Project 001(C) Alternative Jet Fuel Supply Chain Analysis

The Pennsylvania State University

Project Lead Investigator

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University Participants

The Pennsylvania State University

- Project: A Techno-Market Analysis of U.S. Biorefinery Supply Chains from Feedstock to Alternative Jet Fuels
- P.I.(s): Paul M. Smith, Tom Richard
- FAA Award Number: FAA Cooperative Agreement No. 13-C-AJFE-PSU, Amendment 002
- Period of Performance: August 1, 2014 – December 31, 2015
- Tasks:
    - 3.3 (Lead: Wolcott and Richard; supported by Clifford) – Evaluate commercial options for biofuel intermediates insertion into petroleum refineries for conversion to AJF. PSU will identify and evaluate commercial biomass feedstocks or bio-based intermediates that could be inserted in a refinery or be converted to alternative jet fuel with minimal processing.
    - 4.3 (Lead: Wolcott; supported by Smith and Gaffney) - Refine and deploy the biogeophysical (e.g. feedstock production, transportation and production infrastructure, demand centers) and social asset (key measures of collective action, leadership, demographics) decision tools under development in the NARA project to aid in facility siting decisions. Based on key measures of collective action, leadership, and demographics, PSU is working with WSU in developing a Community Asset Assessment Model (CAAM) as part of the NARA project. This quantitative tool will be refined, re-weighted, re-calibrated, and applied to the MASBI region.
    - 5.1 (Lead: Smith; supported by Wolcott) - Examine the role of biorefinery product portfolios and new product/market development to delineate opportunities to add value and mitigate financial risk. PSU will identify and characterize U.S. biorefineries via secondary and primary data collection to examine value stream outputs.
    - 5.2 (Lead: Smith; supported by Gaffney and Ibarrola) – Assess key aviation fuel supply chain stakeholder perceptions regarding the conditions necessary for the adoption and diffusion of AJF. PSU will direct the work of Gaffney and Ibarrola to collect primary data via interviews and surveys to better understand key aviation fuel supply chain stakeholder awareness, opinions, and perspectives regarding to the potential impacts and key success factors for an economically viable biojet fuel production industry in the NARA and MASBI U.S. regions.
    - 7.1 (Lead: Richard; coordinated with ORNL) - Implement an open-access data platform to facilitate supply chain model improvement and comparison toward a global standard of practice for AJF development. PSU

will coordinate with ORNL to develop a common framework that facilitates transparent and open data access for supply chain model intercomparison and improvement relevant to the jet fuel sector.

Project Funding Level

FAA Funding: $200,000.
Matching:
CLH Aviation (Madrid, Spain) - $100,000;
Delta - $80,000;
Penn State - $24,218.
Total Funding: $404,218

Investigation Team

- Task 3.3: Michael Wolcott, WSU; Tom Richard, PSU; Caroline Clifford, PSU
- Task 4.3: Michael Wolcott, WSU; Paul Smith, PSU; Michael Gaffney, WSU; Season Hoard, WSU; Wenping Shi, Postdoc, PSU
- Task 5.1: Paul Smith, PSU; Michael Wolcott, WSU; Min Chen, PhD candidate – funded primarily on USDA funds (NARA)
- Task 5.2: Paul Smith, PSU; Michael Gaffney, WSU; Ibon Ibarrola, CLH; Wenping Shi, Postdoc researcher – part time on FAA ASCENT.
- Task 7.1: Tom Richard, PSU; coordinated with ORNL)

Project Overview

3.3. Evaluate commercial options for biofuel intermediates insertion into petroleum refineries for conversion to AJF. Identify and evaluate commercial biomass feedstocks or bio-based intermediates that could be inserted in a refinery or be converted to alternative jet fuel with minimal processing.

4.3. Refine and deploy the biogeophysical (e.g. feedstock production, transportation and production infrastructure, demand centers) and social asset (key measures of collective action, leadership, demographics) decision tools under development in the NARA project to aid in facility siting decisions. Based on key measures of Social Capital (capacity for collective action, Cultural Capital (creative vitality & leadership), and Human Capital (demographics), PSU and WSU are developing a Community Asset Assessment Model (CAAM) as part of the NARA project. This quantitative tool will be refined, re-weighted, re-calibrated, and applied to the MASBI region.

5.1. Examine the role of biorefinery product portfolios and new product/market development to delineate opportunities to add value and mitigate financial risk. Identify and characterize U.S. biorefineries via secondary and primary data collection to examine value stream outputs.

5.2. Assess key aviation fuel supply chain stakeholder perceptions regarding the conditions necessary for the adoption and diffusion of AJF. Collect primary data via interviews and surveys to better understand key aviation fuel supply chain stakeholder awareness, opinions, and perspectives regarding to the potential impacts and key success factors for an economically viable biojet fuel production industry in the NARA and MASBI U.S. regions.

7.1 Implement an open-access data platform to facilitate supply chain model improvement and comparison toward a global standard of practice for AJF development. PSU will coordinate with ORNL to develop a common framework that facilitates transparent and open data access for supply chain model inter-comparison and improvement relevant to the jet fuel sector.

Task 3.3

Penn State and Washington State

Objective(s)

Evaluate commercial options for biofuel intermediates insertion into petroleum refineries for conversion to AJF.

Research Approach

Introduction

Using an extensive literature review, PSU identified and evaluated commercial biomass feedstocks and bio-based intermediates that could be inserted in a refinery or be converted to alternative jet fuel with minimal processing. The evaluation considered bio-based liquids at three insertion points: 1) "bio-crude" introduced at the front of the refinery for crude processing with petroleum, 2) refinery-ready liquids inserted after crude processing and utilizing conversion and/or finishing unit operations to upgrade the bio-based liquids into fuels, and 3) blend-ready fuels that are inserted during blending to upgrade low-value refinery streams, improve specifications, and take advantage of blending, storage and distribution capacity. Unit operations and process opportunities and constraints were assessed for a range of bio-based liquids relevant to alternative jet fuels.

Milestone(s)

A draft of the report was completed in July 2015 and shared with Delta Airlines in October 2015.

Major Accomplishments

The accomplishments of this task (Task 3.2) will provide the project and stakeholders with a clearer understanding of the options, pros and cons of integrating bio-based feedstocks in a conventional petroleum refinery. Our hope is that Delta will implement one or more of these options for a demonstration at their refinery.

Publications

A Technical Report was developed for discussion with Delta Airlines. This document will form the basis for a publication in the coming year.

Outreach Efforts

Results and recommendations from the Literature Review were communicated to Delta Airlines in October 2015. We have also initiated discussions with Rich Altman of the Commercial Aviation Alternative Fuels Initiative (CAAFI) and the Farm to Fly 2 (F2F2) program. Rich is working with the University of Virginia on distribution systems of alternative fuels to airports in the greater Washington DC area. We had an introductory teleconference with that group in September 2015 had a face-to-face meeting with that group in Virginia in October 2015.

Awards

N/A

Student Involvement

N/A

Plans for Next Period

In the next 3 months we will continue discussions with Delta Airlines about possible bio-based feedstock procurement and integration strategies for their refinery.

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Task 4.3

Penn State and Washington State

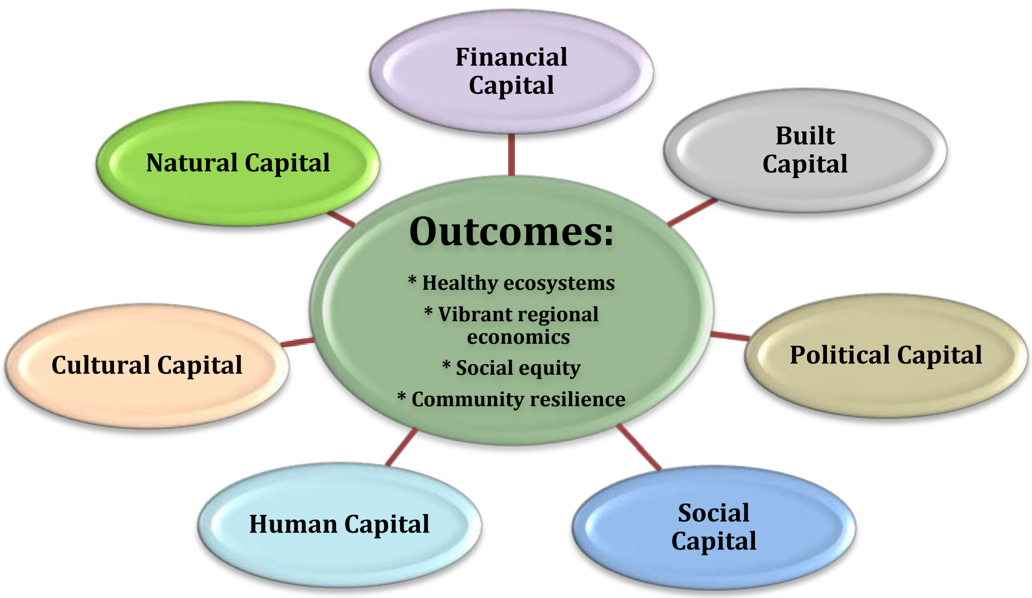
Objective(s)

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

Research Approach

Introduction

Based on key measures of Social Capital (capacity for collective action), Human Capital (Health, Education, Language), and Cultural Capital (creative vitality) which address three of the seven "Community Capitals", WSU and PSU have continued the development of the Community Asset Assessment Model (CAAM) which was originally developed as part of the NARA project. The Community Capitals framework is based on the work of Emory and Flora ("Spiraling Up: Mapping Community Transformation with the Community Capitals Framework." *Journal of the Community Development Society*, Vol. 37, p. 22. 2006). This framework posits that a complete assessment of any community must address seven capitals (see bel0w). The current CAAM model addresses three of the seven.



a. **What was accomplished under the goals?**

This quantitative tool has been refined, re- weighted, re-calibrated, and is now being validated with selected case study comparisons. It provides a three-pronged rating at the county level for nearly every county in the country, and has been used to inform siting decisions for the NARA project. It can currently be applied to any region. Further refinement and validation will enhance confidence in the model as a decision-support tool.

Specifically, the current iteration of the model contains 542 column variables for each 3,108 counties in the United States. These variables were compiled from three separate national studies. These studies are the WESTAF study on creative vitality, which is used as a proxy for Cultural Capital, the Rupasingha study on Social Capital, and the Robert Wood county health rankings data set. Each of these data sets has been updated as more recent data become available. Combining the three data sets and initial validation occurred under the NARA project. Validation was conducted using comparisons to existing regional survey data maintained by WSU, and "ground-truthing to newly-collected primary data from surveys and interviews in the NARA region. Further validation is now underway as part of this project using case-study comparisons to test the efficacy of the current iteration of the CAAM model.

b. **What Major Activities were executed during this period?**
In addition to the research, statistical analysis and validation work done to develop the refined "version three" of the CAAM now available for use, this version has been presented and discussed at several forums, including the Pacific Northwest Political Science Association annual conference, the NARA annual meeting, and the International Bioenergy and Bioproducts Conference. One article has been submitted for peer review publication, and two more are either planned or in draft form. Final Case study validation will complete development of the three-capital model.

Based on feedback from other researchers, ASCENT leadership, and the process of validation and model development, the research team will add a fourth capital: Political Capital, to the model. Data source identification is underway, as is conceptual development of model components and statistical approaches. Addition of Political Capital will result in a model which addresses the four social components of the Community Capital framework. Taken in conjunction with the more fully-developed Bio-Geo-Physical model, ASCENT researchers will now have the only known quantitative decision-support tool which addresses all seven capitals.

Outreach Efforts
N/A

Awards
N/A

Student Involvement
N/A

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Task 5.1
Penn State

Objective(s)
Examine the role of biorefinery product portfolios and new product/market development to delineate opportunities to add value and mitigate financial risk.

Research Approach

Introduction
Population growth and attendant demand for energy and environmentally-friendly products are straining conventional non-renewable resources. The world's dependency on fossil fuels, much of which are imported from unstable sources, is under scrutiny. Bio-based economy, instead, addresses both supply and demand issues, and offers the promise of various benefits related to energy security, environmental benefits and economics (Hoekman, 2009). The bioeconomy, defined by Golden & Handfield (2014), is "…the global industrial transition of sustainably utilizing renewable aquatic and terrestrial resources in energy, intermediate, and final products for economic, environmental, social, and national security benefits."

Biorefineries (BRs) are systems that sustainably convert renewable resources to marketable energy, fuels and chemicals (Cherubini, 2010; Liu et al., 2012). Overall, our research focuses on the U.S. biofuel BR industry, and special attention is paid to cellulosic biofuels. While a significant demand is present for the conversion of lignocellulosic feedstocks into renewable transportation fuels, cellulosic BRs face an uncertain future. Several high entry barriers have constrained their development, including, sustainable feedstock supply, untested technologies, large capital costs per unit of production, and policy uncertainties (Coyle, 2010; Pacini et al., 2014). In practice, KiOR's bankruptcy in November 2014 and Cobalt's asset auction in June 2015 signals the incredible difficulty for cellulosic biofuel startups to scale up and to survive the so-called "Valley of Death" (Jenkins & Mansur, 2011). Researchers, therefore, indicate that innovative solutions are required to prompt the commercialization of cellulosic biofuels (Fiorese et al., 2013).

As mentioned by several studies, one potential solution to high entry barrier is to use initially less sophisticated technologies to produce multiple products, thus providing additional profit and financial incentives to biofuel production (Bozell & Petersen, 2010; Golden & Handfield, 2014). In fact, integrated production of cellulosic biofuels and bio-based chemicals is quite nascent. A search of literature identifies several factors that may affect the commercialization of cellulosic biofuels. Those driving factors include carbon emission reduction, government incentives, reduction of dependence on fossil fuels, food-vs.-fuel debate, and rural economic development; while the impeding factors include feedstock sustainability and costs, technology availability, competition, policy uncertainty, and sustainable customer demand (Cherubini & Strømman, 2011; Cox et al., 2010; Yue et al., 2014). What remains to be explored, however, are the factors affecting the successful integrated production of cellulosic biofuels and biochemicals.

The specific objectives of this research are to: 1) examine factors affecting the scale-up (commercialization) of 2nd Gen (cellulosic) biofuels; and 2) identify & evaluate factors affecting the integration of biochemicals to cellulosic biofuels BRs.

Methodology

Type of Study

This research consists of three major phases. Phase I focuses on population identification and key issues via literature review. Phase II – Integrated Cellulosic Biorefinery - is a mixed-methods exploratory design (Creswell & Clark, 2011) whereby the researcher first collects qualitative data, then analyzes it to further develop follow-up quantitative data collection instruments.

Sampling

Phase II – Integrated cellulosic biorefinery exploratory design. Expert elicitation, used in a wide range of areas, will be deployed (Ayyub, 2001; Fiorese et al., 2013; Hughes, 1996) and has become increasingly commonplace to elicit hidden information, provide useful insights regarding important uncertainties and to make funding or policy decisions (Baker & Keisler, 2011; Fiorese et al., 2013; Oltra, 2011).

The Phase II qualitative survey will query experts with related knowledge and professional backgrounds to gain insights. Experts will be selected from academic and industrial sectors and will consider tangible expert evidence, such as conference presentations and publications related to cellulosic biofuels and bio-based chemicals.

The follow-up quantitative survey will query attendees of relevant USDA National Institute of Food and Agriculture (NIFA) Agricultural and Food Research Initiative (AFRI) annual meetings (2015). The USDA-NIFA AFRI has provided approximately $150M in research funding to seven programs, including Bioenergy Alliance Network of the Rockies (BANR) led by Colorado State University, Advanced Hardwood Biofuels Northwest (AHB) led by University of Washington, Sustainable Bioproducts Initiative (SUBI) led by Louisiana State University, CenUSA led by Iowa State University, Southeast Partnership for Integrated Biomass Supply Systems (IBSS) led by University of Tennessee, the Northeast Woody/Warm-season Biomass Consortium (NewBio) led by Pennsylvania State University, and Northwest Advanced Renewable Alliance (NARA) led by Washington State University. The attendees of these annual meetings represent a unique set of knowledge and experience on all aspects of biorefinery supply chains. Researchers have determined that the following five USDA-NIFA AFRI CAPs will provide adequate coverage and provide a more manageable time schedule for data collection: NewBio at Morgantown, WV on August 3-5, 2015, IBSS at Auburn University on second week of August 10, 2015, AHB at Seattle on September 9-10, 2015, NARA at Spoken, WA on September 15-17, 2015, and BANR at Missoula, MT on Oct. 14-16.

Data Collection

Phase II – Integrated cellulosic biorefinery exploratory design. For qualitative data collection, primary data collection instrument used online-based survey with the advantage of decreased costs, time-saving and increased access to geographically dispersed subjects (Burns, 2010; James, 2007).

For quantitative data collection, the researcher is contacting USDA AFRI CAPs conference organizers to explain the study and acquire permission and support for administering the paper-based survey at relevant conferences.

Data analysis

Phase I – Population Identification. With technology advancement and more feedstock availability, the U.S. biofuel biorefineries (BRs) are evolving into different categories. Currently, 408 U.S. biofuel BRs have been identified via secondary research. These BRs may be classified into four major groups by feedstock input: *Corn Ethanol Biorefineries* (n=207), *Biodiesel Biorefineries* (n=154), *Cellulosic Biofuel Biorefineries* (n=41), and *Algae Biofuel Biorefineries* (n=6).

Because of mature commercial market, corn-grain ethanol is a major player in the U.S. biofuels industry. In 2014, 207 corn-grain ethanol BRs produced over 14 billion gallons of ethanol in the United States. Due to similar performance and lower lifecycle GHG emissions compared to petro-based diesel, pure biodiesel (B100) production totaled approximately 1.27 billion gallons with the United States in 2014 (EIA, 2015). However, the growth of the U.S. first generation biofuels (mainly corn-grain ethanol and biodiesel) is impeded by increased pressure from the "food-versus-fuel" debate and ethanol "blend wall". Cellulosic biofuels and algae biofuels, thus, have gained momentum to enter the U.S. biofuels industry (Schnepf, 2010). Compared to corn ethanol, cellulosic biofuels have several advantages in terms of the use of non-food based feedstocks and lower lifecycle greenhouse gas (GHG) emissions (Balan et al., 2013; FitzPatrick et al., 2010). However, cellulosic alcohol BRs face an uncertain future due to high entry barriers, including, sustainable feedstock supply, advanced technologies, large capital costs per unit of production, and policy uncertainty (Coyle, 2010; Pacini et al., 2014). In practice, only four cellulosic biofuel BRs have achieved commercial-scale production, for example, Abengoa Bioenergy 25 million gallons per year (MGY) on Oct., 2014, INEOS Bio 8 MGY on July, 2014, Quad County Corn Processors 2 MGY on July, 2014, and POET-DSM 25 MGY on Sept., 2014.

Facing these entry barriers, we would suggest that future progress in the U.S. biofuels industry is dependent on hydrocarbon biofuels, which are drop-in replacements for gasoline, diesel, and jet fuel. Another way to scale up the U.S. advanced biofuels industry is to diversify value stream outputs, for example, bio-based chemicals.

Phase II – Integrated cellulosic biorefinery exploratory design. For qualitative online survey, semi-structured surveys were sent to 45 experts in the EU and US in the Spring 2015. The response rate was 40% (n=18), as shown in Fig. 5.1.1.

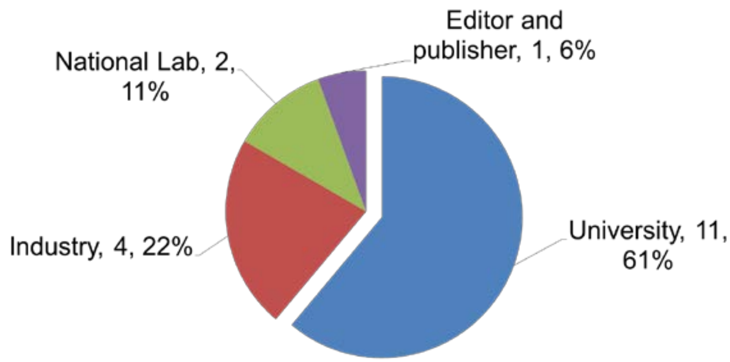

Fig. 5.1.1. Expert survey - participant information (sector, number, percentage)

Participants were provided 6 drivers and asked to rank them in terms of "…*the successful commercialization of the U.S. cellulosic biofuels industry*. Please rank them in order of importance from 1=the most important to 6=the least important". Next, participants were instructed to use a pull-down menu of 9 barriers, and asked to "…*indicate the 3 largest barriers to the successful commercialization of the U.S. cellulosic biofuels industry*". The results show that government incentives is the most important driver for the successful commercialization of cellulosic biofuels in transportation sector, with score achieving 4.61 out of 6. The second most important driver is volatile oil prices, scoring 3.72, and the third most important driver is carbon emission reduction which scores 3.67. The following drivers are reduction of dependence on fossil-fuel (score=3.22), added-value from non-fuel co-product (score=3.11), and rural economic development (score=2.67) (Fig. 5.1.2). Responses of the 3 largest barriers were weighted as follows: #1 barrier = 3 points; #2 barrier = 2 points; and #3 barrier = 1 point. Overall, the eighteen participants rated policy uncertainty as the most important barrier (total points = 25), followed by high production costs (total points = 22), and feedstock costs (total points = 17) (Fig. 5.1.3).

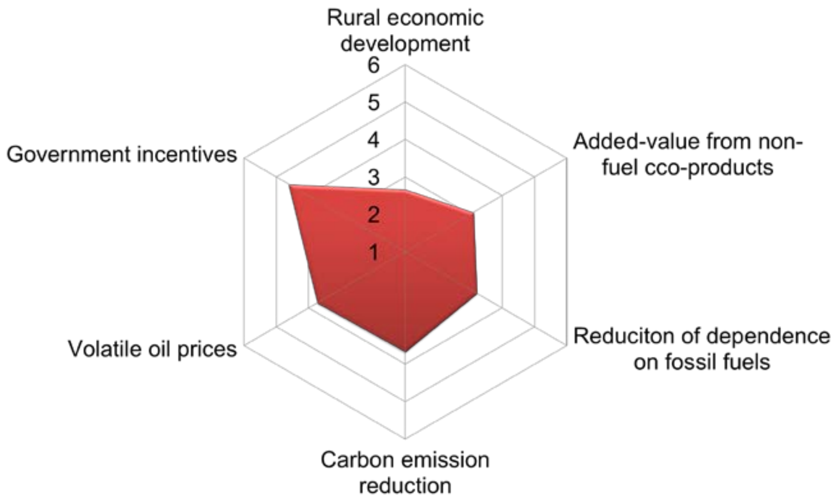

Fig. 5.1.2. Expert survey response - importance of drivers to the scale-up of cellulosic biofuels industry

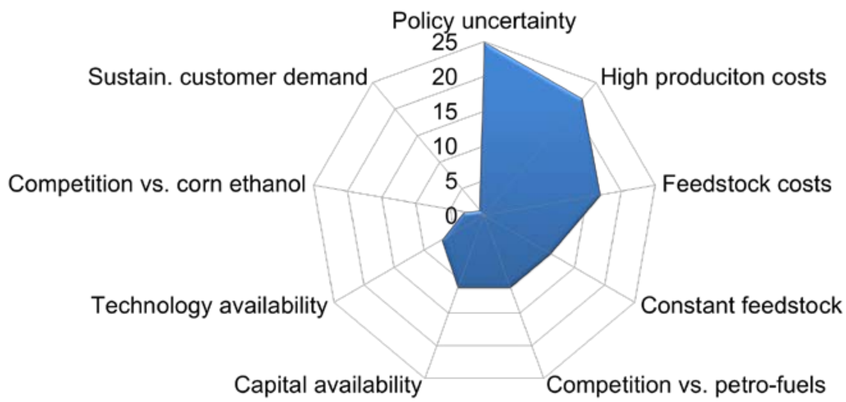

Fig. 5.1.3. Expert survey response - top 3 barriers to the scale-up of cellulosic biofuels industry

In the following two open-ended questions, participants were asked: "… *what are the most important drivers for the integrated production of cellulosic biofuels and biochemicals*?" & "…*what are the top 3 barriers to the integrated production*?" The solicited information is detailed in Fig. 5.1.4. Based on the results, the potential drivers for the integrated production of cellulosic biofuels and biochemicals include 1) profitability enhancement, 2) risk mitigation, 3) government support, 4) customer demand, and 5) market growth. The potential barriers include 1) Process complexity, 2) technology availability, 3) high production cost, 4) lack of capital investment, 5) policy uncertainty, 6) competition vs. petro-chemical, and 7) product/market expertise. Those identified drivers and barriers will serve as important constructs in the next phase of primary data collection.

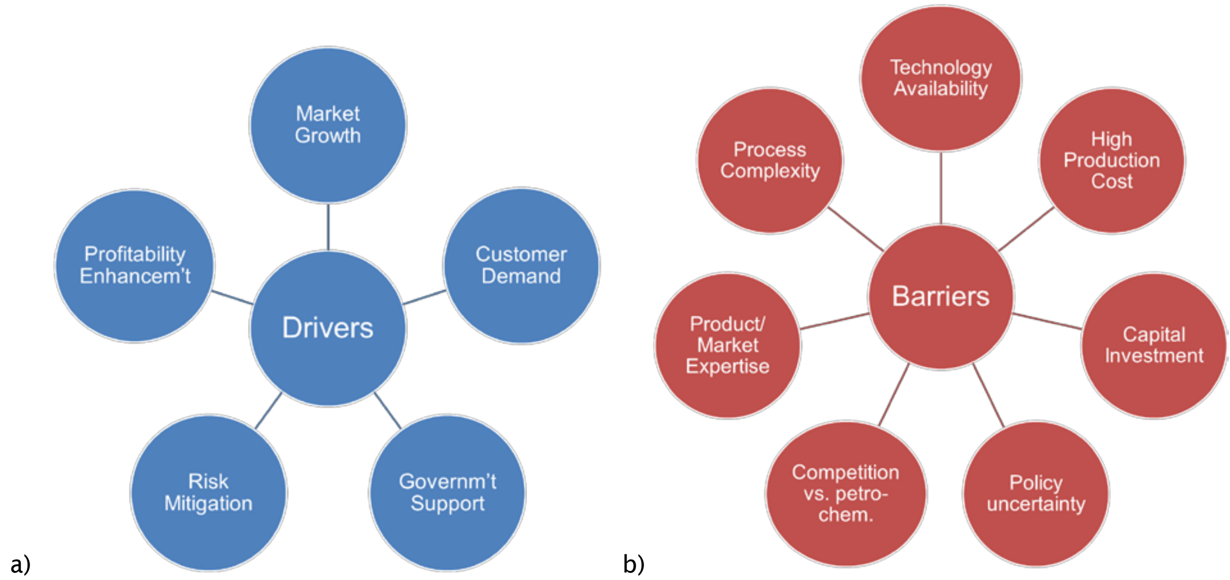

Fig. 5.1.4. Expert survey response - drivers (a) & barriers (b) to integrating biochemicals to cellulosic biofuels BRs

Finally, participants were asked: "*What is your best estimate of the percent of cellulosic biofuels accounting for the U.S. total renewable liquid fuels in the year 2020.*" and "*the percent of bio-based chemicals constituting the entire U.S. chemical market in 2020.*" The 18 expert respondents estimated the percentage of cellulosic biofuels accounting for the U.S. total renewable liquid fuels in the year 2020 at around 2.13%, if using mid-point of each range (Fig. 5.1.5-a). The estimated percentage of biochemical constituting the entire U.S. chemical market in the year 2020 is around 8.91%, if using mid-point of each range (Fig. 5.1.5-b).

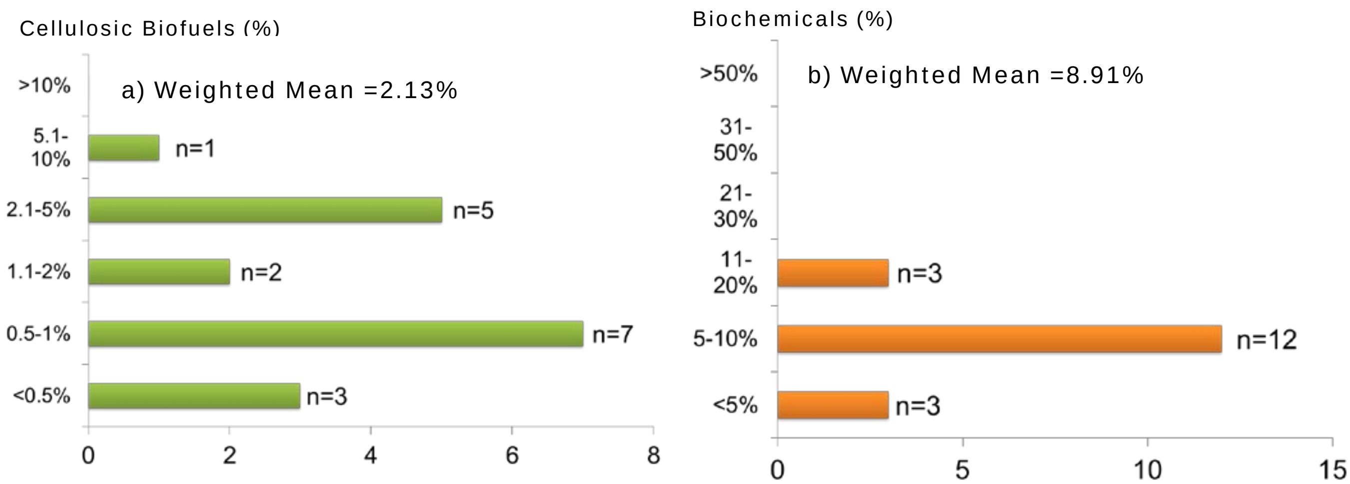

Fig. 5.1.5. Expert survey response - future penetration of (a) U.S. cellulosic biofuels; and (b) biochemicals

Milestone(s)

Key academic and industrial experts in US and EU have been identified via personal communications and secondary data search. A literature review on salient issues regarding the commercialization of cellulosic biofuel and the successful integrated production of cellulosic biofuel and biochemical has been completed. An expert elucidation survey is in-progress. Additional constructs of relevance are under development for a second phase of primary data collection to better understand strategic buyer-seller relationships in channels.

Major Accomplishments

Using secondary sources and GIS, the research team is:

1) Verifying U.S. biofuel & biochemical refineries to better understand their structure, conversion technologies, and value stream outputs – outlined in a peer-reviewed publication (in progress);
2) Examining key success drivers and scale-up barriers for the commercialization of cellulosic biofuel from secondary literature and, subsequently, via in-progress expert elucidation interviews.

Publications

None

Outreach Efforts

Chen, M., and P. Smith. 2015. Toward the Integrated Production of Cellulosic Biofuels and Biochemcials: Lessons Learned from the U.S. Corn & Cellulosic Ethanol Industries. Oral Presentation at the Year 4, NARA Annual Meeting, Spokane, WA. Sept. 15-17.

Chen, M., and P. Smith. 2015. Expert Elicitation on the Integrated Production of 2nd Gen (Cellulosic) Biofuels & Biochemicals. Poster presentation at the Year 4, NARA Annual Meeting, Spokane, WA. Sept. 15-17.

Awards

None

Student Involvement

This research is part of Min Chen's Ph.D. research. Min Chen has conducted a review and analysis of secondary information and developed/pre-tested questionnaires for primary data collection. Ms. Chen plans to graduate Summer 2016, after which she plans a career related to biofuels and biochemicals.

Plans for Next Period

In the next 3-4 months, investigators plan to complete primary data collection for phase II – integrated biorefinery exploratory design, analyze data and develop reports and publication(s).

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Task 5.2 "Refinery-to-Wing" Stakeholders Assessment

The Pennsylvania State University

Objective(s)

Assess key aviation fuel supply chain stakeholders' perceptions regarding the conditions necessary for the adoption and diffusion of Alternative Jet Fuel (AJF) in the Pacific Northwest Region (PNW). Specific issues like the barriers and drivers to blended AJF into the aviation supply chain and AJF molecules tracking and crediting are examined.

Research Approach

Introduction

Aviation Demand in the PNW Region

Jet fuel is the third-most used petroleum fuel in the U.S. after gasoline and diesel, with the 2013 U.S. consumption of 22 billion gallons, 135.5 billion gallons, and 58.7 billion gallons, respectively (EIA 2015) (Figure 1). The four-state PNW region consumed approximate 927 million gallons of jet fuel in 2013 (~4% of the U.S. total), of which Washington accounts for nearly 72% (~ 666 million gallons), followed by Oregon (21%), Montana and Idaho with about 7% combined (EIA 2013).

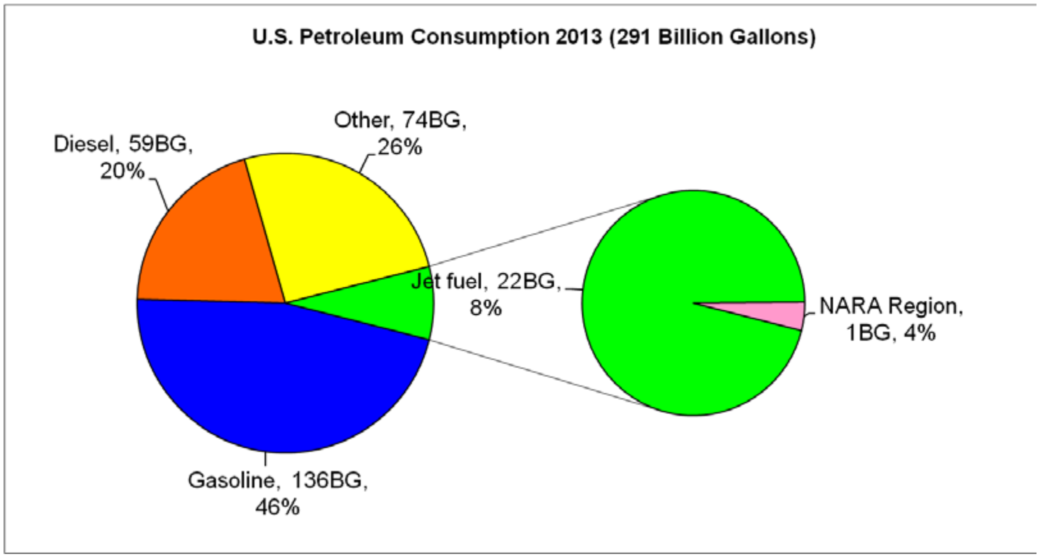

Figure 5.2.1. U.S. Petroleum Consumption and the PNW's share of U.S. Jet Fuel in 2013 (EIA 2015, EIA 2013)

Introduction of Sustainable Alternative Jet Fuels

The volatile crude oil price, political and public pressure on carbon emissions, more stringent environmental targets, growing global demand for air travel, and rural economic development goals have collectively driven research toward sustainable fuel alternatives (Gegg et al. 2014). One of the alternatives to petroleum is biofuel. Biofuel refers to fuels made from biomass, which is material produced from organic plant and animal feedstocks (Eisentraut et al. 2011).

One specific area within the biofuels sector is aviation biofuel, also known as Alternative Jet Fuel (AJF). The sheer scale of the petroleum industry has a massive impact on airlines. According to a report by the Sustainable Aviation Fuels Northwest (SAFN), a one dollar per gallon increase in the price of jet fuel costs the U.S. passenger and cargo airline industry $17.5 billion in operational costs annually (MacFarlane et al. 2011). As consumers have seen in recent years, a spike in fuel prices of one dollar per gallon is not uncommon. Thus, the volatility of the jet fuel prices has a tremendous impact on the airline industry as the fuel is one of their major costs.

As the fastest growing transport sector, aviation has a projected growth rate of 4% per annum and the number of airline passenger is estimated to be double from 2014 to 2034 (IATA 2015a). Currently, aviation accounts for 2-3% of global carbon emissions (FAA 2015a), and is responsible for 12% of CO2 emissions from all transport sources, compared to 74% from road transport (ATAG 2015). These percentages are expected to increase with the growth in operations unless mitigated with new technologies and standards, renewable fuels, operational improvements, and market based measures (FAA 2015a). The use of sustainable alternative jet fuel (SAJF) would significantly reduce the airlines' carbon footprint (Agusdinata et al. 2011). Accordingly, the global aviation industry has committed to ambitious targets to reduce their carbon emissions, including (ATAG 2015):

- 1.5% fuel efficiency improvement from 2009 until 2020;
- Carbon neutral growth from 2020
- A 50% reduction in carbon emission by 2050 relative to a 2005 level.

Sustainable Alternative Jet Fuel Market Opportunities

The aviation jet fuel market is different from the transportation sector in that it is expected to be high-growth, there are no viable electric or natural gas alternatives, it must be "drop-in", and be certified as entirely safe. In addition, accsss to distribution is facilitated by relatively few "filling stations", and customer pull is very strong in both the commercial and military sectors (ATAG 2012). There are roughly 160,000 gas stations in the U.S. alone vs. 190 airports worldwide which handle over 80% of the global fuel uplift (ATAG 2012). Of the total of 1,984 U.S. airports, 381 airports accounted for nearly 99% passenger boardings (enplanement) in 2014 (FAA 2015b).

In the PNW region, commercial airlines account for approximate 86% of region's total civil and military jet fuel demand and the military uses the balance (14%). Seattle-Tacoma International Airport (SEA) and Portland International Airport (PDX) accounted for 487MG (51%) and 153MG (16%), respectively (A4A 2015), representing the two dominant PNW airports.

In addition to the commercial aviation, other market segments exist for SAJF including military aviation, general aviation, airfreight carriers and postal carriers. The U.S. military may provide SAJF market opportunities due to its desire to incorporate alternative fuels into its energy security strategy. Defense Logistics Agency (DLA) Energy is the primary fuel purchaser for the U.S. military, accounting for more than 90% of all fuels utilized. In 2012, DLA purchased about 4.7 billion gallons of fuel, of which 75% represented jet fuel (Milbrandt et al. 2013).

Sustainable Alternative Jet Fuel Challenges
Although biofuels have been proven to be better for the environment in the form of reduced greenhouse gas emissions, challenges remain including high costs, unstable policy, environmental acceptance, capital requirements and supply chain issues. Today's SAJF are largely demonstration-oriented, produced batch-wise and delivered in dedicated consignments (Toop et al. 2015). As a result, reporting the physical use of SAJF has been straightforward for airlines. However, future scaled-up volumes of "drop-in" SAJF (ASTM D7566) will require full integration into conventional jet fuel storage and distribution systems for subsequent approval as ASTM D1655 Jet A, thus potentially requiring a mechanism for molecule tracking, crediting and trading.

Research Design
This task is conducting an examination of opinions and perceptions from key aviation supply chain stakeholder groups in the PNW region. A mixed methods approach was used.

- **Phase I - Population development.** First, the team identified key aviation fuel supply chain stakeholders (SHs) in the 4-state PNW region of Idaho, Montana, Oregon, and Washington. Key groups were identified through secondary data and exploratory interviews: airports with jet fuel service (airport managers), airlines, Fixed Based Operators (FBOs), fuel resellers and pipeline and terminals operators.

- **Phase II- Construct development and verification.** This phase consisted of literature review and exploratory interviews to examine key issues regarding the development and deployment of SAJF. Issues were developed into constructs for interview scripts and a questionnaire (eSurvey). Pretesting with key industrial experts was conducted to assess the applicability of the instrument's use and the precision of interpretation. Key issues included SH perceptions of barriers and opportunities to blended SAJF into aviation supply chain and SAJF molecule tracking, crediting and trading.

- **Phase III - Primary data collection**. eSurveys are in-progress to all identified PNW region airport managers (census) with jet fuel service (n=98). Interviews are also in progress and include approximately 20 select aviation fuel supply chain stakeholders from the large airports plus regionally representative medium-sized airports. Interviews are recorded and transcribed and participants receive the transcripts for their review, edits and approval.

Data Analysis – In progress.

Milestone(s)
Include a description of any and all milestones reached in this research according to previously indicated timelines.

Major Accomplishments
Include descriptions of the accomplishments in this research. Indicate what impact these accomplishments will have on the rest of the project.

To date, some major accomplishments include:
- Initial eSurvey efforts resulted in 26.5% response rate (n=26); additional eSurvey efforts are in-progress;
- 16 in-person interviews have been completed with airport managers, aviation fuel handlers, and pipeline operators with 12 approved transcripts and 4 transcriptions in progress;

The accomplishments of this task (Task 5.2) will provide the project with a better understanding of "refinery-to-wing" stakeholders' perceptions regarding the factors impacting the adoption and diffusion of SAJF into aviation supply chains in the PNW region. This regional effort is being extended to other U.S. regions and potentially other European regions (e.g., Spain). The population development at the national level is in progress.

Publications
N/A

Outreach Efforts
N/A

Awards
N/A

Student Involvement
N/A

Plans for Next Period
In the next 3-4 months, researchers plan to complete primary data collection (eSurveys and interviews) with aviation fuel supply chain stakeholders in the U.S. PNW region, analyze data and develop reports and (a) publication(s) for submission to peer reviewed journal(s). In addition, population and sample frame databases will be produced over the next 3-6 months to extend this work beyond the U.S. PNW region to another region and/or national coverage.

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Task 7.1

Penn State and ORNL

Objective(s)

Implement an open-access data platform to facilitate supply chain model improvement and comparison toward a global standard of practice for AJF development.

Research Approach

PSU worked throughout the year with the ASCENT-1 team to assure needed data is available and accessible. We developed a common framework that facilitates transparent and open data access for supply chain model intercomparison and improvement relevant to the jet fuel sector, using a Box.com folder system accessible only to team members. A data management plan with a formal data use agreement was written and reviewed by the team. Team members uploaded their data files and references into the data management system, while PSU staff assisted with the file naming conventions, cataloguing, and updating data files and reference material. Discussions were initiated with Laurence Eaton of ORNL (currently on assignment in Washington, DC). ORNL has agreed to provide a section of their Bioenergy Knowledge Discovery Framework for public distribution of ASCENT1 data, models and results. That section can be private and password protected should we want to move material to their site prior to public release, but at the time data is submitted researchers must identify a public release date.

Milestone(s)

The first complete draft of the Data Management Plan and Data Use Agreement were completed in December 2014. Templates and metadata were updated continuously, with a team-wide review and revision of the Data Use Agreement initiated in August 2015 and completed in September 2015.

Major Accomplishments

As intended, most members of the team have been actively using the data management system as a shared repository for data. Over 1000 files have been uploaded to the system and have been organized and cataloged.

Publications

A 23 page Data Management Plan has been published for internal use. That document has been distributed to the DOE funded Sun Grant Regional Feedstock Partnership for consideration of the ASCENT1 Data Use Agreement as a possible model for their 50 investigator 7 year project.

Outreach Efforts

N/A

Awards
N/A

Student Involvement
Graduate students at WSU were the primary contributors to the database during the first year of the project. This introduction to data management and coordination will be a benefit to them in their future interdisciplinary and multi-institutional research.

Plans for Next Period
PSU will continue organizing data as it is uploaded into the data management system, and work with team members to identify opportunities for data sharing and model intercomparison.

References
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