

Project 80

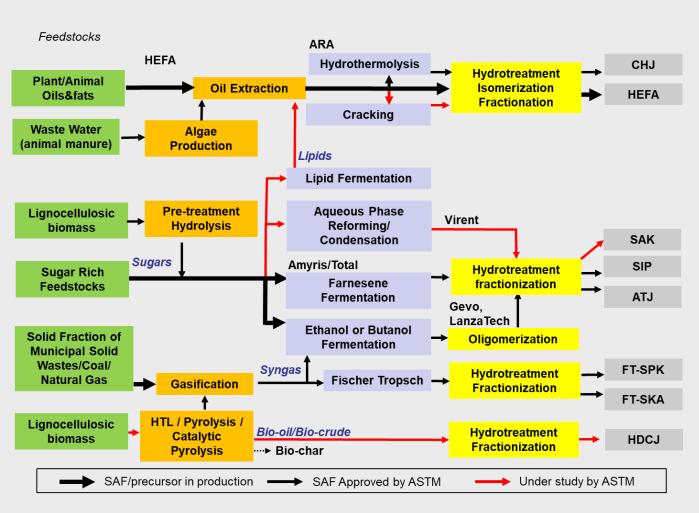
Hydrogen and Power-to-Liquid Concepts for Sustainable Aviation Fuel Production



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Motivation and Objectives

- Hydrogen is a limiting factor in sustainable aviation fuel (SAF) production
- Liquid fuel is 15% hydrogen by mass, while biomass ranges from 6-10%
- Most approved SAF processes involve a hydrotreatment step



- Hydrogen increases fuel yields, but incurs significant environmental and economic costs
- We explore these effects through minimum selling price (MSP), carbon intensity (CI), and abatement costs (AC) of both hydrogen and SAF

Methods and Materials

Hydrogen and SAF Technologies

- Seven hydrogen technologies were tested: water electrolysis (WE), methane pyrolysis (MP), autothermal reforming (ATRM), partial oxidation of methane (POM), dry methane reforming (DMR), steam methane reforming (SMR), and biomass gasification (BG).
 - Electrolysis and gasification generate hydrogen from renewable power and biomass. The rest consume natural gas
- Six SAF technologies were: power-to-liquid (PtL), Hydrogenenhanced gasification Fischer-Tropsch (H-GFT), pyrolysishydrotreatment (PH), Alcohol-to-jet (ATJ), gasification Fischer-Tropsch (GFT), and hydrotreated esters and fatty acids (HEFA).
 - Ptl and HEFA consume waste CO₂ and greases. The rest consume cellulosic biomass.
 - GFT consumes no external hydrogen

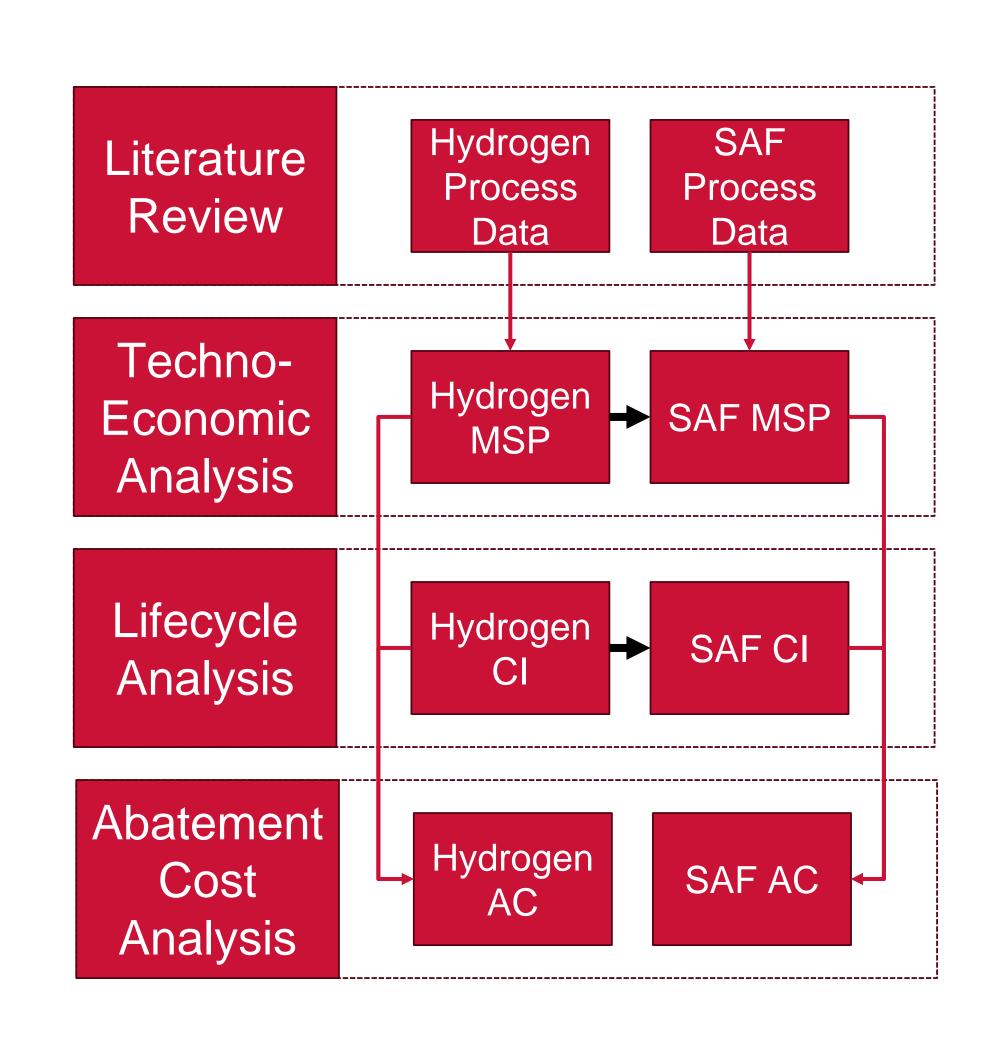
$$AC(\$/_{tCO_2}) = \frac{MSP_{prod} - SP_{fos}}{CI_{prod} - CI_{fos}}$$

Process Metrics

- MSP measures the break-even price at which a plant can sell fuel or hydrogen
- CI measures the emissions of a product in terms of grams CO₂ equivalent per functional unit. This is measured per kg of hydrogen or megajoule of liquid fuel
- AC measures how efficiently a given fuel or product reduces emissions. It attributes any cost increase to emissions reduction, and is measured in \$/tonne of CO₂

Summary

- Hydrogen is a key resource for SAF production
- Various hydrogen technologies were analyzed to determine their costs and emissions
- Results for these hydrogen technologies were then used to determine their effect on SAF processes using them as hydrogen sources

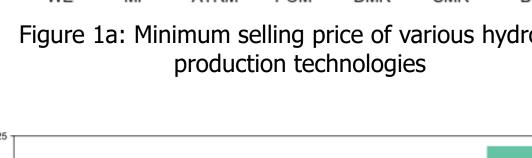


- Electrolytic hydrogen has the highest cost, but greatest emissions abatement potential
- Improvements in hydrogen technologies favor hydrogen-intensive SAF technologies such as pyrolysis and PtL over independent technologies like GFT or ATJ
- Improvements in hydrogen technologies do not significantly benefit SAF from cellulosic biomass or lipids, but will make or break SAF produced from CO₂ (PTL)

Results and Discussion

Hydrogen

- Most fossil hydrogen sources (MP, ATRM, POM, and SMR) offer low cost and high CI (Fig. 1a and
- Renewable hydrogen (AWE, BG) achieves higher cost and lower emissions (Fig. 1a and b)
- Electrolytic hydrogen achieves lowest abatement costs (Fig.



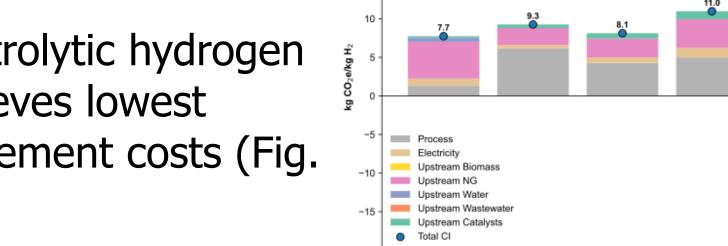
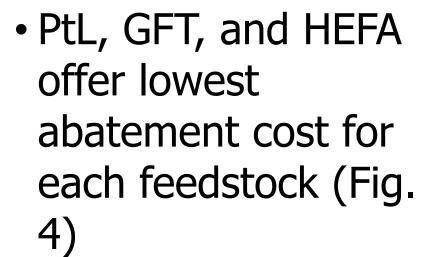


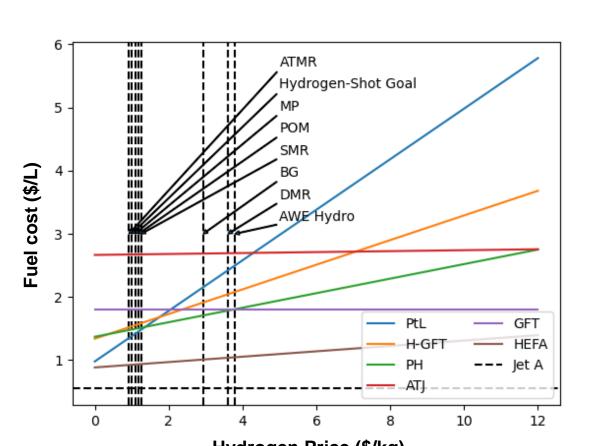
Figure 1b: CI of various hydrogen production

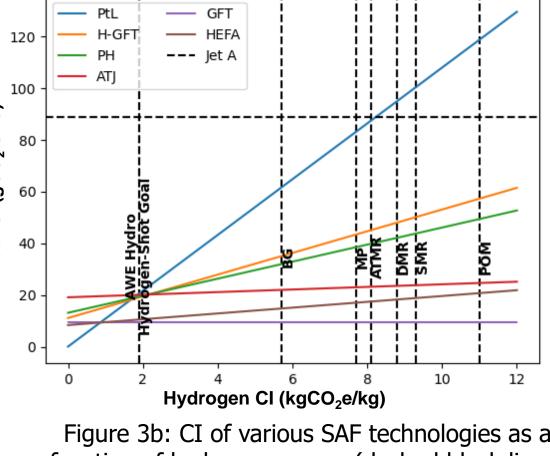
SAF

 Hydrogen-intensive processes (PtL, PH) benefit most from hydrogen improvements (Fig. 3a and b)

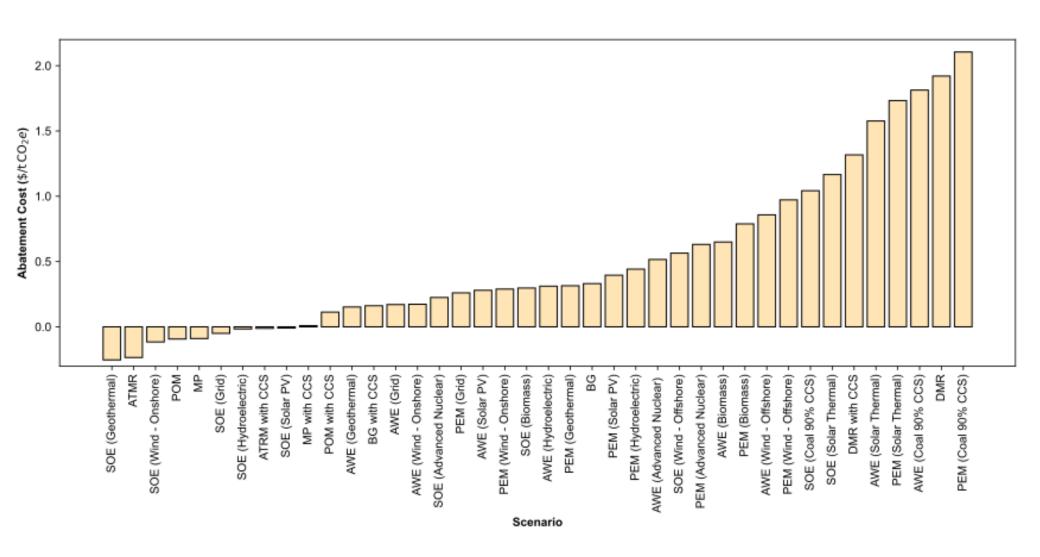


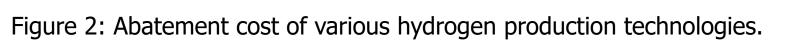
 Electrolytic hydrogen offers similar abatement cost to fossil hydrogen in SAF production (Fig. 4)

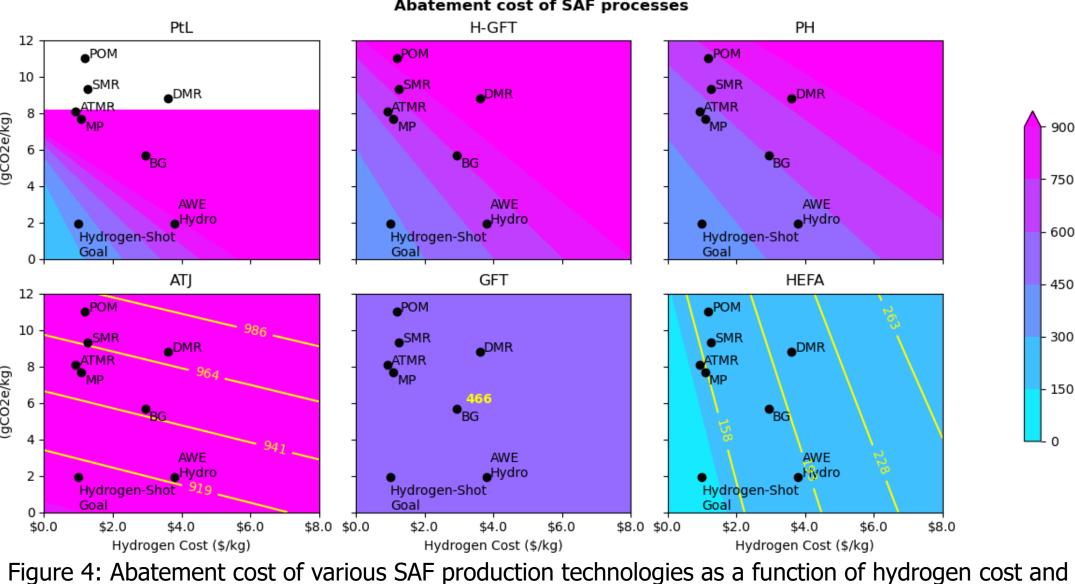




function of hydrogen source (dashed black lines)







CI. Black dots indicate previously evaluated hydrogen sources.

Conclusions and Next Steps

Hydrogen

- Conventional reforming technologies such as SMR and ATRM remain the most cost-competitive
 - This comes at the cost of high CI
- Preliminary CCS results indicate possible improvement
- Renewable hydrogen (BG, AWE) remains expensive unless supported by cheap feedstocks, low-carbon electricity, or co-product revenues
- Strong policy incentives are essential to make lowcarbon hydrogen competitive

SAF

- PtL shows the most improvement with electrolytic hydrogen
 - Viability possible with hydrogen improvements
- GFT performs best for cellulosic SAF
 - Hydrogen improvements may favor pyrolysis
- Current hydrogen production technologies do not favor its inclusion in SAF
 - Future work will explore integration of hydrogen production into SAF processes

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