Unlocking the Potential of Algal Biomass: from Wastewater to drop-in Sustainable Aviation Fuel via Hydrothermal Liquefaction

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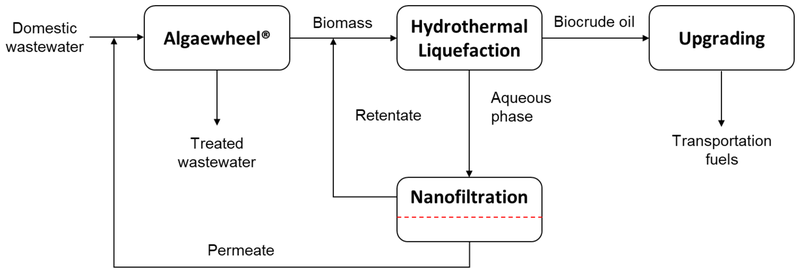
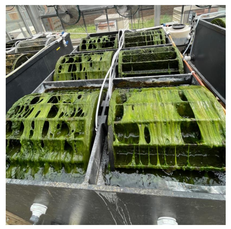
Drop-in sustainable fuels from algal-bacterial biomass

- Integrated approach for wastewater treatment and drop-in fuel production
- Nanofiltration (pressure-driven membrane filtration process) is used to concentrate hydrothermal aqueous phase (high-strength waste stream)



Algaewheel® (algal wastewater treatment system)

- Commercially available algal rotating contactor for wastewater treatment
- Buoyant wheels are rotated (1-2 rpm) by a very low-energy aeration system
- Produces biosolids suitable for hydrothermal liquefaction (HTL)



Pilot system (200 gal) at the University of Illinois

Biomedia
Support for bacterial biofilm growth

Fins
Symbiotic growth of algal-bacterial biofilm

Hydrothermal liquefaction (HTL)

- Thermochemical process that can convert wet biomass into biocrude oil and valuable chemicals
- Biocrude oil can be refined into drop-in sustainable transportation fuels
- Aqueous phase can be recirculated to improve conversion efficiency

Wet biomass (e.g., algae) + **High temperature** (250 – 400 °C) + **High pressure** (4 – 22 MPa) = **Biocrude oil** (petroleum substitute)

Increasing biomass productivity

Field demonstration

- 30,000 gal/day Algaewheel® plant
- Duration: May 2023 – March 2024
- Location: Gardner, IL

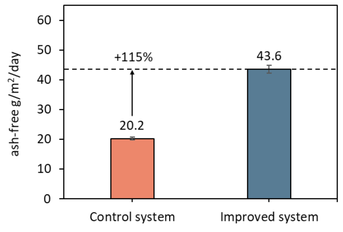
Main goal

- Simultaneously increase biomass productivity and decrease ash content

Approach

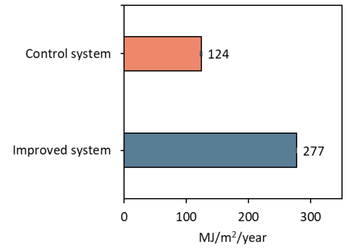
- Optimization of operational parameters (organic loading, aeration rate, harvesting frequency)

Biomass productivity



- Biomass productivity more than doubled while keeping wastewater treatment capabilities

Biomass energy yield



- 123% biomass energy yield increase
- More than five times higher than current energy crops, which varies between 7-60 MJ/m²/year [1]

[1] Haberl, Helmut, et al. "The global technical potential of bio-energy in 2050 considering sustainability constraints." Current Opinion in Environmental Sustainability 2.5-6 (2010): 394-403.

Improving biocrude oil yield and quality

Experimental details:

- HTL conditions: 300˚C (30 minutes)
- 1L stirred Parr reactor

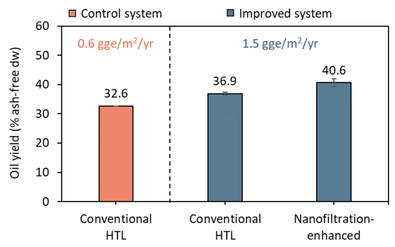
Biomass characteristics:

- 18% dry solids
- Dewatered via freeze-drying

Nanofiltration:

- Dead-end filtration system (200 mL)
- Membrane: NF270 (commercially available)

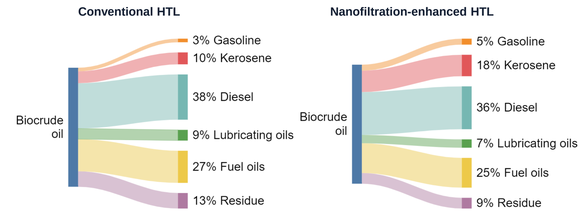
Biocrude oil yield



*gge: gasoline gallon equivalent

- Combined effect of better biomass quality and nanofiltration-enhanced HTL, resulted in 25% increase in conversion efficiency

Boiling point distribution
(Before upgrading)

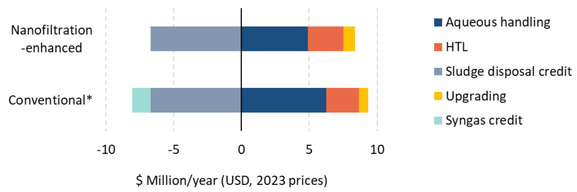


- Nanofiltration-enhanced HTL yields 8% (wt/wt) more light fuel fractions, requiring less upgrading of heavy fractions

Preliminary techno-economic analysis

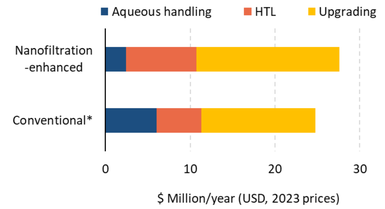
- Plant capacity: 110 dry tons/day (nth of its kind)

Operating costs



* Conventional: assumed catalytic hydrothermal gasification for HTL aqueous treatment

Total capital investment



Scenario	Fuel production (gge/year)	MFSP ($/gge)
Conventional	2,773,717	6.12
Nanofiltration	3,821,021	4.66

MFSP: minimum fuel selling price
gge: gasoline gallon equivalent

Takeaways

- The Algaewheel® system can be optimized for increased algal-biomass productivity (up to 115% increase)
- Nanofiltration-enhanced HTL approach produces 27% more drop-in fuels per unit of biomass, reducing MFSP in 24%

Acknowledgment

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