Project 080(A) Hydrogen and Power-to-Liquid Concepts for Sustainable Aviation Fuel Production

Washington State University

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- P.I.s: Prof. Manuel Garcia-Perez, Prof. Michael P. Wolcott
- FAA Award Number: 13-C-AJFE-WaSU-031
- Period of Performance: October 1, 2023, to September 30, 2024
- Tasks:
    1. Evaluate the strengths and weaknesses of hydrogen production and power-to-liquid (PtL) concepts in the United States
    2. Co-location and incorporation of hydrogen technologies into existing sustainable aviation fuel (SAF) production and infrastructure
    3. Evolution of SAF production pathways to integrate alternative hydrogen and carbon sources

Project Funding Level

The ASCENT Project 080 received $450,000 in Federal Aviation Administration (FAA) funding and $450,000 in matching funds. State-committed graduate school contributions for PhD students and faculty time for Michael Wolcott, Manuel Garcia-Perez, Xiao Zhang, and Su Ha contribute to the cost share. WSU funding is reported for this reporting period.

Investigation Team

Washington State University

Prof. Manuel Garcia-Perez (P.I.), Tasks 1, 2, 3, and 4
Prof. Michael P. Wolcott (P.I.), Tasks 1, 2, 3, and 4
Prof. Xiao Zhang (Co-PI), Tasks 3 and 4
Prof. Su Ha (Co-PI), Tasks 1, 3, and 4
Dr. Jonathan Male (Co-P.I.), Tasks 1, 2, 3, and 4
Kristin Brandt (adjoint faculty), Tasks 1, 2, and 3
Aidan Garcia (research associate), Tasks 2 and 3
Valentina Sierra (graduate research assistant/post doctoral fellow), Tasks 1 and 2
Brandon Lewis (graduate research assistant) Task 3

Collaborating Researchers

Corinne Drennan, Pacific Northwest National Laboratory (PNNL)

Project Overview

The aviation industry is under pressure to reduce its greenhouse gas (GHG) emissions. SAFs are considered a promising approach for achieving the sector's GHG emissions reduction targets. To date, no comprehensive assessment exists for analyzing how different carbon, hydrogen, and energy sources can be combined with different conversion processes to produce SAF with high GHG emission reductions and low costs. The goals of this project are to (a) evaluate the strengths and weaknesses of hydrogen production concepts, (b) assess the cost and environmental impacts of these hydrogen sources on existing SAF technologies (c) synthesize this information to guide the development of new technologies using novel hydrogen and energy sources, and (d) assess how hydrogen can be utilized more efficiently within SAF synthesis and hydrotreatment. This research will enable the identification of new pathways to optimize SAF production for maximum GHG reductions with minimal fuel costs.

Approved SAF pathways commonly use photosynthesis-derived carbon from sugars, lignocellulosic materials, or lipids. Some SAF technologies that are currently being investigated include those based on hydro-processed ester and fatty acid synthetic paraffinic kerosene (HEFA-SPK), Fischer–Tropsch (FT) synthetic paraffinic kerosene (FT-SPK), Fischer–Tropsch synthetic kerosene with aromatics (FT-SKA), synthesized iso-paraffins (SIP), Virent® BioForming synthesized aromatic kerosene, hydrodeoxygenation synthesized kerosene, catalytic hydro-thermolysis, alcohol-to-jet (ATJ) fuel, hydropyrolysis (Shell® IH2®), fast pyrolysis, and hydro-processed depolymerized cellulosic jet fuel. The jet fuels produced from eight paths (FT-SPK, HEFA-SPK, SIP, FT-SKA, ATJ, catalytic hydro-thermolysis, and HEFA) (ASTM International, 2024a) and by co-processing lipids and FT biocrude in refineries (ASTM International, 2024b) are now approved by ASTM International (formerly known as the American Society for Testing Materials) for use in commercial aircraft. Although these processes can result in substantial GHG reductions, their production costs are still substantially higher than those of conventional jet fuels derived from petroleum distillation ($0.88–$3.86/L) (Tanzil et al., 2021).

Previous studies have shown that the quality of the carbon source determines the SAF yield. Although lignocellulosic materials are ten times cheaper than lipids (on a mass basis), the latter's quality as a carbon source makes triglyceride-derived fuels much cheaper (two to five times) than those derived from cellulose, hemicellulose, or lignin (Tanzil et al., 2021). Carbon in organic matrices containing a higher level of oxygen, nitrogen, and sulfur is more challenging to convert to jet fuel because of the penalties associated with the removal of oxygen, nitrogen, and sulfur, a process that typically consumes hydrogen. Carbon in polymeric molecules is also more challenging to convert to jet fuel because it requires costly molecular weight reduction technologies and often lacks selectivity to the targeted jet fuel cut. Carbon in the form of aliphatic molecules can be more easily converted to jet fuel than carbon as aromatics, which have a higher tendency to form coke. Carbon sources such as carbon dioxide (CO_2), biomass, coal, petroleum, and municipal solid waste (MSW) must be thoroughly investigated as feedstocks for SAF production. Because carbon is the most abundant element in jet fuel, high fuel yields can only be achieved in processes with high carbon conversion efficiencies.

Most technologies that produce SAF consumed large amounts of hydrogen, ranging from 2 mass percent of the fuel produced for ATJ (Snowden-Swan et al., 2017) to 11-12 mass percent for pyrolysis (Brandt et al., 2022). Although hydrogen can currently be produced using clean electricity from wind and solar farms, most hydrogen is currently produced through steam methane reforming (SMR) (which is associated with significant CO_2 emissions) due to its low production cost. Commonly considered paths for hydrogen production include (a) steam and dry reforming, partial oxidation or electrochemical reforming of (oxygenated) hydrocarbons, (b) low-temperature water electrolysis, (c) plasma arc decomposition, (d) water thermolysis, (e) thermochemical water splitting, (f) thermochemical conversion of biomass (biomass gasification and biofuel reforming), (g) photovoltaic electrolysis, photocatalysis, and photochemical methods, (h) dark fermentation, (i) high-temperature water electrolysis, (j) hybrid thermochemical cycles, (k) coal and petroleum gasification, (l) MSW gasification, (m) fossil fuel reforming, (n) biophotolysis and photo-fermentation, (o) artificial photosynthesis, and (p) photo-electrolysis (Dincer & Acar, 2015). One goal of this project is to evaluate the strengths and

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weaknesses of hydrogen production concepts, determine how they can be integrated with existing infrastructure to produce cheap green hydrogen, and identify the potential impact of these technologies in producing SAF.

In some biomass and waste conversion processes, CO_2 and methane (CH_4) are produced as a side product or as the starting material. To meet SAF specifications, hydrogen will be needed to hydrogenate alkenes and hydrotreat oxygenates. Utilizing waste CO_2 and CH_4 can increase the amount of carbon obtained from resources in the SAF while reducing emissions. This can be done in conjunction with hydrogen production with a lower carbon intensity. Our analysis will examine the trade-offs between enhanced carbon utilization, the effects of increased renewable energy use, the need for stability in the grid and energy storage, access to lower-carbon-intensity (or even the carbon negative) hydrogen against positive impacts on environmental indicators, the cost impact of such changes, and technology uncertainty in emerging science and engineering.

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Task 1 - Evaluate the Strengths and Weaknesses of Hydrogen and PtL Concepts in the United States

Washington State University

Objectives

The objective of this task is to perform a literature review and develop design cases for hydrogen and PtL concepts.

Research Approach

In this task, the ASCENT Project 080 team will identify areas that require more research and development to reduce technology uncertainty. Specifically, our team analyzed six technologies for hydrogen production: (a) steam reforming, (b) dry reforming, (c) water electrolysis, (d) gasification of carbonaceous materials (biomass, coal, bitumen, and MSW) (with steam and CO_2), (e) thermal decomposition of hydrocarbons (methane pyrolysis with capture and use of solid carbon), and (f) fossil fuel reforming. This task is being conducted by WSU and PNNL and started during 2022. The main goal of this task is to build design cases for each of these hydrogen production technologies (i.e., mass and energy balances, and techno-economic analyses [TEA]) and identify the strengths and weaknesses of each technology studied. A team of hydrogen production experts from WSU and PNNL meets monthly with a PhD student and post-doctoral associate from WSU to guide them in the literature review and in the creation of a road map for constructing design cases and identifying the opportunities and challenges for each of the technologies studied.

Milestones

- Completed a literature review for hydrogen production within the context of SAF technologies.
- Developed design cases of standalone hydrogen production technologies.
- Obtained minimum selling price, carbon intensity (CI), and abatement cost (AC) results for all hydrogen technology design cases.

Major Accomplishments

- Completed a literature review on the TEAs of hydrogen production technologies (low and high-pressure gasification, steam reforming, methane partial oxidation, autothermal oxidation, methane pyrolysis, and low- and high-temperature water electrolysis). Figure 1 summarizes the environmental and economic performance of all hydrogen technologies examined, except for electrolytic hydrogen. Electrolysis is sensitive to the cost and CI of power available, which is explored more fully in the submitted manuscript.

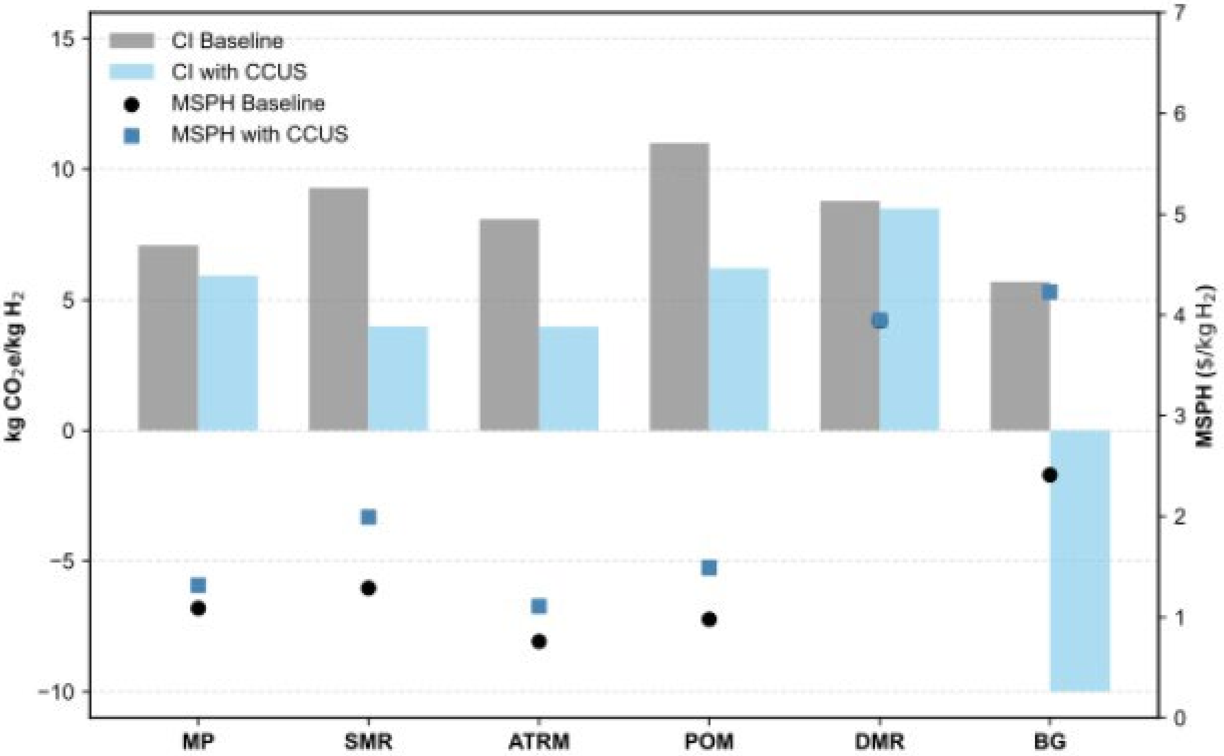

Figure 1. Minimum selling price and CI of representative hydrogen technologies. CI: carbon intensity; CCUS: carbon capture, utilization, and storage; MSPH: minimum selling price of hydrogen.

- Developed standardized design cases to estimate hydrogen production costs for each of the technologies studied. These cases will provide a harmonized set of process models, TEA, and lifecycle analysis (LCA) results for future studies utilizing hydrogen from various sources, and they have already proved useful as reference values for Tasks 2 and 3.
- Expanded TEAs to include monetary policy, including support from the Inflation Reduction Act that was modified in the One Big Beautiful Bill Act. Specifically, the credits for the production of clean hydrogen (45V) and the credit for CO_2 capture and sequestration (45Q).
- Updated the methodology for our TEA to a cost of equity (COE) model during this project. This methodology represents a more realistic assessment of the risk and profits assumed by investors.

Publication

Peer-Reviewed Journal Publication

Sierra, V., Wolcott, M., Zhang, X., Ha, S., Male, J., Garcia, A., Brandt, K., Garcia-Perez, M., Drennan, C., & Holladay, J. (Under review). *Evaluating Hydrogen Production Through Techno-Economic, Carbon Intensity, and Policy Perspectives in the U.S.* Pending submission.

Presentations

Sierra-Jimenez, V., Brandt, K., Wolcott, M., Male, J., Garcia-Perez, M. (2024, November 20-21). *Hydrogen Production Techno-economic and Carbon Intensity Insights for a Sustainable Energy Transition in the U.S.* [Poster presentation]. Re+CHARGE H_2 Conference (PNWH2 Hub), Seattle, Washington.

Garcia, A., Sierra-Jimenez, V., Garcia-Perez, M. (2025, October 15) *Hydrogen and Power-to-Liquid Concepts for Sustainable Aviation Fuel Production* [Poster presentation]. ASCENT 2025 Fall Meeting, Alexandria, Virginia.

Outreach Efforts

- Presented results at the ASCENT 2025 Fall Meeting in Alexandria, Virginia.

Student Involvement

Valentina Sierra, a graduate student majoring in biological systems engineering at WSU, performed the literature review of hydrogen production technologies and the role that hydrogen has in SAF production. Sierra has graduated and is continuing work on this project as a post doctoral fellow.

Plans for Next Period

- Publish the revised hydrogen production manuscript and the standardized TEAs.

Task 2 – Evaluate the Effect of Emerging Hydrogen Sources on Existing SAF Production Technologies

Washington State University

Objective

The goal of this task is to estimate the cost and emissions-reduction potential of different hydrogen sources for SAF production. A harmonized set of techno-economic and lifecycle assessments will determine the minimum selling price (MSP) and CI of different SAF technologies as a function of hydrogen cost and CI. While LCA and TEA do exist for these SAF technologies, their assumed source of hydrogen varies between studies and is usually fixed (De Jong et al., 2017; Tanzil et al., 2021). Harmonized abatement cost data will allow stakeholders to make better decisions about which SAF technologies will benefit from investments in hydrogen technical improvements or infrastructure. It will also indicate which SAF technologies reduce emissions most effectively when paired with a given hydrogen technology.

Research Approach

In this task, the ASCENT Project 080 team will use hydrogen cost and CI data from Task 1 to determine their effect on existing SAF technologies - namely power-to-liquid (PtL), HEFA, pyrolysis-hydrotreatment (PH), ATJ, and gasification Fischer-Tröpsch (GFT). Each of these technologies will be evaluated by TEA and LCA to determine minimum selling prices and CIs of the resultant fuels. Abatement costs will be compared within individual technologies to determine the benefits of hydrogen technical improvements, while comparison of abatement cost between technologies will determine which are most effective under various hydrogen costs and CIs.

Milestones

- Developed a gasification TEA that allows the purchase of supplemental hydrogen and production of power.
- Conducted lifecycle assessments of technologies listed above as a function of hydrogen CI.
- Classified all processes analyzed according to the fraction of biomass oxygen they remove in the form of water (to link them with our stoichiometric models in Task 3).

Major Accomplishments

We have compiled the results above into a first draft on the effect of hydrogen sources on SAF technologies. Figure 2 shows the range of abatement costs achieved by six SAF technologies under a range of hydrogen costs and CIs. Notably, the abatement cost of HEFA is lowest with fossil hydrogen sources. PtL achieves a distinct abatement cost optimum with electrolytic hydrogen, which is expected given its exorbitant hydrogen consumption. The remaining stover-consuming technologies are relatively insensitive to the hydrogen source. Despite individual technologies being insensitive to hydrogen price, differing hydrogen cost and CI may still favor one or the other, with key implications for which SAF technologies will perform best with a given hydrogen source. Figure 3 illustrates a composite abatement cost of all stover-consuming SAF technologies, constructed by selecting the technology of lowest abatement cost for each combination of hydrogen cost and CI. This reveals the SAF technology favored by each hydrogen technology, all of which fall within the region for which gasification Fischer-Tropsch is the optimal technology. This indicates that current and emerging hydrogen technologies still favor the use of hydrogen-independent SAF production for carbon abatement, despite its low yields and high fuel cost. However, projections for hydrogen cost may favor pyrolysis-hydrotreatment. These results are explained further in our forthcoming manuscript.

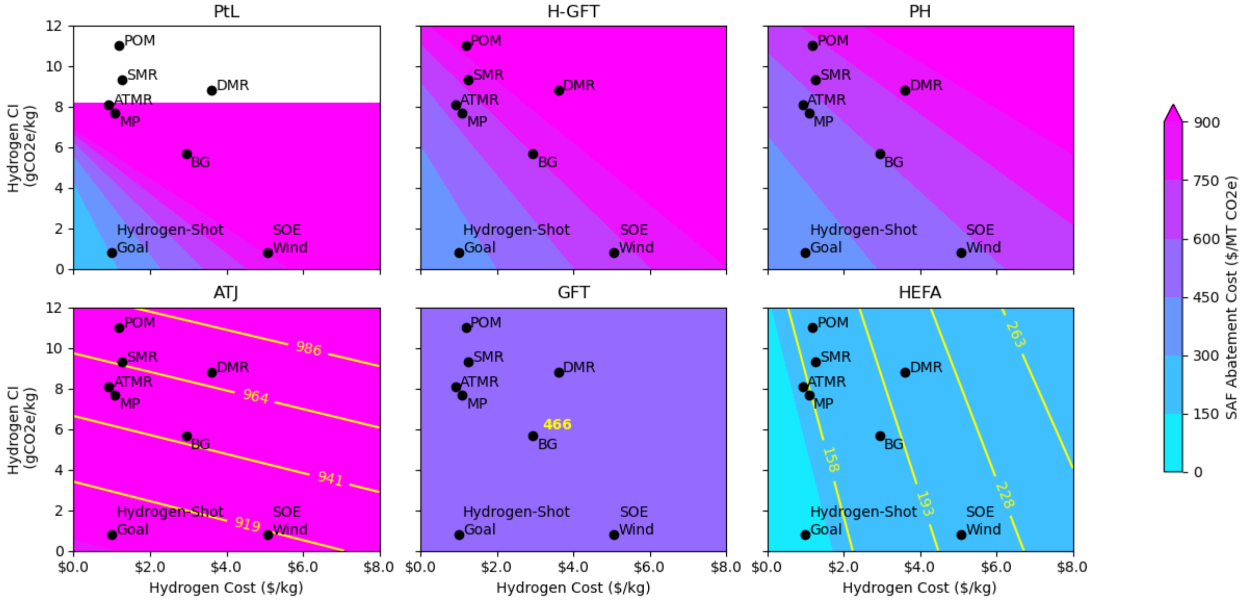

Figure 2. Abatement cost of SAF technologies as a function of hydrogen cost and carbon intensity (CI). Black dots represent hydrogen sources, while yellow lines provide additional detail for fuel abatement costs. ATJ: alcohol-to-jet; GFT: gasification Fischer-Tröpsch; H-GFT: Hydrogen-enhanced Gasification Fischer-Tropsch; HEFA: hydro-processed ester and fatty acid; PH: pyrolysis-hydrotreatment; and PtL: power-to-liquid.

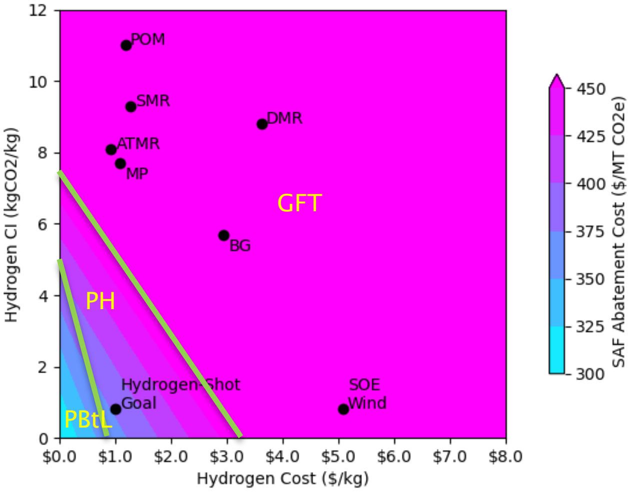

Figure 3. Lowest abatement cost technologies for stover conversion to SAF as a function of hydrogen price and carbon intensity (CI). Black dots represent hydrogen sources, while yellow lines illustrate the transition between different favorable technologies. GFT: gasification Fischer-Tröpsch; and PBtl: power- and biomass-to-liquid.

Publications

Presentations

Garcia, A., Sierra-Jimenez, V., Garcia-Perez, M. (2025, October 15) *Hydrogen and Power-to-Liquid Concepts for Sustainable Aviation Fuel Production* [Poster presentation]. ASCENT 2025 Fall Meeting, Alexandria, Virginia.

Garcia, A., Sierra-Jimenez, V., Garcia-Perez, M. (2024, October 15-16) *Screening and Optimization of Sustainable Aviation Fuel (SAF) Technologies in an Evolving Hydrogen Market* [Poster presentation]. Northwest Bioenergy Summit, Spokane, Washington.

Outreach Efforts

Presented preliminary results from this study at the 2024 Northwest Bioenergy Summit and Ascent 2025 Fall meetings.

Awards

None.

Student Involvement

None.

Plans for Next Period

Complete revision of the draft manuscript and publish results.

References

De Jong, S., Antonissen, K., Hoefnagels, R., Lonza, L., Wang, M., Faaij, A., & Junginger, M. (2017). Life-cycle analysis of greenhouse gas emissions from renewable jet fuel production. *Biotechnology for Biofuels, 10*(1), 64. https://doi.org/10.1186/s13068-017-0739-7

Tanzil, A. H., Brandt, K., Wolcott, M., Zhang, X., & Garcia-Perez, M. (2021). Strategic assessment of sustainable aviation fuel production technologies: Yield improvement and cost reduction opportunities. *Biomass and Bioenergy*, *145*. https://doi.org/10.1016/j.biombioe.2020.105942

Task 3 – Evaluate Potential for Integration of Hydrogen and Power into SAF Production

Washington State University

Objective

The objective of this task is to identify new pathways to optimize SAF production for maximum GHG reductions with minimal fuel costs.

Research Approach

This task involves both a theoretical and an applied approach. The theoretical subtask uses heuristic models to explore broader trends in SAF production using simplified SAF process models that expel oxygen in the form of CO_2, H_2O, and dioxygen (O_2), as well as the potential for hydrogen inclusion in a simplified gasification model (Garcia et al., 2024). Hydrogen data from Task 1 were used to determine which processes are favored by different hydrogen sources MSP, CI, and abatement cost data from these processes will provide data about more general trends in SAF production. This approach was also used to evaluate the effect of plastic co-feeding and char production on these idealized SAF processes, to understand the effect of consuming and sequestering fossil carbon on SAF abatement costs (Garcia et al., 2024).

In the second subtask, our team will evaluate the integration and co-location of these technologies with the new hydrogen production technologies discussed in Task 1. Using guidance from the previous subtask, we will develop explicit process models, TEAs, and complete LCAs to determine the economic and environmental impacts of different process modifications on SAF production. These include the introduction of power at different points in a gasification process (whether as supplemental heat during gasification or supplemental electrolytic hydrogen).

Milestones

- Developed a heuristic correlation to estimate fuel MSP without explicit equipment costing.
- Developed three purely stoichiometric mass balances to estimate the effect of deoxygenation method (e.g., oxygen removal as O_2, H_2O, or CO_2) on production cost and CI under various hydrogen costs and CIs.
- Used our cost heuristic to evaluate the effect of many hydrogen production technologies on a simplified gasification model. The introduction of technical constraints for a simplified oxygen gasification model yielded a tipping point of about 2.75 $/kg hydrogen. An assessment of this simplified gasification model with different oxidizers (O_2, steam, and CO_2) indicated that current gasification technologies (O_2, steam) do not justify its inclusion in these simplified cases.
- Analyzed biomass gasification technologies for more detailed optimization. We concluded that existing technologies for the conversion of biomass into syngas are limited by very low carbon conversion efficiencies. To achieve carbon conversion efficiencies close to 100%, the introduction of outside hydrogen and energy is necessary. While low-temperature gasification technologies have higher cold-gas efficiencies, the use of existing high-temperature gasification technologies may allow for better yields and heat integration with hydrogen technologies through reactive quenching by reverse water gas shift (Hillestad et al., 2018). Syngas cleaning methods must also be optimized accordingly (de Oliveira et al., 2023).
- Developed preliminary models for gasification control, integrated electrolysis, and direct heating cases. Our base-case is modelled on the results of Swanson (Swanson et al., 2010). Preliminary results indicate that introduction of power to gasifier may be more efficient than electrolysis.
- Expanded our gasification TEA to include methanol production for product diversification (Tan et al., 2015)

Major Accomplishments

The ASCENT Project 080 team has learned that the most critical factor governing production cost is fuel yield, which is directly related to carbon conversion efficiency (Tanzil et al, 2021). At 79% carbon conversion (Swanson et al., 2010), gasification outcompetes the 72% and 32% conversion achieved by PH (Jones et al., 2009a) and ATJ (Humbird et al., 2011) for lignocellulosic feedstocks. It's ability to process MSW (Jones et al., 2009b) and synthesize a variety of end products (Tan et al., 2015) makes it a good candidate for development. However, an overall mass and energy balance shows that typical gasification systems are energy- and hydrogen-deficient, requiring the oxidation of carbon that could otherwise go to fuel. This is typically accomplished by introducing oxygen to the gasifier to release necessary energy for conversion, while using water to oxidize carbon monoxide (CO) in the produced syngas and evolve additional hydrogen through the water-gas-shift reaction (Swanson et al., 2010). This creates an opportunity to supplement hydrogen and energy from outside the system (e.g., via the low-temperature or high-temperature water electrolysis) maximizing the carbon available for fuel production and removing additional oxygen in the form of water (Garcia et al., 2024). The high temperatures required for gasification also leave syngas with an energy content higher than that of the fuel produced; therefore, nearly one-third of the system's energy is released as heat (Lange, 2007). Heat integration is critical to maximizing the economic viability of technologies producing a syngas intermediate and may provide additional opportunities for integration with hydrogen production technologies (Dossow et al., 2024; Hillestad et al., 2018). Because hydrogen must be produced externally to maximize fuel production yields, hydrogen production technologies and their potential synergisms with SAF production must be carefully studied to develop optimized systems.

For this purpose, our team has produced a holistic analysis of the hydrogen market's effect on the potential of oxygen, steam, and CO_2 gasification technologies. This overall analysis was then integrated with the hydrogen production technologies examined in Task 1 to forecast which pathways will become favorable as the hydrogen market evolves. We have also produced a Microsoft® Excel®-based model that accounts for both stoichiometric and thermodynamic constraints in fuel production from biomass. This tool has not been utilized but could theoretically be updated and deployed for the testing of basic process optimization. Our extended Lange model has been placed into a Python® module that allows the calculation of economics for simple stoichiometric processes. We can easily extend this model to accept generalized user inputs, if needed for public outreach. Through this analysis, our team was able to determine a tipping point of 2.50 $/kg for the inclusion of hydrogen in stoichiometric SAF production processes. Without the availability of hydrogen below this price, removal of biogenic oxygen in the form of CO_2 is more cost effective than removal in the form of water for the stoichiometric models evaluated. The results of this holistic analysis have been published in *ACS Energy and Fuels* (Garcia et al., 2024). These results are currently being evaluated in more detail using standard techno-economic and lifecycle methods.

Publications

Peer-Reviewed Journal Publication

Garcia, A., Sierra-Jimenez, V., Brandt, K., Martinez-Valencia, L. P., Wolcott, M., Male, J., & Garcia-Perez, M. (2024). Holistic methodology to guide the evolution of sustainable aviation fuel production technologies. *Energy & Fuels, 38*(18), 17706–17716. https://doi.org/10.1021/acs.energyfuels.4c02795

Presentations

Alroggen, F., Garcia, A., (2025, April 23-24). *ASCENT Project 80: Hydrogen and Power-to-Liquid Concepts for SAF Production* [Conference presentation]. ASCENT Spring Meeting, Knoxville, Tennessee.

Garcia-Perez, M., Garcia, A., & Wolcott, M. (2024, October 2-4). Holistic methodology to guide the evolution of sustainable aviation fuel production technologies [Conference presentation]. Sustainable Aviation Futures, North America, Houston, Texas.

Outreach Efforts

Presented our results at the Spring 2024 and Fall 2024 ASCENT meetings in Hawai'i and Alexandria, Virginia, respectively.

Student Involvement

Valentina Sierra (PhD student-graduated), Brandon Lewis (PhD student), Aidan Garcia (research associate), and Robert Macias (research associate) contributed to this task.

Plans for Next Period

- Extend TEA and LCA analysis to new gasification models.
- Use these results to determine the effectiveness of power use in electrolysis or direct heating of gasification.

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Task 4 – Improvement of Hydrogen Efficiency in Hydrotreatment and Synthesis

Washington State University

Objective

In this task, our team will study how hydrogen is used in hydrotreatment steps. Hydrogen utilization for SAF production typically occurs in a hydrotreatment step that varies depending on the technology (Tanzil et al., 2021; Han et al., 2019). This step can proceed from a simple hydrogenation, hydrodeoxygenation, hydrocracking, or all of them together, depending on the technology (Han et al., 2019). Especially troublesome is the hydrotreatment of oligomers and materials with a high tendency to form coke (Han et al., 2019). A more detailed understanding of the mechanisms at play will allow for supplemental hydrogen to be used more effectively.

Research Approach

In addition, we will develop a detailed phenomenological mathematical model for the hydrotreatment step of the HEFA and fast pyrolysis pathways, which the team will then use to study potential strategies to reduce hydrogen consumption during SAF production (Chen et al., 2019; Plazas-González et al., 2018). This type of model requires a detailed description of the chemical composition of the feedstock, the reaction mechanism, and associated kinetics (Gutiérrez-Antonio et al., 2018; Talib Jarullah, 2011; Boesen, 2011; Jeništová et al., 2017; Tieuli et al., 2019; Hachemi & Murzin, 2018). The modeling work will complement studies in batch and continuous hydrotreatment reactors with different catalysts to validate the mathematical model.

Milestones

- Conducted an investigation of hydrogen efficiency in hydrotreatment, which began in January 2023 with a literature review of catalytic hydrotreatment reactions.
- Began development of atomistic models of hydrotreatment processes and a description of pyrolysis oils in terms of representative compounds.
- Began hydrotreatment trials of coconut oil and used cooking oil mixtures to maximize SAF yields.
- Began trials of co-hydrotreatment of coconut oil and kerosene to simulate hydrotreatment in existing refinery infrastructure.

Major Accomplishments

We have made progress on a literature review on pyrolysis oils hydrotreatment reactions and a preliminary atomistic model of pyrolysis oil molecules catalytic hydrodeoxygenation.

Publications

Peer-Reviewed Journal Publication

Denson, M. D., Manrique, R., Olarte, M., & Garcia-Perez, M. (2024). *Co-hydrotreatment of Bio-oil and Waste Cooking Oil to Produce Transportation Fuels.* Energy & Fuels, 38(8), 6982-6991. https://doi.org/10.1021/acs.energyfuels.3c05176

Dissertation

Denson, M. (2023). *Contributions to understanding oligomeric sugars derived from biomass pyrolysis* [Doctoral dissertation], Washington State University. Washington State University.

Outreach Efforts

None.

Student Involvement

Melba Denson, a PhD student at WSU, has contributed applied and theoretical hydrotreatment work to this task as part of her thesis. Rona Landoy and Emmanuel Villaruel (Visiting Master's students) are also contributing to this step.

Plans for Next Period

This work was planned for the extended period of performance for the project. As additional funding was not received, we will focus on delivering on previous tasks and do not plan to continue this one.

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