Project 001(A) Alternative Jet Fuel Supply Chain Analysis

Washington State University

Project Lead Investigator

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University Participants

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- P.I.(s): Michael P. Wolcott, Regents Professor; Michael Gaffney, Director, DGSS; Manuel Garcia-Perez, Associate Professor; and Xiao Zhang, Assistant Professor
- FAA Award Number: 13-C-AJFE-WaSU-003
- Period of Performance: August 18, 2014 to July 31, 2015
- Task(s):
  - 3.1 Evaluate the current alternative jet fuel (AJF) pathways, fuel properties, feedstock requirements, and commercial offerings being considered for certification by ASTM to serve these options by constructing a series of "design cases" for four alternative jet fuel (AJF) pathways – Garcia-Perez, Zhang
  - 3.2 Identify potential intermediates (e.g. bio-oil, sugars, densified feedstock, etc.) and co-products (e.g. biochemicals, carbon, etc) for each pathway – Garcia-Perez, Zhang
  - 4.2 Inventory biorefinery infrastructure for production with an emphasis on retrofit - Wolcott
  - 4.3 Refine and deploy the biogeophysical (e.g. feedstock production, transportation and production infrastructure, demand centers) and social asset (e.g. key measures of collective action, leadership, demographics) decision tools under development in the NARA project to aid in facility siting decisions – Gaffney
  - 5.2 Assess key aviation fuel supply chain stakeholder perceptions regarding the conditions necessary for the adoption and diffusion of AJF -Gaffney

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- P.I.(s): Michael P. Wolcott, Regents Professor; Michael Gaffney, Director, DGSS; Manuel Garcia-Perez, Associate Professor; and Xiao Zhang, Assistant Professor
- FAA Award Number: 13-C-AJFE-WaSU-006
- Period of Performance: August 1, 2015 to July 31, 2016
- Task(s):
  - WSU.1 Review and use of design cases for standalone AJF production facilities.
  - WSU.2 Evaluation of most promising bio-refinery concepts for AJF production.
  - WSU.3 Supplement the current inventory of biorefinery infrastructure identified in the conversion design cases that are useful for production of AJF.
  - WSU.4 Continue work on social asset decision tools developed in Phase 1 for plant siting (Community Asset & Attribute Model—CAAM) through additional statistical testing and case study validation. Extend application to full NARA region and another US region (e.g. MASBI or Chesapeake). Prepare for extension nationally & replication for select EU countries.
  - WSU.5 Refine and deploy the facility siting tools for determining regional demand and potential conversion sites to be used in regional analyses.

- o WSU.6 Complete assessment of key aviation fuel supply chain stakeholder perceptions regarding the conditions necessary for the adoption and diffusion of AJF in the NARA region. Assess perceptions in another US region (e.g. MASBI or Chesapeake)

Project Funding Level

Year 1: $400,00 FAA funding and $400,00 matching funds. Source of matching funds are $100,000 from CLH Aviation, Madrid, Spain; $250,000 from BioJet Canada Team – a project under Transport Canada's Clean Transportation Initiatiave; and $50,000 Washington State University salary contribution.

Year 2: $370,00 FAA funding and $370,00 matching funds. Source of matching funds are $100,000 from CLH Aviation, Madrid, Spain; and approximately $270,000 Washington State University salary contribution. Additional cost share is planned to be obtained from external partners that will participate in the review of the design cases (Petroleum refineries, pulp and paper mills, sugarcane mills, and corn ethanol mills).

Investigation Team

Leads:

- Michael Wolcott – Washington State University
- Paul Smith – The Pennsylvania State University

Other Lead Personnel:

- Jody Endres – University of Illinois
- Robert Malina –Massachusetts Institute of Technology
- Tim Rials – University of Tennessee, Knoxville
- Tom Richard – The Pennsylvania State University
- Wallace Tyner – Purdue

Other WSU Research Personnel:

- Manuel Garcia-Perez, Co-I
- Michael Gaffney, Co-I
- Xiao Zhang, Co-I
- Kristin Brandt – Research Engineer

Project Overview

Year 1: This research effort has two objectives. The first objective is to develop information on regional supply chains for use in creating scenarios of future alternative jet fuel production. Outputs from this project will be used as inputs to a regional supply chain analysis tool being developed by the Volpe Center. The second objective is to identify the key barriers in regional supply chains that must be overcome to produce 1-billion gallons of alternative jet fuel by 2018 and an order of magnitude larger production in the longer term.

Year 2: This research will develop analyses of (1) design cases for conversion pathway, (2) social attitudes and industrial fuels logistics to benefit (3) regional supply chain analyses of an emerging alternative jet fuel industry aimed at reducing aviation greenhouse gas emissions.

Task 3.1 Evaluate the current alternative jet fuel (AJF) pathways, fuel properties, feedstock requirements, and commercial offerings being considered for certification by ASTM to serve these options by constructing a series of "design cases" for four alternative jet fuel (AJF) pathways

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Objective(s)

Include a description of the task and the goal(s) of this research.

Specific Objectives: While delineating the needs and requirements of the various AJF pathways, the specific objectives of Task 3 are to:

- Build design cases for alternative jet fuel (AJF) production technologies and existing infrastructure that could help with the growth of this industry (pulp and paper mill, sugar cane mills, corn ethanol plants and petroleum refineries);
- Identify routes to generate value added chemical along with fuel production;
- Identify potential synergisms of AJF production technologies with existing infrastructure;
- Generate and analyze the alternatives to produce aviation fuels in the two supply chain regions; and
- Identify technical gaps.

Research Approach

Background: While the US Federal Aviation Administration (FAA) targets to reach carbon neutral growth by 2020, the International Airline Industry Association (IATA) aims to a net reduction of 50 % of CO2 emissions relative to the 2005 baseline by 2050 [1]. Meeting the ambitious goal of reducing green house emissions by 50 % of the 2005 levels will require changes in the aircraft design and the extensive use of alternative fuels with low environmental impact [1]. A strategy to create scenarios for economical alternative jet fuel production should include the addition of biofuel modules or technologies to the existing infrastructure [2,3,4,5]. This requires the analysis of many potential schemes integrating technological modules within a clear strategy to diversify products, reduce environmental impact and maximize socio-economic impact [6,6,7]. Today there are three technologies approved by ASTM (ASTM D7566) to produce alternative jet fuels [8]: (1) Hydroprocessed Ester and Fatty Acid (HEFA) [8,9,10,11], (2) Fischer Tropsch (FT) [11,12,13,14,15,16], and (3) Direct Sugars to Hydrocarbons (DSHC | Amyris [17,18]. In addition, the (4) Alcohol to Jet (ATJ | Gevo) [19,20] pathway is under consideration and expected to be balloted in 2014 [21]. Finally, four additional pathways are under various stage of the ASTM process; these are (5) Hydrotreated depolymerized cellulosic jet (HDCJ | UOP, Kior) [22,23,24,25,26], (6) Synthesized kerosene containing aromatics (SKA | UOP), (7) Synthetic kerosene and synthetic aromatic kerosene (SK&SAK | Virent), and (8) Catalytic hydro-thermolysis (CH | ARA) [27].

Several authors have reported on the process of producing conventional and alternative jet fuels and their potential environmental impact [29,28,29,30,31]. Although several design cases have been published in the literature [9,10,11,26], the design criteria used vary considerably. The evaluation of all the alternative technologies under the same set of criteria is needed to gain an objective vision of the current state and potential of each of the technologies studied. To create scenarios of future alternative jet fuel production we also need a thorough understanding of the potential synergisms between the available feedstock (forest, agricultural and urban wastes or energy crops), existing infrastructure that could be leveraged to support the growth of this industry, and these emerging AJF technologies. Industrial infrastructure of particular interest includes pulp and paper mills [32], petroleum refineries [5,33,34], sugar cane mills [35], and corn ethanol plants.

The HEFA and FT pathways to produce AJF have already been studied by some of the PARTNER members [9,10,11,12]. In this task we will focus on the other 6 pathways (HDCJ, SK&SAK, AJF, DSHC, SKA and CH) as well as on four of the existing technologies (pulp and paper mills, sugarcane mills, corn ethanol mills, and petroleum refineries) that could be retrofitted to facilitate the deployment of AJF production units in the United States.

Subtask 3.1: Development of design cases: The design cases for the technologies studied will be built by two Post-docs, two PhD students and two teams of chemical engineering students working in their capstone projects. Each design case will have the following components:

- Feedstock requirement (Availability and feedstock composition)
- Flow diagram of technology
- Companies commercializing the technology (level of maturity)
- 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)
- Literature review on papers reporting data relevant to the operation of the technology (operating conditions, type of reactor used, catalysts, yield of products)

- Properties of Jet fuel produced
- 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
- Literature review on alternatives to use biofuel intermediates in Petroleum refineries or another existing infrastructure.
- Literature review on techno-economic analyses conducted with the technology
- Construct ASPEN based process modeling diagrams for mass and energy balances. Estimation of production and consumption indexes (fuel, and water consumption, CO2 production)
- Construction of simplified block diagram of the system for high level mass and energy balances
- Identification of Technological Challenges and Gaps

Responsible: Manuel Garcia-Perez (HEFA, FT, HDCJ, SK&SAK, Petroleum Refinery), Xiao Zhang (AJF, DSHC, SKA, CH, Pulp and Paper).

Subtask 3.2: Building a platform (Integration of Block diagram in MS Excel) to study AJF production alternatives.
Responsible: Manuel Garcia-Perez and Xiao Zhang

Subtask 3.3: Generation and technical analysis of alternatives to produce AJF in the two supply chain regions.
Responsible: Manuel Garcia-Perez, Xiao Zhang and Michael Wolcott

Milestone(s)
Literature search complete for all pathways and design cases
Draft design cases complete for all pathways and design cases
Internal reports reviewed by team members

Major Accomplishments
None – Task in Progress

Publications
None – Task in Progress

Outreach Efforts
None – Task in Progress

Awards
None – Task in Progress

Student Involvement
- Pulp and Paper: PhD Student Senthil Subramaniam and an undergraduate team (Ameen Alali, Brady Seroshek, David Fugiel, Leon Li, Min Zheng).
- Alcohol-to-Jet (ATJ): An undergraduate team (Alex Hadera, Luda Ledsukin, Armin Mehinagic, Serah Njau) worked with PhD candidate Scott Geleynse.
- Catalytic Hydrothermolysis (CH): PhD students Senthil Subramaniam and Mond Guo compiled an overview of the CH process and detailed analysis of process conditions.
- Direct Sugars to Hydrocarbon (DSHC): An undergraduate team (Joe Evans, Roger Kim, Lindsey Malkames, Matt Tyler, Jenny Voss) worked under supervision of PhD candidate Carlos Alvarez-Vasco.
- Fisher-Tropsch Synthesied Kerosene Containing Aromatics (FT-SKA): An undergraduate team (Alex Dunsmoor, Kirstin Egerton, Lara Heersema, Chris Huff) and PhD students Senthil Subramaniam and Ruoshui Ma led the design case, an overview of the process and conditions and industrial options.
- Synergy for the production of Jet Fuel in Sugarcane Mills: Research associate Jonathan Pulgarin-Leon led the design case for this technology. He has compiled literature and developed the mass and energy balances of the technology.

- Hydrotreated Depolymerized cellulosic Jet (HDCJ): This design case was also assigned to Jonathan Pulgarin-Leon. He has compiled literature and developed the mass and energy balances.
- Synergy for the production of jet fuel in Dry Mill: PhD candidate Tanzil Hossain completed this design case. He has conducted a literature review and the mass and energy balances.
- Synergy for the production of jet fuel in a Petroleum Refinery: An undergraduate team (Mohammad Abdulelah, Ali Alramadhan, Shawn Elder, Parker Scott) worked under the supervision of Jonathan Pulagrin-Leon.

Plans for Next Period

- The group working with Dr. Garcia-Perez (PhD candidates: Tanzil Hossain and Jonathan Pulgarin) will work this year on the evaluation of potential cost reductions that could be achieved if jet fuel is produced taking advantage of existing infrastructure (dry mill corn ethanol, petroleum refinery and sugarcane mill).
- The group working with Dr. Zhang will compare the performance of alternative jet fuel production concepts studied
- Complete the industrial review of case design reports.
- Prepare draft manuscripts to present a high level comparison of different AJF pathways and potential integration of selected AJF pathway (i.e. ATJ) to pulp and paper mill infrastructure.

Task 4.2 Inventory biorefinery infrastructure for production with an emphasis on retrofit

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Objective(s)

Include a description of the task and the goal(s) of this research.

Specific Objectives: While assessing the existing assets for potential conversion to biorefineries, the specific objectives of Task 4.2 and 4.3 are to:

- Compile and combine existing databases of industrial assets useful to the mid-stream components of biofuels supply chain. These include but are not exclusive of pulp and paper facilities, sugar refineries, corn ethanol plants, biodiesel production, etc.;
- Work with Volpe to assess downstream oil refining and blending capacity;
- Work with Volpe to compile market centers and requirements.
- Work with PSU on developing social asset decision tools for plant siting

Research Approach

Background: One of the largest barriers to large-scale production of all bio-fuels is the high-capital costs of greenfield facilities translating to risk in the investment community [36]. The capital costs of cellulosic ethanol plants range from $10-13/gal capacity [39]. The additional process steps required to convert the intermediate to a drop-in AJF could increase this cost to over $25/gal capacity [37]. The realities of these initial commercialization efforts into second-generation biofuels have led to studies that envision alternate conversion scenarios including transitioning existing facilities [38]. Gevo is employing retrofit strategies of corn ethanol plants for producing isobutanol, a potential intermediate for the alcohol-to-jet process of producing iso-paraffinc kerosene [20,21]. Research to envision scenarios to achieve the FAA aspiration goal of AJF consumption relied upon “switching” scenarios where existing and planned capacity would be used for producing the drop-in fuel [39]. 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 [40,41].

Subtask 4.2: Inventory biorefinery infrastructure for production with an emphasis on retrofit
Responsible: Michael Wolcott

- Compile existing databases available from a number of sources will be assessed for use and validity. Useful examples include: Wood2Energy.org, EthanolProducers.com, BioDieselmagazine.com

- Assess valuable capital components of facilities based on databases, public records, and direct contact. Examples include, capacity of feedstock storage, fermentation capacity, wastewater treatment, energy production, hydrogen production, etc.
- Develop site selection decision matrix and weighting factors
- Conduct primary level GIS analysis using algorithm developed above.

Milestone(s)
National databases are compiled, geolocated, validated and shared for biodiesel, corn ethanol, energy pellet, pulp & paper, and sugar mill production.

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

Publications
None – these are shared assets for later analyses

Outreach Efforts
None – these are shared assets for later analyses

Awards
None – these are shared assets for later analyses

Student Involvement
None

Plans for Next Period
This task is complete for these assets

Task 4.3 Refine and deploy the biogeophysical (e.g. feedstock production, transportation and production infrastructure, demand centers) and social asset (e.g. key measures of collective action, leadership, demographics) decision tools under development in the NARA project to aid in facility siting decisions
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Objective(s)

Specific Objectives: While assessing the existing assets for potential conversion to biorefineries, the specific objectives of Task 4.2 and 4.3 are to:
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- Work with Volpe to assess downstream oil refining and blending capacity;
- Work with Volpe to compile market centers and requirements.
- Work with PSU on developing social asset decision tools for plant siting

Research Approach

Include a description of the approach to this research, including literature reviews, methodology, data analysis, experiments, etc. This section can be broken up into smaller sections, e.g. introduction, methodology, etc. Please use subheadings as indicated if needed. Please center-align all figures, figure titles, and figure captions.

Subtask 4.3: Refine and deploy the biogeophysical (e.g. feedstock production, transportation and production infrastructure, demand centers) and social asset (e.g. key measures of collective action, leadership, demographics) decision tools under development in the NARA project to aid in facility siting decisions

Building on two iterations of the CAAM model developed under the NARA project, the ASCENT applications for this subtask include substituting original data for previously-used aggregated sources, statistically testing and validating the model, refining the comparative benchmarks used to establish county-level ratings on the three community capitals (Social, Human, Cultural) previously incorporated into the model, and collecting case study information for use in further validation of the model's efficacy. The research remains focused on refining a model which is based on readily available national datasets (aggregated at the county level) which can be used to conduct a preliminary assessment of community characteristics for three (Cultural, Social, Human) of the seven "Community Capitals" framework. (Emery, Mary and Cornelia Flora. 2006. "Spiraling Up: Mapping Community Transformation with the Community Capitals Framework." Journal of the Community Development Society, Vol. 37, p. 22.) which informs the NARA project.

Milestone(s)

CAAM v.3.0 statistically analyzed and validated

Major Accomplishments

During this reporting period The CAAM v.3.0 has been researched, statistically analyzed, and validated against other pre-existing local and regional datasets from the NARA region. This version of the model was presented at the NARA annual meeting, and demonstrated the capacity to present a county-level rating, against a regional norm, on each of the three relevant community capitals. In addition, this version has been presented and discussed at several forums, including the Pacific Northwest Political Science Association annual conference, and the International Bioenergy and Bioproducts Conference. A number of potentially suitable case study sites have been identified, and data on those case studies is being collected and analyzed for another validation of application of the model to specific situations and locations. This will result in a fourth, more robust, version of the model, which will also include a fourth community capital – political capital.

Publications

None – these are shared assets for later analyses

Outreach Efforts

None – these are shared assets for later analyses

Awards

None – these are shared assets for later analyses

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Student Involvement

Sanne Rijkhoff, Ph.D. candidate in Political Science, held a funded Research Assistant position working on this project, helped develop the second and third iterations of the CAAM model, and contributed to outreach and publication efforts. Dr. Rijkhoff obtained a faculty position at Portland State University following her graduation in 2015.

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, further validation of the model, and the (continuing) development of the fourth iteration of the CAAM.

Plans for Next Period

In the next year, a fourth iteration of the CAAM will be fully developed, validated, and applied in the NARA region, with expansion to other regions. This model will be based upon:

1. Primary source data replacing the Creative Vitality aggregate measure previously used so as to support more robust and focused analyses and modelling.
2. Addition of new data so support addition of the fourth Political Capital to the model.
3. Final validation, after statistical confirmation, using selected case studies to confirm the efficacy of the model.

The Fourth CAAM will be available for use nationally, allowing comparison of counties against regional norms on Cultural, Social, Human, and Political Capital scales that have been statistically tested and validated through triangulated testing with external data.

Task 5.2 Assess key aviation fuel supply chain stakeholder perceptions regarding the conditions necessary for the adoption and diffusion of AJF

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

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