Analysis of Sustainable Aviation Fuel Efficacy Using Alternative Syngas Conditioning Methods

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Sustainable Aviation Fuel (SAF) provides an effective way to meet the increasing demands of the aviation industry and optimize energy efficiency, carbon neutrality, and overall cost.

Syngas Conditioning

To convert unconditioned syngas to SAF with high selectivity, it must first be treated to increase its H_2:CO ratio. An overview of three viable H_2 addition methods are given below.

Steam-Methane Reformation

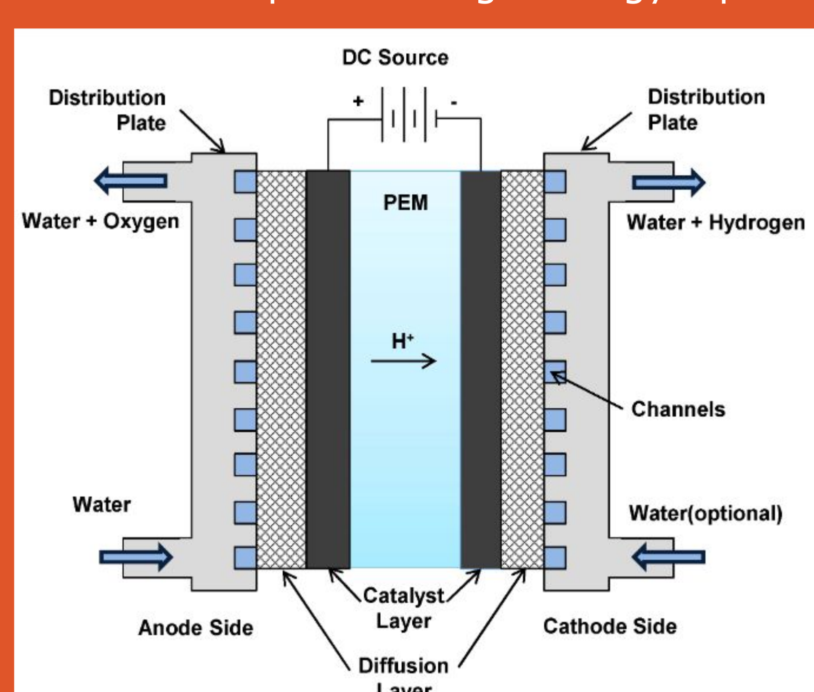
$$CH_4 + H_2O \rightarrow CO + 3H_2$$

Steam-methane reforming is the production of H_2 using natural gas under a Ni catalyst. This process is the most cost-effective but the least sustainable. To combat this unsustainability the CO_2 emitted will be captured and stored.

PEM Electrolysis

$$2H_2O_{(l)} \rightarrow O_2 + 2H_2$$

Electrolysis is the splitting of water into H_2 and O_2 using a circuit to facilitate charge transfer. The figure below shows a polymer electrolyte membrane (PEM) electrolyzer. This is a carbon-free method of H_2 addition, but is more expensive and requires a large energy input.

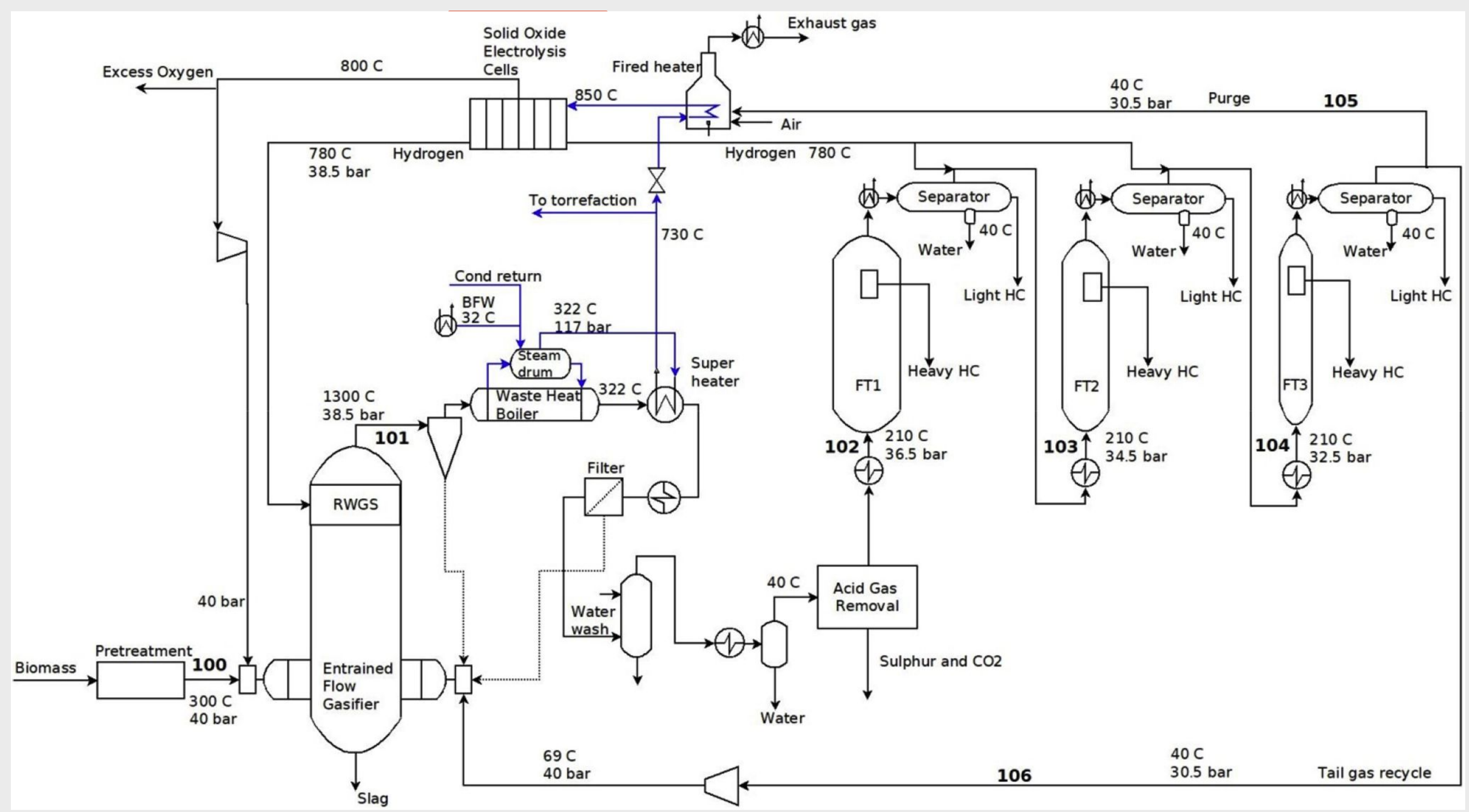


Sood, S.; Prakash, O.; Boukerdja, M.; Dieulot, J.-Y.; Ould-Bouamama, B.; Bressel, M.; Gehin, A.-L. Generic Dynamical Model of PEM Electrolyser under Intermittent Sources. *Energies* 2020, *13*, 6556.

Water-Gas Shift (WGS)

$$CO + H_2O \rightarrow CO_2 + H_2$$

The unconditioned syngas can be treated with H_2O under an iron catalyst to produce H_2. This acts as an extra gasification step and removes the need to source H_2 externally. However, additional CO_2 is emitted and must be separated from the syngas prior to FT synthesis.



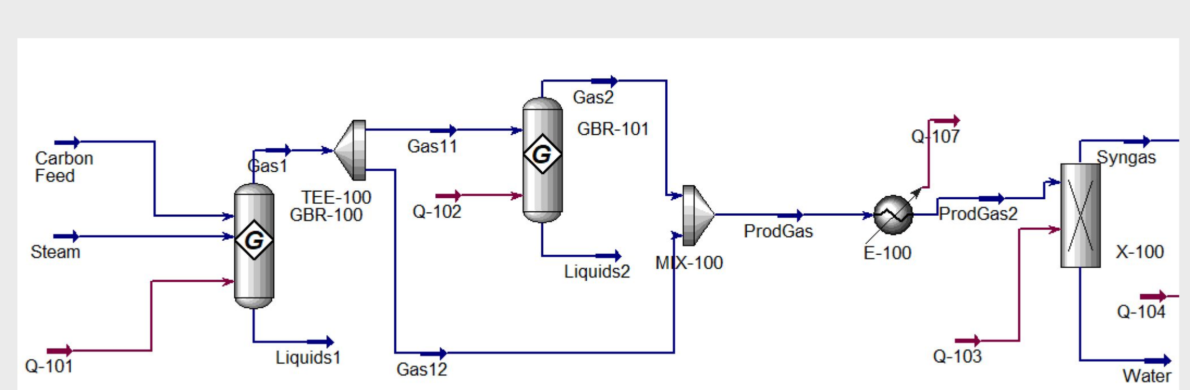
Ostadi, M.; Rytter, E.; Hillestad, M. Boosting Carbon Efficiency of the Biomass to Liquid Process with Hydrogen from Power: The Effect of H2/CO Ratio to the Fischer-Tropsch Reactors on the Production and Power Consumption. *Biomass Bioenergy* 2019, *127*, 105282. https://doi.org/10.1016/j.biombioe.2019.105282

Biomass Gasification

$$(CH_2O)_{n\ (s)} \rightarrow nCO + nH_2$$

The design goal is to produce SAF with an emissions coefficient of **45 g CO_2e per MJ**. The biomass first undergoes gasification at high temperature (800 ℃) and is converted to CO and H_2 in the presence of O_2. This gas mixture is called "syngas"; the yield depends on feed composition, catalyst, and reactor conditions.

The figure below depicts the team's preliminary design for the biomass gasification process.



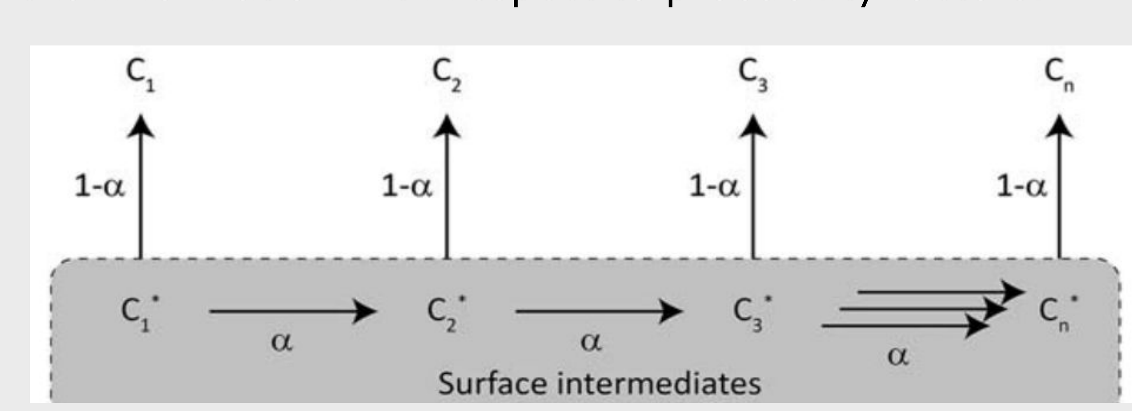
Fischer-Tropsch Synthesis

$$(2n)H_2 + nCO \rightarrow C_nH_{2n} + nH_2O$$

$$(2n+1)H_2 + nCO \rightarrow C_nH_{2n+2} + nH_2O$$

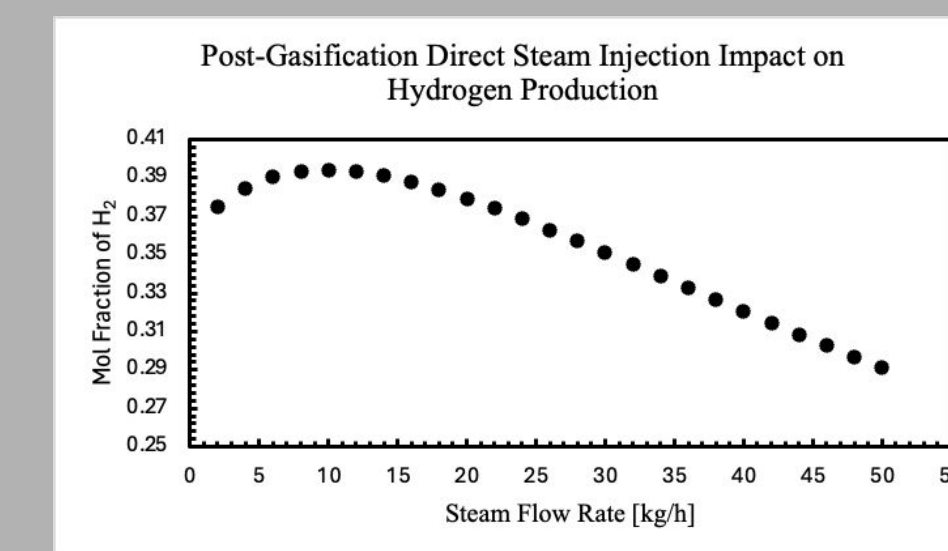
FT synthesis is the conversion of syngas into a range of hydrocarbon products, including olefins, paraffins, and oxygenates using iron- or cobalt-based catalysts.

The process involves a polymerization reaction of stepwise coupling of C_1 monomeric units generated in situ from CO and H_2. The figure below shows carbon chain formation with respect to probability factors.

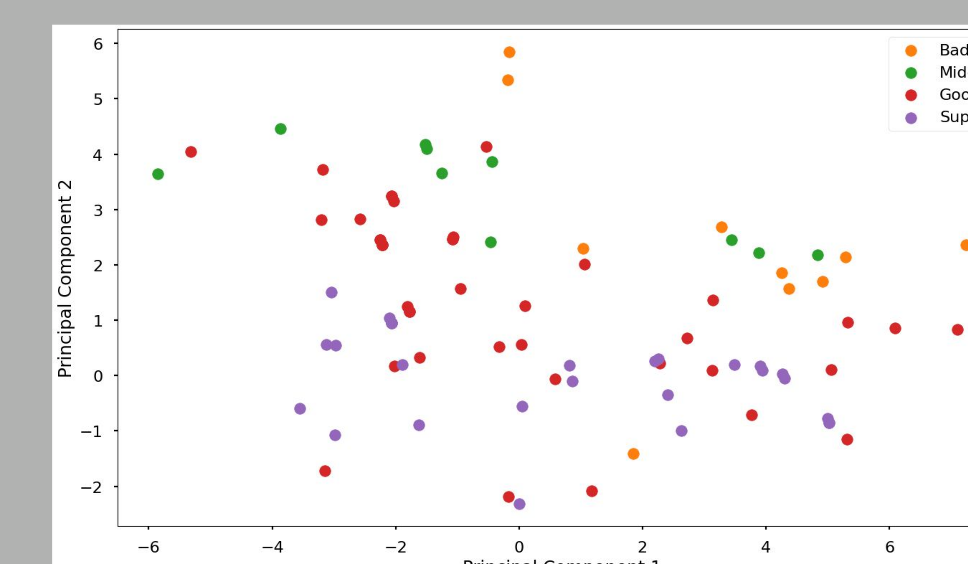


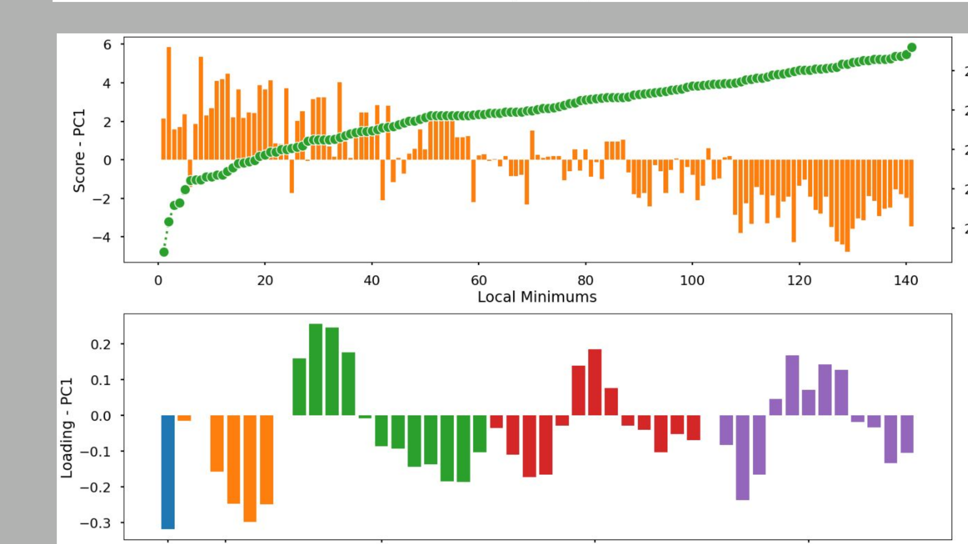
Sensitivity Analysis

For WGS, steam flow rate is varied to observe its effect on H_2 production and syngas composition. Ultimately, the more H_2 that is produced, the more valuable final product obtained. Adding 10 kg/hr of steam at 200 °C results in maximum H_2 production.



Additionally, the PCA below studies variation across reflux ratio, intermediate location/draw, gasoline location/draw, temperature, catalyst type, and feed composition.





Future Work

- Economic analysis of overall design for each of the hydrogen addition methods
- Analysis of biomass composition to increase process selectivity and efficiency
- Catalyst optimization for gasification, steam-methane reformation, WGS, and FT synthesis
- Carbon sequestration methods for process emissions (e.g., storing as a carbonate)

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