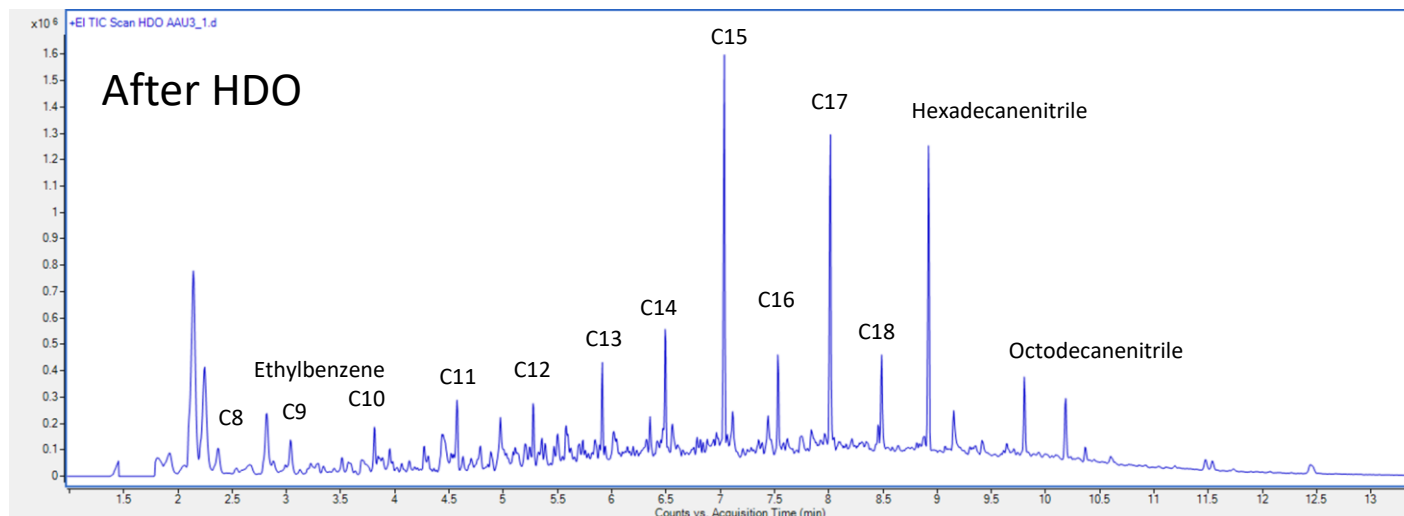
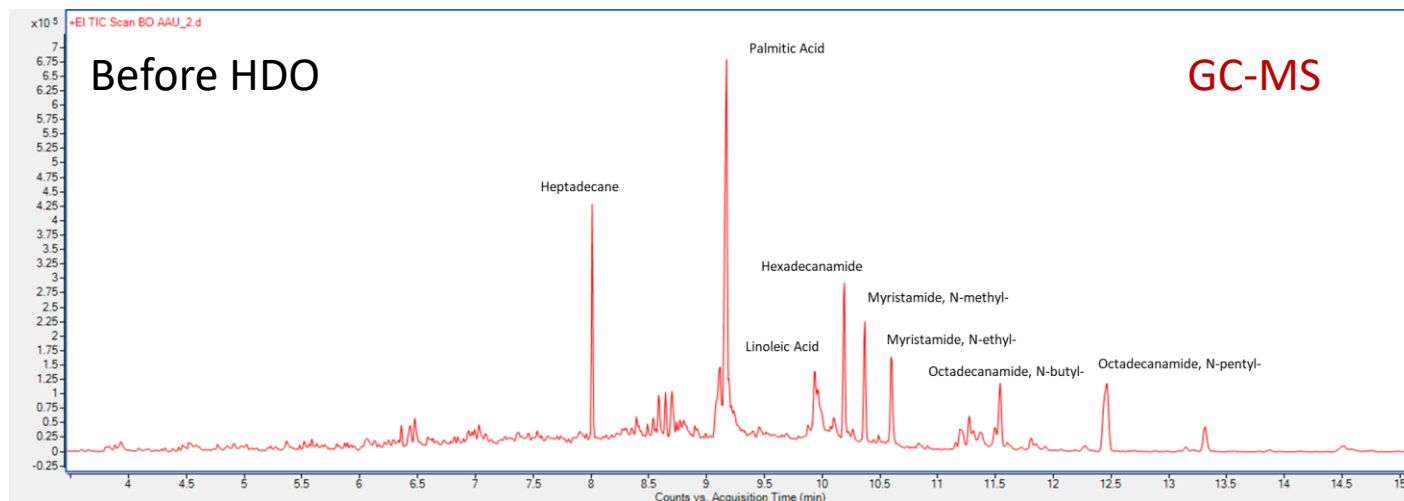
Hydrogen pressure: 20 to 100 bar, which may vary depending on the type of catalyst.

Catalysts: Usually metals such as nickel (Ni), molybdenum (Mo), cobalt (Co) supported on alumina (Al₂O₃) or other supports.

Reaction time: Can vary from minutes to several hours, depending on the system.

Conditions used: 400°C, 30 min, initial pressure 5.5bar, run pressure 40 - 110 bar, Co-Mo, Ni-Mo.

Hydrotreatment of HTL-biocrude oil



Biocrude HTL

After HDO



yield =38%

After distillation



yield=50%

Best data

Biocrude oil	Before HDO	After HDO	
C	73	81.2	% wt
H	9.2	9.88	%wt
N	7.0	3.19	% wt
S	0.57	<0.2	% wt
O	10.4	3.61	%wt

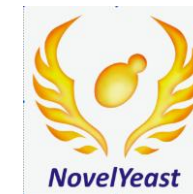
CONCLUSIONS

- HEFA - biocrude-to-SAF pathway can only be playing a leading role for SAF production beyond 2030 if new Sustainable Oils sources will be available
- Microalgae biomass is technically converted to biocrude oils through Hydrothermal Liquefaction (HTL), however faces technical complexity, namely high N-content and high O-content and chemical instability.
- In particular, Spirulina biomass is a very challenging feedstock for HTL/HDT due to their high nitrogen content (~ 7%)
- At ICARUS, Spirulina biomass N-content was reduced to a minimum of 3.2% in the upgraded biocrude oil when thermal and acid pre-treatments (H_2SO_4) have been used, while the oxygen content was successfully reduced to below 5%.
- The use of different catalyst blends during HDO process did not further improve the quality of the final product.
- Catalysts deactivation mechanisms must be further studied.

Thank you



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