Biofuel Generation via Hydrothermal Processing of Municipal Wastewater Sludge

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AECOM

NC STATE

I) Motivation

Current Disposal Methods
- Landfill, land application, incineration
- Requires decontamination & dewatering

Concerns
- Regulations & costs (controlling nutrients)
- Emerging contaminates (PFAS)
- Odor, public health & perception

Santa Rosa Water Agency Costs: 27,000 wet tons/year	Composting	Land Application	Landfill
Price per ton	$150	$29	$42

Hydrothermal Processing (HTP)
- High temperature and pressure converts biomass to usable fuels

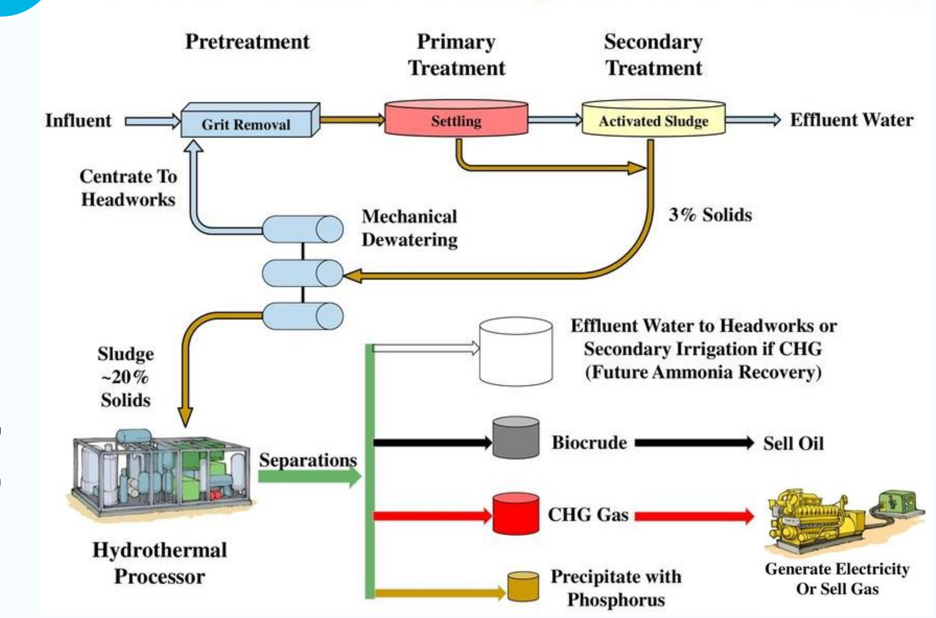
Benefits
- Solids management
- Low emission
- Resource recovery
- Fuel incentives

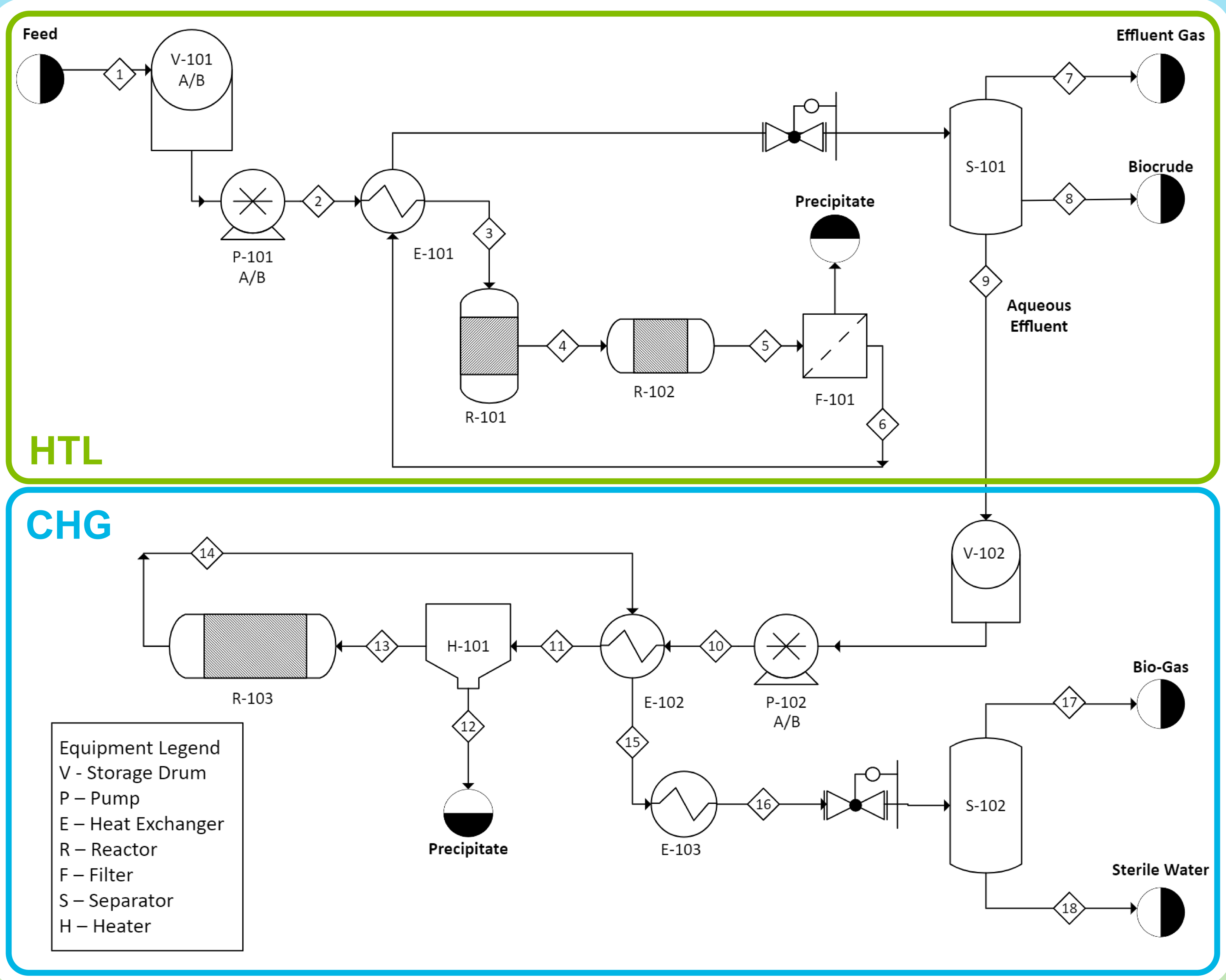
II) Goal

Scale up pilot HTP process for 10 dry tons/day wastewater sludge into sellable biocrude keeping in mind:

Economics, Application, Health, Safety, Pollutants & Contaminates, Practicality, and the Environment

WRRF Process Flow with Hydrothermal Processing





III) Process Design

Feed Mixture: 40:60 primary to secondary sludge and dewatered to 20wt% solids
Process Conditions (PC): 350°C and 2900psig
Assumptions In Heat: CHG feed is water, all sulfur is sulfate

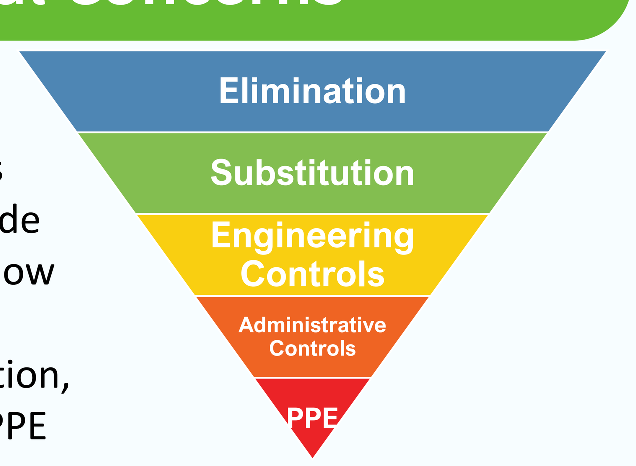
Property	Value	Units
Total Feed Mass Flowrate	96.464	Tonnes/day
Biocrude Mass Flowrate	3.363	Tonnes/day
Aqueous Phase Mass Flowrate	90.515	Tonnes/day
Biocrude Moisture	22.36%	Tonnes H2O/Tonnes Biocrude
Biocrude Ash Content	0.40%	Tonnes Ash/Tonnes Biocrude
Biocrude Yield	29.80%	Tonnes Biocrude/Tonnes Feed
HTL Mass Balance Value* *Including Gas and Solids production not in table	100.33%	
Biogas Mass Flowrate	0.487	Tonnes/day
Aqueous Phase Waste Mass Flowrate	90.028	Tonnes/day

Hydrothermal Liquefaction (HTL)
- Heat recycled in E-101 and R-101 is oil heated
- Water approaches critical point → hydrophobic compounds dissolve and inorganic salts precipitate

Catalytic Hydrothermal Gasification (CHG)
- Requires significant heating and cooling water
- Effluent water is cycled back into headworks
- Raney Nickel precedes Ruthenium-Graphite catalyst to prevent sulfur poisoning

IV) Safety, Health, and Environmental Concerns

Health & Safety
- Extreme Temperatures and Pressures
  - High safety factor
  - Personal protective equipment
  - Double containment and insulation
  - High-grade material of construction
- Sulfur Compounds
  - Hydrogen sulfide and sulfate at low concentration
  - Proper ventilation, controls, and PPE



High Nitrogen in CHG Aqueous Effluent
- Air stripping
- Agricultural discharge

High Sulfur Content in HTL gas Effluent
- Air mixing
- Scrubber (greener solution)
- Ion exchange

Solid Precipitate positive for Barium and Chromium
- Toxicity characteristic leaching procedure test

Polyfluoroalkyl Substances (PFAS)
- 99% destroyed
- Potassium hydroxide additive

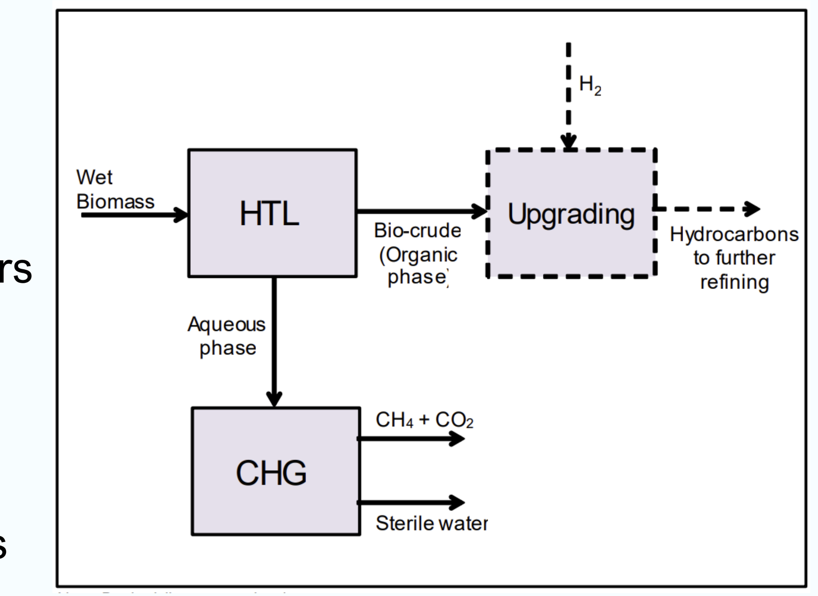
Siloxanes
- Not present in significant quantities to be concerned

V) Economics

Product Quality

Biocrude:
- Comparable to *#6 Fuel Oil*
  - Used for marine diesels and stationary generators
- Upgrade to remove O_2 and ammonia for use in internal combustion engines

CHG Gas:
- Used directly as natural gas

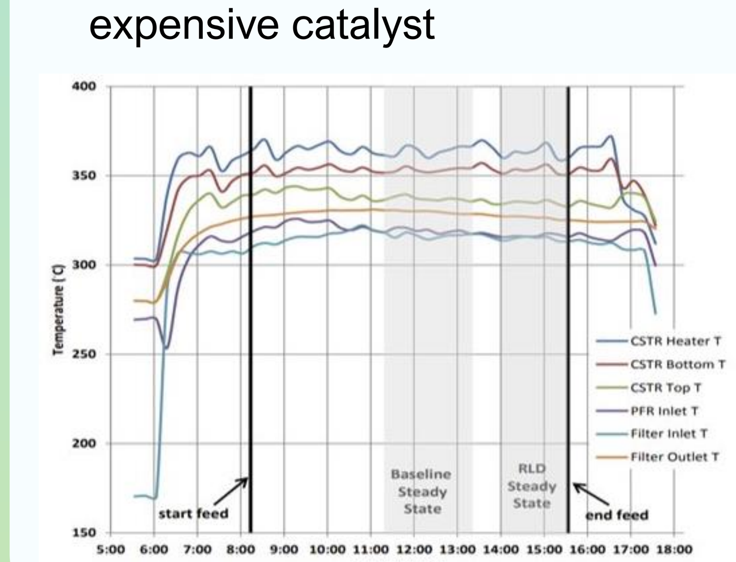


Item	Cost over 20 years
Fixed Capital Cost of Equipment	$250.8 Million
Cost of Operations Labor	$34.56 Million
Cost of Utilities	$448.85 Million
Cost of Waste Treatment	$408.13 Thousand
Cost of Raw Materials	$44.15 Million
Cost of Manufacture	$745.88 Million
HTL Biocrude Revenue	$12.59 Million
CHG Biogas Revenue	$0.50 Million

Economic Analysis
- Raney nickel and Ruthenium on graphite catalysts are responsible for most of the raw materials cost
  - Rainey-nickel: $34.21/kg
  - Ruthenium-graphite: $10,450/kg
- Plant requires 29 operators on staff

VI) Conclusions and Recommendations

Challenges
- Reaching and maintaining process conditions
- Not enough thermodynamic data for in-depth analysis
- Preventing sulfur poisoning in expensive catalyst



Recommendations
- Research thermodynamics of reactions and HTL organic phase
- Consider alternate uses of precipitate such as fertilizer from high N and P content
- Remove CHG process
  - Very costly with little economic return

VII) Acknowledgements

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Citations

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Lachos-Perez, D., César Torres-Mayanga, P., Abaide, E. R., Zabot, G. L., & De Castilhos, F. (2022). Hydrothermal carbonization and Liquefaction: differences, progress, challenges, and opportunities. *Bioresource Technology*, *343*, 126084. https://doi.org/10.1016/j.biortech.2021.126084
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