Bringing Hydrothermal Liquefaction Out of the Laboratory with the Construction of a Fully Integrated Commercial System

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tcbiomass

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Two challenges:

Sewage sludge disposal

- Sewage sludge fractions
  - Primary sludge
  - Secondary sludge (waste-activated sludge)
  - Organic solids on grate and scum/FOG
  - Other wet wastes (food, MSW organic fraction)
- Sewage sludge characteristics
  - Wet – 70-90% water, therefore energy-intensive to dry and expensive to transport
  - Distributed: a small number of large sites and a large number of small sites
  - Contaminated (pharmaceuticals, personal care products, PFAS, microplastics, heavy metals, etc.)
  - High phosphate content

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Two challenges:

Sewage sludge disposal

- Thermal methods require drying
  - Slow pyrolysis (biochar)
  - Gasification (syngas)
  - Incineration (energy)
- Anaerobic digestion is effective but with limitations
  - Partial solids reduction
  - Minimal contaminant removal
  - Slow, large footprint, gaseous product
  - Innovation is ongoing to address limitations

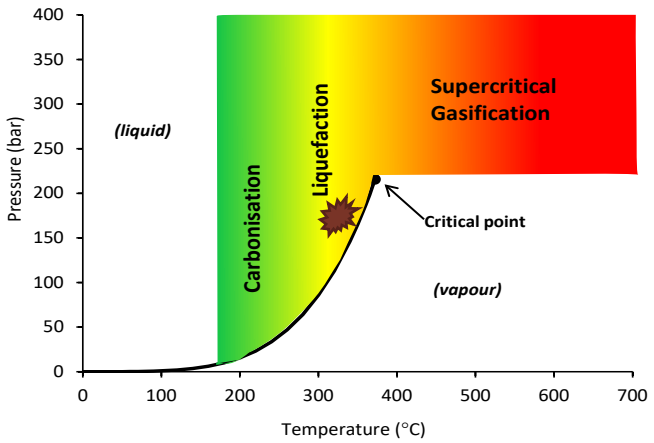
Two challenges:

Demand for sustainable liquid fuels

- Solid biomass is needed to meet the demand for sustainable fuels
  - Climate policy: RFS, LCFS, CFS, RED II
  - Energy security: geopolitics back in focus
  - The market for 'used cooking oil' is distorted
  - The market is screaming for sustainable alternatives
  - SARA: sustainable, available, reliable, affordable
- Cars and light trucks can run on electricity, but aircraft, ships and heavy industry need sustainable fuels

One solution:

Circlia Nordic's HTL technology



- Hydrothermal conversion of biomass into crude oil at 325-350 °C and 160-200 bar
- Pilot plant at AU Foulum operating for 7 years
- HTL technology is the most promising path approach for wet biomass – Circlia Nordic has made it compact and energy efficient
  - No drying, contaminant destruction, 95% reduction in volatile solids, >80% thermal efficiency

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Innovative engineering drives gains in efficiency

Sludge

Pressure exchanger

Heat exchanger

Trim heater +reactor

Filter 350°C

Product Separator

CO_2
Biocrude
Aqueous phase

Solids (phosphate and hydrochar)

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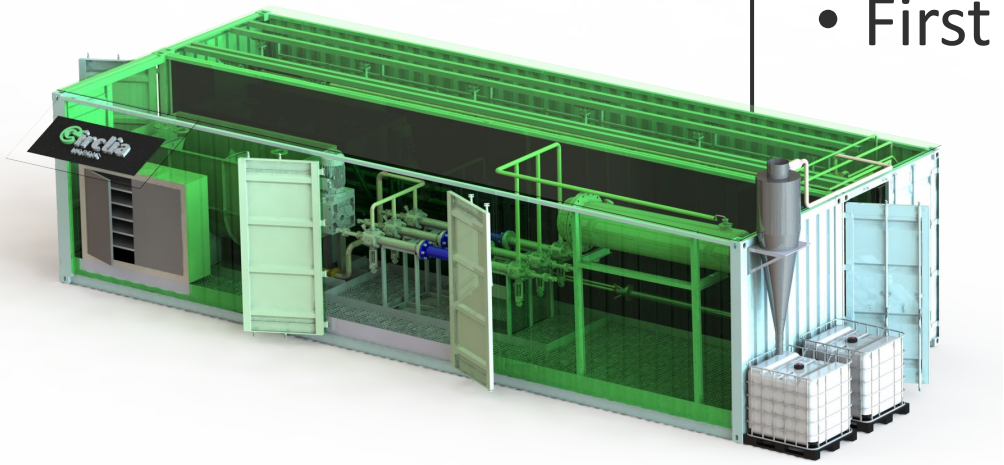
Our product

- Efficient, decentralized and modular units
- 25,000 wet ton/yr capacity (~15 dry ton/day)
- 1600-2000 ton/yr biocrude (30-38 BPD)
- Two 40' containers with 35’ x 80’ total footprint
- EROI: 7-8, >70% GHG reduction, €2 M base cost
- First unit under construction, more in pipeline



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Small is beautiful

- Conventional TEAs for biomass conversion specify 100, 1000, or 2000 dry ton/day to achieve economies of scale
- Small, modular processes scale by numbering up and have the following advantages:
  - Deployable to distributed biomass resources
  - Lower capital barrier to entry (try and see)
  - Faster design iteration and product refinement
  - Flexible capacity and resilience to upsets
  - Staggered maintenance cycles

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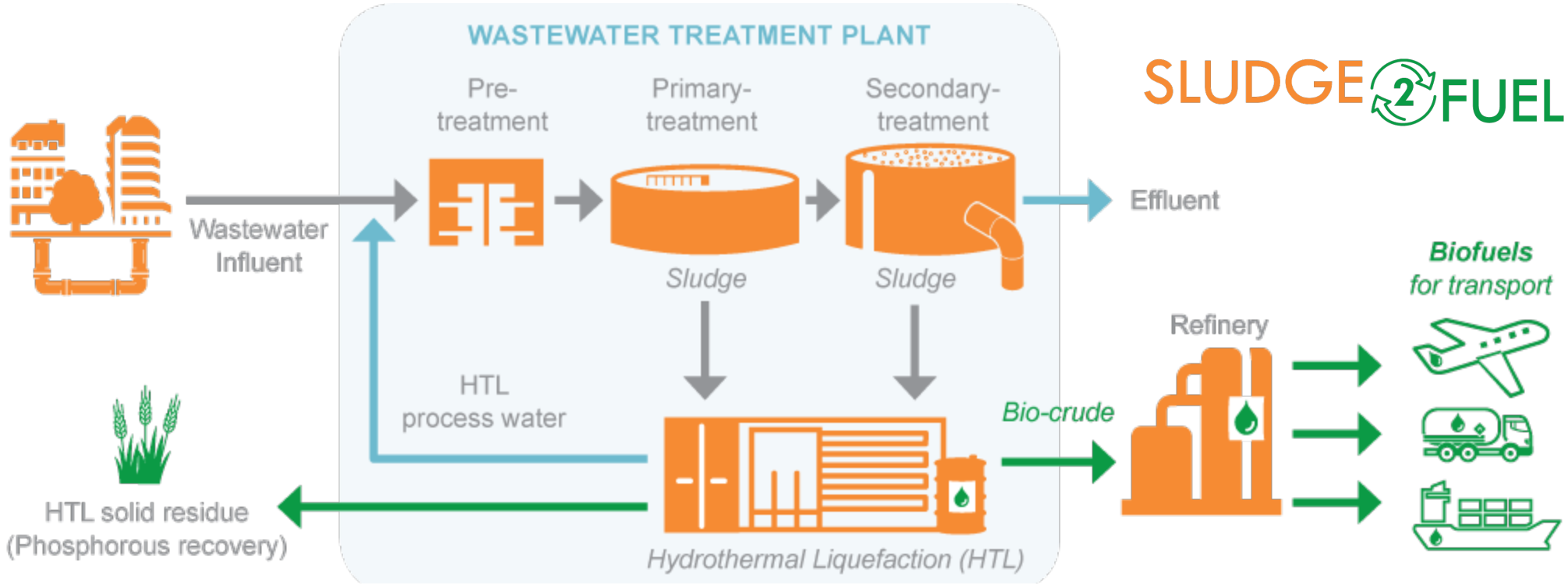
Sludge2fuel commercial demonstration

Funded by The Energy Technology and Demonstration Program (EUDP)



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Technical challenges and opportunities

- Process Water
  - Challenge: high COD requires treatment
  - Baseline: recycle to WWTP/WRRF, utilities lead
  - Future: partial wet oxidation
- Biocrude Upgrading and Utilization
  - Challenge: differs from petroleum crude
  - Baseline: refinery partners lead upgrading
- Phosphate from Solid Residue
  - Challenge: produced in mixed, wet slurry form
  - Baseline: separations, phosphate extraction
- Gas
  - Opportunity: 96% CO_2 stream for CCUS

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The road ahead

- Installation (Nov 2022) and integration of the first full-scale plant (Mar 2023) in Fredericia
- Deploy, deploy, deploy!
- Utilize the energy contained in the process water to achieve even higher energy efficiency
- Thank you!

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