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Techno-Economic Comparison of Thermochemical Liquefaction Pathways for Producing Drop-In Biofuels from Microalgae Remnants

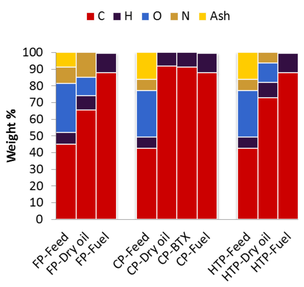
Introduction

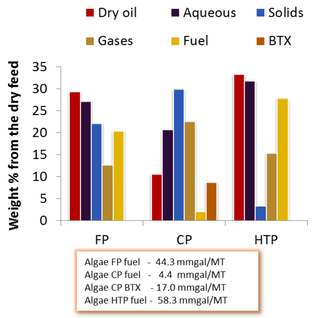
Fast growing microalgae are a potential source of lipids and renewable biofuels. Recent developments enable wet lipid extraction from algae providing protein-rich remnants. Algae remnants could be used in anaerobic digestion or animal feed but a potential exist for its conversion to drop-in biofuels. However, high moisture and nitrogen content are key challenges to this process. This study investigates fast pyrolysis (FP), catalytic pyrolysis (CP) and hydrothermal processing (HTP) as possible pathways for algae remnant biofuel production.

Base Case Assumptions

- 2000 (dry) MTPD of algae remnant is fed with a moisture content of 80 wt.%.
- For pyrolysis and catalytic pyrolysis process base cases, algae remnant is dewatered thermally to 10 wt.% moisture content followed by grinding to 2mm particle size.
- For hydrothermal processing (HTP), the algae remnant is fed to the HTP reactor as received (wet).

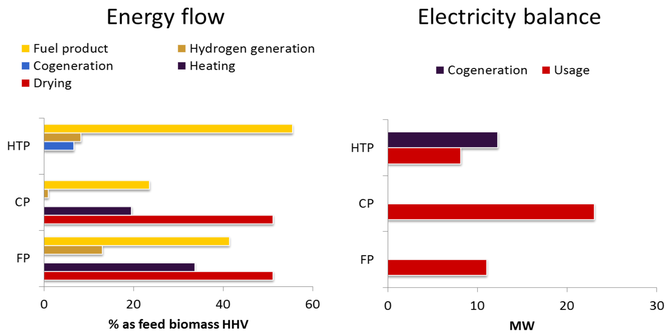
Material Balance Summary





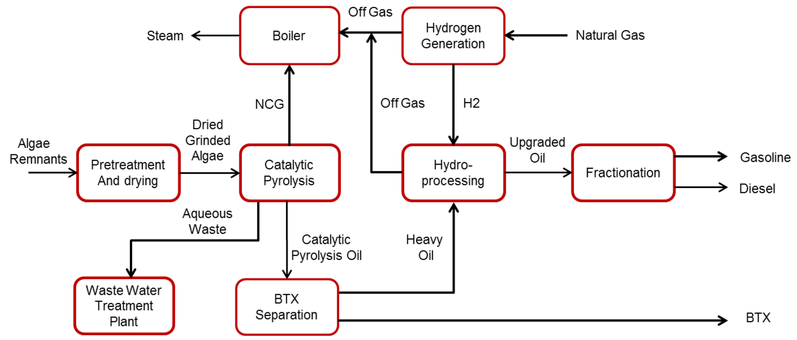
- Yields and CHN analysis results for dry oil and solids obtained from CSET experiments and published work
- CP dry oil nitrogen level is negligible

Energy Comparison of Pathways

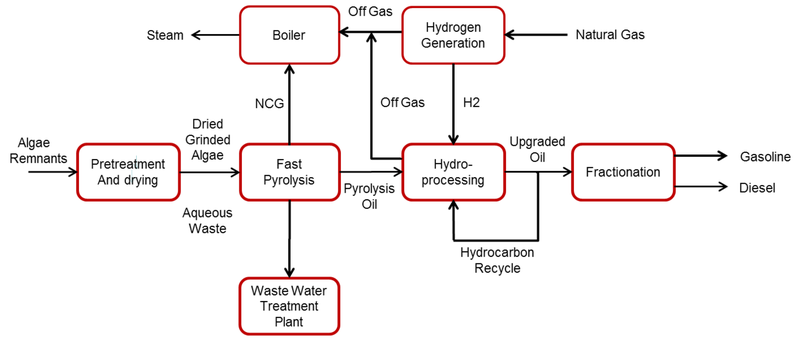


- Drying energy excludes sensible heat of drying air

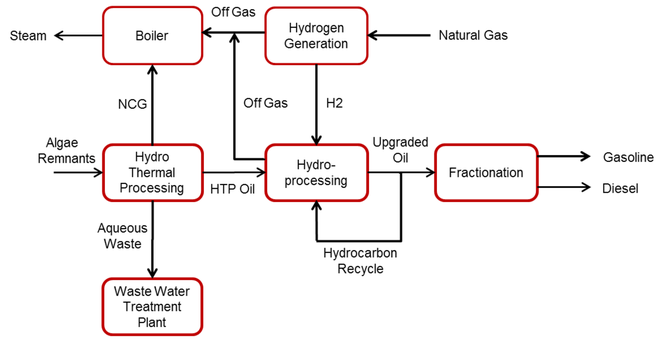
Process Block Diagram for Catalytic Pyrolysis



Process Block Diagram for Fast Pyrolysis



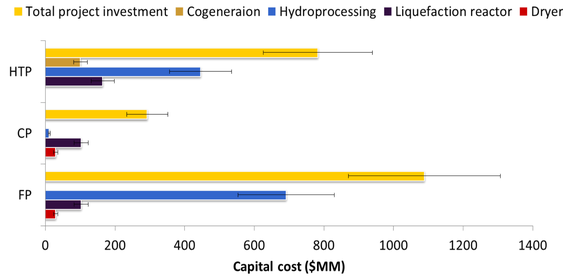
Process Block Diagram for Hydrothermal Processing



Key Process Assumptions

- Natural gas reforming provides 4.82, 1.27, and 3.51 wt. % hydrogen input in the FP, CP, and HTP scenarios.
- Upgraded hydrocarbons are recycled at a sufficient rate to dilute nitrogen containing feed streams to a nitrogen concentration of 5000 ppm prior to hydroprocessing.
- Benzene, toluene and xylene (BTX) mixture are separated from the catalytic pyrolysis oil before heavy ends are upgraded.
- Hydroprocessing upgrades the intermediate oil into gasoline and diesel fuels of similar composition.

Capital Cost Comparison Among Pathways



•Diluting the feed streams in hydroprocessing increases the capital cost significantly in both the pyrolysis and HTP processes

Contributions to Minimum Fuel Selling Price (MFSP)

* All cost are in 2011 US dollars
* Financial costs include the cost of capital depreciation, income tax and rate of return for the investment
* Algae remnant cost estimated to be equal to market price of wet distillers' grains and solubles (WDGS) in 2011 ($66/MT)
* BTX is priced at the gasoline value

Conclusions

- Fast pyrolysis had the highest capital costs due to need for extensive hydroprocessing of the high-nitrogen bio-oil.
- Catalytic pyrolysis had the lowest capital costs because product upgrading requirement was minimum.
- Hydrothermal processing had the lowest MFSP, primarily because of the absence of feedstock drying and higher yields than the other pathways.
- Fast pyrolysis had the highest MFSP, primarily due to the high financing costs for the capital equipment

Key References

- Wang K, Brown RC, Homsy S, Martinez L, Sidhu SS. Fast pyrolysis of microalgae remnants in a fluidized bed reactor for bio-oil and biochar production. Bioresour Technol. 2013;127:494-9. Epub 2012/10/17.
- Wang K, Brown RC. Catalytic pyrolysis of microalgae for production of aromatics and ammonia. Green Chemistry. 2013.
- Valdez PJ, Dickinson JG, Savage PE. Characterization of Product Fractions from Hydrothermal Liquefaction of Nannochloropsissp. and the Influence of Solvents. Energy & Fuels. 2011;25(7):3235-43.

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*MTPD: Metric Tonnes Per Day