Project 001(A) Alternative Jet Fuel Supply Chain Analysis

Washington State University

Project Lead Investigator

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University Participants

Washington State University

- P.I.(s): Michael P. Wolcott, Regents Professor; Christina Sanders, Acting Director, DGSS; Manuel Garcia-Perez, Associate Professor; and Xiao Zhang, Associate Professor
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- Task(s):
    - WSU 1. Design cases– Garcia-Perez, Zhang
    - WSU 2. Evaluation of the most promising biorefinery concepts for AJF production. Garcia-Perez, Zhang
    - WSU 3. Supplement and maintain the current inventory of biorefinery infrastructure identified in the conversion design cases that are useful for production of AJF. Wolcott
    - WSU 4. Community Social Asset Assessment Gaffney
    - WSU.5 Refine and deploy the facility siting tools for determining regional demand and potential conversion sites to be used in regional analyses. Wolcott
    - WSU.6 Refinery to Wing Stakeholder Assessment. Gaffney
    - WSU.7 Supply Chain analysis. Wolcott-Garcia-Perez
    - WSU. 8 Analytical support for regional CAAFI and USDA jet fuel project. Wolcott

Project Funding Level

$396,037 FAA funding and $396,037 matching funds. State committed graduate school contributions for four PhD students. Faculty time for Michael Wolcott, Manuel Garcia-Perez and Xiao Zhang are contributing to cost share.

Investigation Team

- Michael Wolcott, Project Director/Principal Investigator
- Christina Sanders, Co-Project Director(s) /Co-Principal Investigator (Co-PI)
- Season Hoard, Co-Project Director(s)/Co-Principal Investigator (Co-PI)
- Manuel Garcia-Perez, Co-project Director(s)/Co-Principal Investigator
- Xiao Zhang, Co-project Director(s)/Co-principal Investigator
- Paul Smith, Faculty
- Michael Gaffney, faculty
- Kristin Brandt, Staff Engineer
- Natalie Martinkus, Staff Engineer
- Scott Geleynse, post-doctoral
- Dane Camenzind, Graduate Student
- Lina Pilar Martinez Valencia, Graduate Student
- Tanzil Abid Hossain, Graduate Student

- Anamaria Paiva, Graduate Student
- Daniel Mueller, Graduate Student
- Kelly Nguyen, Graduate Student

Collaborating Researchers

- Burton English, University of Tennessee
- Kristin C. Lewis, Volpe

Project Overview

As part of an effort to realize an "aviation system in which air traffic will move safely, swiftly efficiently, and seamlessly around the globe", the Federal Aviation Administration (FAA) has set a series of goals and supporting outcomes, strategies, and performance metrics (Hileman et al 2013). The goal entitled, "Sustaining our Future" outlines a number of strategies that are collectively aimed at reducing the environmental and energy impacts of the aviation system. To achieve this goal, the FAA set an aspirational goal of aviation utilizing 1 billion gallons of alternative jet fuel (AJF) by the year 2018. This goal was created from an economic, emissions, and overall feasibility perspective (Richard 2010, Staples et al. 2014).

Current approaches to supply chain analysis for AJF optimize transportation logistics of feedstocks-to-refinery and refinery-to-wing (Bond et al 2014). One of the largest barriers to large scale production of all alternative jet fuels is the high capital cost of greenfield facilities translating to risk in the investment community (Huber et al 2007). The capital cost of cellulosic ethanol plants ranges from $10-13/gal capacity (Hileman and Stratton, 2014). The additional process steps required to convert the intermediate to a drop-in AJF could increase this cost to over $25/gal capacity (Hileman 2014).

The realities of these initial commercialization efforts into second-generation alternative jet fuel have led to studies that envision alternate conversion scenarios including transitioning existing facilities (Brown 2013). Gevo is employing retrofit strategies of corn ethanol plants for producing isobutanol, a potential intermediate for the alcohol-to-jet process of producing iso-paraffinic kerosene (Pearlson 2011, Pearlson et al 2013). Research to envision scenarios to achieve the FAA aspirational goal of AJF consumption relied upon "switching" scenarios where existing and planned capacity would be used for producing the drop-in fuel (Malina et al 2012). All of these approaches require identifying existing industrial assets to target for future AJF production. Siting becomes, not just an exercise of optimizing feedstock transportation, but aligning this critical factor with a host of existing infrastructure, markets within regions with the proper social capital for developing this new industry (Seber et al 2014, Henrich et al 2007).

Up to now all the published AJF supply chain analyses have been limited to standalone jet fuel production technologies that do not generate bio-products. The potential techno-economic and environmental benefits of using existing industrial infrastructure and the production of coproducts on the development of jet fuel production scenarios has to be considered in future studies.

The design cases of the standalone AJF production facilities will be used in supply chain evaluations. Community Social Asset Modeling (CAAM): Social Asset modeling is not well-developed and efforts are likely hampered by the difficulty in quantifying social assets when compared to improved environmental performance or a reduction in alternative jet fuel costs that may be observed by optimizing economic and environmental constraints. However, considering the community characteristics of a potential site is important when determining preferred locations for a new biorefinery. Community resistance or enthusiasm for the alternative jet fuels industry can play a large role in the success or failure of a facility (Martinkus et al 2014). CAAM efforts conducted within this project will inform disciplinary applications and advances. It is clear that social factors can have a significant effect – positive or negative – on project adoption and implementation, especially high technology or energy-related projects (Lewis et al 2012, Martinkus et al 2012). Accounting for social factors to inform selection of sites and implementation decisions to maximize positive social support and minimize opposition and social negatives can significantly enhance project success. The CAAM model originally piloted in the NARA project is designed to provide a quantitative rating of select social factors at the county level (Martinkus et al 2014).

This research is targeted at identifying the key barriers, in regional supply chains, that must be overcome to produce 1-billion gallons of alternative jet fuel. This overall goal is addressed by developing tools to support the AJF supply chain assessment by the Volpe Center. Our effort will provide facility siting analyses that assess (a) conversion design cases combined with (b) regional supply chain assets and (c) social capacity assessments for communities to act collectively for

development goals. Finally, a refinery-to-wing stakeholder assessment will support modeling and accounting of AJF distribution for downstream fuel logistics.

Task 1- Design Cases

Washington State University

Objective(s)

Continuation from previous years

Our team will complete the reviews and final report of the design cases for six standalone AJF technologies and four important industries (sugarcane, pulp and paper, corn ethanol and petroleum refineries) developed in previous years and will start developing the design cases for targeted co-products that could improve the economic viability of AJFs.

New Tasks

1. New case design report "Alternative Jet Fuel Supply Chain Analysis: hydrothermal liquefaction processing of tall oil for jet fuel production". This work involved collecting primary data, establishing process flow diagram and conducting a detailed TEA. This task will be carried out in collaboration with PNNL HTL group.
2. Conduct detailed TEA analyses of integrating lignin co-products technologies in Alcohol-to-Jet pathway to determine the potential to lower fuel cost to $2.00/gge.
3. New design case reports on technology review and process evaluation of lipid conversion processes (HEFA, CH, SBI, Forge, Tyton, decarboxylation) and new technologies for the production of alternative lipids (HTL and sugars to lipid).
4. Conduct detailed TEA analysis integrating lignin co-products technologies in biorefinery cases integrated with the corn ethanol, and the sugarcane industry

Research Approach

Background

The design cases developed for AJFs and for existing industrial infrastructure are being used in the development of supply chains and the identification of synergisms that could eventually lead to the construction of integrated systems of AJF production that take advantage of the infrastructure in a given region. Analysis of the location of existing infrastructure showed that the United States can be divided in regions by dominant biomass of the region. So, we believe that a viable approach to evaluate the synergism between the AJF pathways, the existing infrastructure and the co-products is to generate advanced biorefinery concepts around the Petroleum Refineries, Pulp and Paper Mills, Sugar Cane Mills, and Corn Ethanol Mills. Then we will compare the biorefinery concepts developed for each of these technologies to decide the most promising ones. The most promising biorefinery concepts for the synergistic production of AJFs and co-products with these industries will then be used in the supply chain analyses.

Standalone design case reports are generated by conducting reviews of research related to each in academic literature and public information available from commercial interests developing the technology. The reports are meant to detail the processes involved in each conversion pathway and outline the technology readiness and particular barriers to implementation. Publically available information on the commercial processes and research literature will provide the foundation of information later used in modeling efforts. Where detailed process engineering information is lacking, new models will be built to estimate the parameters needed to complete assessments such as techno-economic modeling, lifecycle analysis and supply chain modeling. Aspen Plus is primarily used to generate process models and details including mass balances, energy balances, energy requirements, and equipment size and cost. These results will also aim to provide the basis for comparative analysis between design cases, identifying key advantages and markets for each technology.

Each design case has the following components:

1. Feedstock requirement (availability and feedstock composition)
2. Flow diagram of technology
3. Companies commercializing the technology (level of maturity)
4. Current location of units in the United States (In case of an existing technology it will be the inventory of units that could be retrofitted)
5. Literature review on papers reporting data relevant to the operation of the technology (operating conditions, type of reactor used, catalysts, yield of products)

6. Properties of jet fuel produced
7. Identification of potential intermediates (bio-oil, sugars, densified feedstock); current and potential uses of wastes and effluents; and co-products (biochemicals, carbon, etc.) that can be obtained from the technology.

Last year we submitted the MS Word technical reports and the MS Excel files, with mass and energy balances and techno-economic analyses, (TEA) for the pathways listed below. All files are available on shared drives for the Project 01 team members. Where indicated, TEAs are still undergoing internal review.

- Pyrolysis-bio-oil hydro-treatment concept (Hydro-treated Depolymerized Cellulosic Jet HDCJ).
- Synthetic Kerosene and Synthetic Aromatic Kerosene (SK&SAK). [Under review]
- Alcohol to Jet (ATJ)- A manuscript with the information for the mass and energy balances and its TEA was recently published. [The TEA of Direct Sugars to Hydrocarbons (DSHC) is under internal review.]
- Syngas Fischer Tropsch (FT)- Design cases were prepared for biomass gasification. The first one was for micro-reactors. The second design was for a technology using large standard reactors. [The TEAs for general FT and micro-FT are under internal review.]
- HEFA Mass and Energy Balances and the TEA. [Under review].

We are currently working on a manuscript comparing the economic and environmental performance of the alternative jet fuel technologies discussed above. Last year we also made progresses in design cases for the existing industries that could be used to reduce production cost of alternative jet fuels.

A very preliminary technical report with information of mass and energy balances and TEA of the petroleum refinery are still being developed for the corn ethanol and sugarcane design cases. We have made major progress on the analysis of corn ethanol, and sugarcane biorefineries for jet fuel production. Two papers in this area are under internal review.

We are working with PNNL to complete a case design report on HTL for AJF conversion. This work involved collecting primary data, establishing process flow diagrams for several feedstocks including, municipal wastewater (primary and secondary sludge), algae and tall oil, and conducting a detailed TEA. We have discussed the draft report with PNNL. We will also work with PNNL to help identify ways to improve HTL conversion efficiency.

A summary report on several lipid conversion pathways including SBI, Forge, Tyton, decarboxylation and co-processing was prepared. We have also revised the design case for the Catalytic Hydrothermolysis (CH) process and a manuscript "Techno-economic analysis of Catalytic Hydrothermolysis Pathway for Jet Fuel Production was prepared. The manuscript reviews the technological development and commercialization progress of CH pathway and assess the advantages of the CH pathway to utilize a wider range of feedstocks including edible and non-edible vegetable oils as well as fats, oils, and greases (FOGs) and generate a broader mix of hydrocarbons. Potential cost savings for the use of low-cost feedstocks like FOGs are assessed considering the added costs for preconditioning and feedstock availability. A draft manuscript has been reviewed by Agrisoma. We plan to complete the manuscript revision and submission by January 31, 2019.

Milestone(s)

Completed the Excel file with TEAs of all the alternative jet fuel technologies. The design cases for the corn ethanol and the sugarcane industry are still under review by the standardization team. We are still working on the design case for the petroleum refinery. We completed the analysis of corn-ethanol alternatives for jet fuel production.

Major Accomplishments

Models were developed for the main AJF production technologies and for relevant technologies that can be used as baseline for the synthesis of biorefinery concepts. The methodology for these models is provides data to form a baseline for comparative analysis with other design cases. Key process variations have been identified in several design cases and have been modeled to determine their effects on process economics and viability, as well as to identify the key barrier toward commercialization in complete biorefinery concepts.

Data generated from the design cases were also supplied to A01 partners to assist with supply chain, techno-economic models by improving the conversion and cost figures database values. Evaluations of the effects of process variations on the chemical properties of products generated are being used to provide insight into the challenges that will be faced when blending the AJFs into commercial jet fuel.

Publications

Scott Geleynse, Kristin Brandt, Manuel Garcia-Perez, Michael Wolcott, Xiao Zhang, The Alcohol to Jet Conversion Pathway for Drop-In Alternative jet fuels: Techno-Economic Evaluation. ChemSusChem, 11,3728 –3741 (2018).

Outreach Efforts

During the preparation of design case reports, we have closely interacted with industrial companies including Gevo, LanzaTech and Agrisoma. These companies have also helped us review the reports and draft manuscripts.

Awards

The publication listed above was selected as a VIP (very important paper) and invited for cover art and cover profile in ChemSusChem.

Student Involvement

Several graduate (Scott Geleynse, Mond Guo, Carlos Alvarez Vasco, Ruoshui Ma, Kelly Nguyen, Tanzil Hossain, Anamaria Paiva, Lina Martinez) and undergraduate students participated in the creation, editing and updating of the design cases for standalone AJF technologies, for relevant existing infrastructure and for co-products from lignin.

Plans for Next Period

Release the final version of all design cases for standalone AJF production technologies, for relevant infrastructure (corn ethanol, sugarcane, pulp and paper and petroleum refinery)

Task 2- Evaluation of the Most Promising Biorefinery Concepts for AJF Production

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Objective(s)

Continuation from previous years

This year we will complete the evaluation of biorefinery scenarios for AJF production in corn ethanol, sugarcane, pulp and paper mills and petroleum refineries. Last year we advanced the analysis for corn ethanol and pulp and paper mills. This year we should complete the analysis for sugarcane and petroleum refineries.

New Tasks

Conduct detailed TEA analyses of integrating lignin co-products technologies with the Alcohol to Jet pathway to determine the potential to lower fuel cost to $2.00/gge.

Research Approach

Background

In this task we are using the design cases of existing infrastructure, AJF production technology and co-products identified to generate new biorefinery concepts for Petroleum Refineries, Pulp and Paper Mills, Sugarcane Mills and Corn Ethanol Mills. The results from this effort will allow us to identify and select the most commercially feasible biorefinery concepts. Major technical gaps/barriers toward commercialization of each of the biorefinery concepts will also be revealed from the results of this study.

Integration of process technologies through a similar approach to the standalone design cases is assessed. Further evaluation of integration concepts will be developed by pairing standalone cases with these opportunities to evaluate the economic and environmental advantage of the integration approaches. During this period, we conducted detailed analyses of alcohol to jet conversion (ATJ) and integration with pulp mill operations. We have also investigated the potential of lignin co-products contribution to the overall process economy.

A dry grind corn ethanol mill (DGCEM) with a capacity of 80 million gallons of ethanol per year (MGY) was studied in order to evaluate potential biorefinery scenarios for AJF production. Five alternative jet fuel (AJF) technologies were studied: Virent's BioForming, "Gevo" alcohol to jet (ATJ), direct sugar to hydrocarbon (DSHC), fast pyrolysis (FP) and Fischer-Tropsch (FT). A standardized methodology was adopted to evaluate twelve integration scenarios between DGCEM and AJF technologies in terms of minimum fuel selling price (MFSP) and greenhouse gas (GHG) emission. We are currently conducting similar analyses for a corn ethanol plant and petroleum refineries. The comparison of sugarcane bio-refinery concepts for aviation fuel production has progressing well.

We will complete a draft paper of integration of ATJ technologies in pulp mill infrastructure this year. We will then apply this methodology for analyzing other advanced fermentation technology (direct sugar to hydrocarbon by Amyris) in pulp mill next year. We will also expand the lignin co-product analysis to all other AJF pathways.

Major Accomplishments

Economic models and Life Cycle Assessments were used to support the selection of the most promising biorefinery concepts for the corn ethanol plant, sugarcane and pulp and paper. Manuscripts on corn ethanol, sugarcane and pulp and paper bio-refineries for jet fuel production will be submitted shortly. We are now working on the petroleum refinery biorefinery concepts.

Publications

None

Outreach Efforts

Scott Geleynse, Xiao Zhang. Techno-Economic Assessment of Pulp Mill Infrastructure Integration with the Alcohol-to-Jet Pathway for Aviation Fuel Production. International Bioenergy & Bioproducts Conference, October 30, 2018

Awards

None

Student Involvement

Graduate students Scott Geleynse, Senthil Subramaniam, Kelly Nguyen, Abid Tanzil Hossain, Lina Martinez Valencia, Anamaria Paiva, and Ruoshui Ma have received trained working in this project. An undergraduate student, Kitana Kaiphanliam, funded under an NSF REU grant assisted with building techno-economic models for co-products production scenarios.

Plans for Next Period

Next period Dr. Garcia-Perez's team will focus on the potential cost reductions if alternative jet fuels are integrated with a petroleum refinery.

Task 3- Supplement and Maintain the Current Inventory of Biorefinery Infrastructure Identified in the Conversion Design Cases that are Useful for Production of AJF

Washington State University

Objective(s)

Continuation from previous years

This task requires annual evaluation of the database to add or eliminate new and closed facilities in each category so that the geospatially specific assets are current with reality.

Research Approach

Utilizing existing infrastructure assets is key to retrofit approaches to developing the industry. In order to differentiate between the relative value of different options, the specific assets must be valued with respect to their potential use within

a conversion pathway. Regional databases of industrial assets that might be utilized by a developing AJF industry, have been assessed on a national level. These baseline databases are compiled from a variety of sources that include industry associations, universities, and news outlets. These databases will be expanded, refined, and validated as the conversion design cases articulate additional needs for the regional analyses.

Milestone(s)

National databases are compiled, geolocated, validated and shared for biodiesel, corn ethanol, energy pellet, pulp & paper, and sugar mill production. We are evaluating the database to add or eliminate new and closed facilities in each category so that the geospatially specific assets are current with reality.

Geospatially specific facility databases, waste feedstocks estimates, and forest residual inventories were developed and prepared with the Volpe Center in their FTOT analysis. FTOT analysis of specific scenarios are compared to similar versions analyzed with the National Renewable Energy Laboratory's (NREL) Alternative jet fuels Scenario Model (BSM) to estimate adoption of alternative jet fuel technologies for determining potential national targets.

Major Accomplishments

The national databases have been compiled, validated, and shared with the A01 teams. All of the metadata is complete for use in the regional analyses.

Publications

Databases were used in the following publication submitted for peer review in BioFPR:

Lewis, Kristin C., Emily K. Newes, Steven O. Peterson, Matthew N. Pearlson, Emily A. Lawless, Kristin Brandt, Dane Camenzind et al. US alternative jet fuel deployment scenario analyses identifying key drivers and geospatial patterns for the first billion gallons. Biofuels, Bioproducts and Biorefining. 2018. Doi:10.1002/bbb.1951

Outreach Efforts

None

Awards

None – these are shared assets for later analyses

Student Involvement

Dane Camenzind, Master's student in Civil Engineering, validated the operating status of previously identified production facilities, compiled and geolocated MSW incinerators and landfill gas to energy facilities and worked to assemble and update all county level feedstock information.

Plans for Next Period

None

Task 4- Continue Work on Social Asset Decision Tools Developed in Phase 1 for Plant Siting (Community Asset & Attribute Model—CAAM); Including Additional Validation and Incorporation of Multi-decision Making Tools. Extend Application to Another US Region in Coordination with Other Team Members (Inland Northwest, Appalachian Region). Prepare for Extension Nationally & Replication in Select Countries.

Washington State University

Objective(s)

Expand and refine social asset decision tools for biorefinery plant siting (Community Asset & Attribute Model—CAAM) through addition of political capital. Prepare for extension nationally and replication for Canada and select EU countries.

Research Approach

Based on key measures of social, cultural, human, and political capitals, WSU has developed and finalized a Community Asset and Attribute Model (CAAM). The first tool was initially applied to the NARA region in the Pacific Northwest, and the refined tool that added more complete measures of social, cultural, and human capital was deployed in two sub-regions of NARA. The initial measure of political capital has now been added to the CAAM and the tool can be used across the continental United States. The refined CAAM (excluding the political capital) has been used to assess social capacity for biorefinery siting in two separate studies, including retrofitting paper mill facilities in the Pacific Northwest. Ground-truthing analysis was used to assess the role of social, cultural and human capitals in the success or failure of alternative jet fuel related projects in both the NARA and BANR regions. This ground-truthing analysis supported the role of CAAM measures in project success, and suggested opportunities to further improve the CAAM which are completed. The final CAAM includes measurements for political capital, and the ways in which each capital is measured were altered for each capital. We have also completed the strategic application model which combines the final CAAM with supplementary data to make strategic recommendations for community engagement to increase the likelihood of project success. Efforts to validate the final CAAM and strategic application are currently underway, and involve application in the BANR region and the inland Northwest. We are also using past case-studies in the Pacific Northwest to help validate the strategic application model.

Milestone(s)

The validated CAAM model based on county-level comparative rankings on Social, Human Cultural, and Political Capitals is tested and available for use.

Major Accomplishments

The final CAAM model with the addition of social capital is completed. The strategic application model has been created based off the final, completed CAAM and the addition of supplementary data. The supplementary data includes diversity and segregation data at the county-level to assess the type of social capital for the community, and necessary strategic approaches based on this information. We have developed a codebook for the final dataset to help researchers utilize the CAAM and create their own scores tailored to their specific regions. The papers submitted based on previous CAAMs have been published: the development of the CAAM prior to the addition of political capital was published by Politics and the Life Sciences in 2017, the manuscript details the model's measurements of cultural, human, and social capital and presents validation of the model based on case studies from the Pacific Northwest. The site-selection manuscript combining this refined model was also published in 2017 by Biomass and Bioenergy. Significant research collaborations have been organized to further test the CAAM's effectiveness, including in areas outside aviation alternative jet fuel and refinery site selection (namely, climate change resiliency and community vulnerability to climate change). A third manuscript is also currently being written that further demonstrates the validity of the CAAM through a case study analysis in the Pacific Northwest.

Publications

Martinkus, N., Rijkoff, S.A.M., Hoard, S.A., Shi, W., Smith, P., Gaffney, M. & Wolcott, M. (2017). Biorefinery site selection using a stepwise biogeophysical and social analysis approach. Biomass and Bioenergy, 97, 139-148. doi:10.1016/j.biombioe.2016.12.022

Rijkhoff, S.A.M., Hoard, S., Gaffney, M.J. & Smith, P.M. (2017). Communities ready for takeoff: Integrating social assets for alternative jet fuel site-selection modeling. Politics and the Life Sciences, 36(1):14-26. doi:10.1017/pls.2017.6

Outreach Efforts

Mueller, D., Hoard, S., Sanders, C. & Gaffney, M. *From Field to Flight: Using Community Capitals to Predict Sustainable Aviation Alternative jet fuel Scale-Up*. Washington State University Academic Showcase. Pullman, WA.

Mueller, D., Hoard, S., Sanders, C., & Gaffney, M. *From Field to Flight: Using Community Capitals to Predict Sustainable Aviation Alternative jet fuel Scale-Up*. Northwest Climate Conference. Tacoma, WA.

Awards

None

Student Involvement
Daniel Mueller, Ph.D. candidate in political science at WSU and research assistant on this project, will continue validation efforts for the CAAM and has finalized measurements for political capital and finished developing strategic applications of the CAAM. Future work includes further validation of the CAAM and testing the model through various collaborative research efforts.

Plans for Next Period
The final CAAM and strategic application will be validated in the Inland Northwest and BANR regions. This approach will include incorporating in multi-method decision-making tools, and appropriate weighting of the capitals based on their correlation.

Task 5- Refine and Deploy the Facility Siting Tools for Determining Regional Demand and Potential Conversion Sites to be Used in Regional Analyses
Washington State University

Objective(s)
Continuation from last year
Develop readiness level tools for regional projects.

Research Approach
The CAAM model, developed under the NARA project and refined for ASCENT applications, provides county-level data collected from national datasets to conduct a preliminary assessment of community characteristics for four (Cultural, Social, Human, Political) of the seven "Community Capitals" developed by Emery and Flora 2006.

To help improve facility siting tools, prior CAAM models (focusing on 3 assets: social, cultural, and human capital) were added to economic assets to assess the suitability of communities in the Pacific Northwest for bio-refineries. Expanding on these analyses, our CAAM measures have been added to a decision support tool (DST) to assess the repurpose potential of pulp mills in the Pacific Northwest for a biorefinery. An additional manuscript has been written on the effectiveness of this tool and will be submitted for review. These approaches have been utilized for cellulosic Alcohol-to-Jet supply chains in the Pacific Northwest, and we will work to demonstrate the tool for supply chain siting analyses for alternative jet fuel production using HEFA conversion technology and FOGs as feedstock in the Inland Northwest.

Milestone(s)
CAAM has been updated with four capitals, and readiness level tools for regional projects have been developed.

Major Accomplishments
During this reporting period, a manuscript combining CAAM with economic indicators to assess site-selection in the Cascades-to-Pacific region (western Oregon and western Washington) was developed and will be submitted. Supplementary data for strategic application has been added to strategic recommendations model which we plan to integrate with future DSTs.

Publications
Martinkus, Natalie, Greg Latta, Kristin Lynne Brandt, and Michael P. Wolcott. 2018. A Multi-Criteria Decision Analysis Approach to Facility Siting in a Wood-Based Depot-and-Biorefinery Supply Chain Model. Frontiers in Energy Research, 6:124. Doi: 10.3389/fenrg.2018.00124

Outreach Efforts
None

Awards
None

Student Involvement

Daniel Mueller, Ph.D. candidate in Political Science, now holds a funded Research Assistant appointment working on this project, and has been primarily responsible for acquisition of new primary data, and continuing validation of the model.

Plans for Next Period

In the next year, the latest iteration of the CAAM will be further validated and applied in the Inland Northwest and BANR regions, with expansion to at least one additional U.S. region (Inland Northwest and potentially Central Appalachian Region in cooperation with team members). This model is based upon the addition of measurements for political capital, development of more refined measurement of capital comparative ranking beyond dichotomous outperform/under-perform ratings using standard deviations to examine distance from regional average and impact on successful development and implementation of alternative measurements for cultural capital and slight changes in measurements for human and social capitals, additional supplementary demographic data to enhance the nuance of the model, and final validation, after statistical confirmation, using selected case studies to confirm the efficacy of the model.

The updated CAAM is available for use nationally, allowing comparison of counties against defined regional norms on cultural, social, human, and political capital scales that have been statistically tested and validated through triangulated testing with external data. The new version of the CAAM allows for further enhancing predictive capacity through the development of strategic applications of the model, including, for example, the level of political support for alternative jet fuels in any given community. Finalized codebooks for this model have been developed and made available and will continue to be refined as the model is further validated.

Task 6- Refinery-to-Wing Stakeholder

Washington State University
This is a shared task lead by Penn State University. The reporting is provided in Award No. 13-C-AJFE-PSU-002.

Objective(s)

Continuation from last year
Extend Stakeholder assessment to a limited sample of informed stakeholders in the remaining sections of the country to provide insight into market & industry dynamics which will help optimize successful outcomes.

Research Approach

The team will collect primary data via surveys to better understand the awareness, opinions, and perspectives of key aviation fuel supply chain stakeholders regarding to the potential impacts and key success factors for an economically viable biojet fuel production industry in the United States. These aviation fuel supply chain stakeholders include airport management, FBOs, other aviation fuel handlers, relevant airlines, and CAAFI personnel. Data collection to assess aviation fuel supply chain stakeholder opinions, awareness, and perceptions regarding factors impacting the adoption and diffusion of AJF in the Pacific Northwest region has been completed, and Midwest region analysis is continuing. A national survey of aviation management has been developed and has been distributed to several hundred stakeholders across the United States. This survey replaced efforts to conduct interviews due to low response rates and is currently ongoing. As respondents submit their answers, further outreach efforts will be conducted to improve the survey response rate, primarily by calling directly recipients of the survey who have not yet completed it.

Milestone(s)

Assessment in the Pacific Northwest region of stakeholder perceptions using interviews and a survey of airport management have been completed, resulting in one previously published paper and a second paper soon to be published in late 2018. Interview protocols have been completely converted into surveys, and a national survey has been distributed to stakeholders across every region of the country. Responses continue to be collected, and further outreach to enhance survey completion will start soon.

Major Accomplishments

The team has written a second manuscript describing airport management opinions on aviation alternative jet fuel in the Pacific Northwest. The paper has been accepted for publication in the International Journal of Aviation Management. Interview protocols have been converted into a national survey, which has been distributed to hundreds of aviation fuel stakeholders at airports across the country.

Publications
Mueller, D., Hoard, S., Smith, P. M., Sanders, C., & Gaffney, M. (2019). Airport Management Perspectives on Aviation Biofuels: Drivers, Barriers, and Policy Requirements in the U.S. Pacific Northwest. *International Journal of Aviation Management*. https://doi.org/10.1504/IJAM.2019.098380

Outreach Efforts
None

Awards
None

Student Involvement
Daniel Mueller, Ph.D. candidate in political science at WSU and research assistant on this project, has helped develop the national survey and is currently administrating this survey. He will also be assisting in outreach to survey recipients to improve response rates.

Plans for Next Period
The next year will see the completion of the national stakeholder assessment, with the team continuing to gather responses from across the country and analyzing the incoming data. When data gathering and analysis is complete, the team will begin drafting a manuscript reporting survey results.

Task 7- Supply Chain Analysis
Washington State University-Volpe

Objective(s)
Continuation from previous years
Oilseeds production and use for production of AJF using HEFA refining is one potential pathway to production of fuels in the Pacific and Inland Northwest. A logistical optimization routine is used to assess the most likely supply chain scenarios that may result in this region.

Research Approach
Oilseed production is estimated based upon previous USDA-funded research addressing sustainable agricultural practices in the dry-land farming area of the Inland Northwest. The yield and rotation information from this project, called REACCH (reacchpna.org), was used to assess 50% and 100% of maximum sustainable oilseed production in this region as a rotation crop to traditional wheat production. A variety of storage facility types (country, shuttle, and barge elevators) and transportation modes (road, rail, and barge) were assessed. Siting methods in this report were used to determine potential locations for oilseed crushing. Plant oil refining for biodiesel production at the REG facility in Grays Harbor, WA and coproduction of alternative jet fuel at an oil refinery near Anacortes, WA were considered for supplying diesel and jet fuel demands in the Greater Seattle and Portland markets. The location of crushing facilities and transportation modes/routes were determined using optimization routines that considered both plant oil and oilseed meal delivery. The oilseed meal was assumed to be used regionally as a protein source for cattle and diary production.

Milestone(s)
Analysis is complete and an MS thesis is completed.

Major Accomplishments
WSU and the Volpe AFTOT analysis team has teamed with the NREL BSM team for a joint analysis of the ability to reach 1-billion gallon of AJF production in the US.

Publications
Camenzind, D. 2018. Supply Chain Analysis for the Production of Alternative Jet Fuel from Oilseeds produced within the U.S. Pacific Northwest. MS Thesis. Washington State University.

Outreach Efforts
None

Awards
None

Student Involvement
Dane Camenzind, MS Environmental Engineering, Washington State University

Plans for Next Period
Compare optimized supply chains to those assessed by Volpe using FTOT.
Utilize regional supply chain tools in assessing forest residuals to alternative jet fuels using pyrolysis methods in Task 8 below.

Task 8- Analytical Support for Regional CAAFI and USDA Jet Fuel Project
Washington State University

Objective(s)
Continuation from previous years
Develop a readiness level tool to assess the status of regional alternatives jet production projects. In addition, use the supply chain and standalone design cases to support the USDA BANR project in TEA and supply chain analysis. This regional CAP project focuses on the use of softwood forest salvage feedstock for fuels via a catalyzed pyrolysis conversion pathway.

Research Approach
We will develop readiness level tools for regional projects to assess their status of developing fuel project and assist in understanding critical missing components. This tool will take similar form and approaches to the CAAFI Feedstock and Fuel Readiness Levels and will be used to assist CAAFI in understanding the stage of development for projects of interest and assess critical gaps. In addition, we will assist the regional USDA BANR team in deploying TEA and Supply Chain analysis to their project. This effort is structured around using softwood forest salvage feedstock with a thermochemical conversion process to produce fuels and coproducts.

Milestone(s)
We are progressing on the use of the supply chain and standalone design cases to support the USDA BANR project in TEA and supply chain analysis. We have supported the BANR team in creating TEAs for the technologies under consideration.

Major Accomplishments
In collaboration with the USDA BANR project and attending their annual meeting to coordinate analysis. We currently await their completion of beetle-killed softwood estimates to complete the supply chain analysis.

Publications
None

Outreach Efforts
None

Awards
None

Student Involvement
Dane Carmenzind, MS Environmental Engineering, Washington State University
Lina Martinez, PhD Biosystems Engineering, Washington State University

Plans for Next Period

Analysis of the BANR Region is ongoing and will be complete within the project year.

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