Project 001(C) Alternative Jet Fuel Supply Chain Analysis

Purdue University

Project Lead Investigator

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University Participants

Purdue University

- Wallace E. Tyner, James and Lois Ackerman Professor
- FAA Award Number: 13-C-AJFE-PU
- Period of Performance: July 14, 2014 – August 31, 2018
- Task(s):

1. **Lead: Tyner; supported by graduate students)** – Develop stochastic techno-economic models for relevant pathways and identify key stochastic variables to be modeled for assessing risk in conversion pathways. This work will lead to our capability to compare pathways, their expected economic cost plus the inherent uncertainty in each pathway.
2. **Lead: Tyner; supported by Taheripour, Zhao, and Malina (Hasselt University)** – Life cycle analysis of alternative aviation biofuel pathways in coordination with ICAO CAEP/AFTF. Work with the CAEP/AFTF life cycle assessment group on issues such as system boundaries, induced land use change, LCA methodology, and pathway GHG emissions assessment.
3. **Lead**: **Tyner; supported by Zhao and Taheripour** – Develop estimates of land use change associated emissions for aviation biofuels for the ICAO Alternative Fuels Task Force. This task is closely related to Task #2,
4. **Lead: Tyner** - **P**rovide support for the other ASCENT universities on aviation biofuels policy analysis.
5. **Lead: Tyner** – Provide support for the Farm to Fly initiative as needed.

Project Funding Level

Amendment 3 - $250,000, Amendment 6 - $110,000, Amendment 10 - $230,000, Amendment 15 - $373,750, Amendment 19 - $400,000.
Current cost sharing for this project year was from Oliver Wyman

Investigation Team

Wallace E. Tyner – PI – James and Lois Ackerman Professor
Farzad Taheripour – Research Associate Professor – involved in several aspects of the project, but especially life cycle analysis and land use change
Xin Zhao – PhD student Purdue University – stochastic techno-economic analysis and GTAP ILUC analysis
Elspeth McGarvey – MS student, Purdue University - stochastic techno-economic analysis
Jeremiah Stevens – MS student, Purdue University – stochastic techno-economic analysis

Project Overview

This project has five main components. First is advancement of stochastic techno-economic analysis for aviation biofuel pathways. Second is life cycle and production potential analysis of alternative aviation biofuel pathways in coordination with ICAO-AFTF. The third component also involves working with ICAO-AFTF but specifically on estimation of land use

change associated emissions for aviation biofuels. The fourth and fifth components are smaller. The fourth is to provide support for the policy sub-group in AFTF. The fifth will be providing support for "Farm to Fly 2.0" (F2F2). F2F2 is a collaboration of government and industry to enable commercially viable, sustainable bio-jet fuel supply chains in the U.S. at the state and regional level that are able to support the goal of one billion gallons of bio-jet fuel production capacity and use by 2018.To support this effort, Purdue would provide necessary analytical support to this process.

Task 1- Develop Stochastic Techno-economic Models for Relevant Pathways and Identify Key Stochastic Variables for Assessing Risk in Conversion Pathways

Purdue University

Objective(s)

Develop stochastic techno-economic models for relevant pathways and identify key stochastic variables to be modeled for assessing risk in conversion pathways. This work will lead to our capability to compare pathways, their expected economic cost, plus the inherent uncertainty in each pathway.

Research Approach

For each pathway being evaluated, we develop a stochastic model that covers the entire pathway so that it can be used for both techno-economic and life cycle analysis. Over this period, we have evaluated alcohol-to-jet and the Catalytic Hydrothermolysis (CH) processes. We have also developed some new approaches to stochastic TEA.

Milestone(s)

We continue to get refereed journal papers published in the area of stochastic techno-economic analysis. See the publications in the publications section below.

Major Accomplishments

See the publications section below.

Publications

Yao, Guolin, Mark D. Staples, Robert Malina, and Wallace E. Tyner. "Stochastic techno-economic analysis of alcohol-to-jet fuel production." *Biotechnology for Biofuels* 10:18 (2017), 13 pages.

McGarvey, Elspeth, and Wallace E. Tyner (2018). "A Stochastic Techno-Economic Analysis of the Catalytic Hydrothermolysis Aviation Biofuel Technology." *Biofuels, Bioproducts, & Biorefining* DOI: 10.1002/bbb.1863.

Outreach Efforts

Tyner made a presentation on stochastic TEA for aviation biofuels at the ASCENT meeting in Boston in April 2018.

Awards

None

Student Involvement

Elspeth McGarvey – MS student, Purdue University
Jeremiah Stevens – MS student, Purdue University
These students have worked on the stochastic techno-economic analysis during this project year.

Plans for Next Period

We will continue stochastic TEA, with the next pathway to be completed being pennycress to jet fuel. We also anticipate an analysis on camelina based jet fuel.

Task 2- Life Cycle Analysis of Alternative Aviation Biofuel Pathways in Coordination with ICAO-AFTF

Purdue University

Objective(s)

Work with the CAEP/AFTF life cycle assessment committee (WP3) on issues such as system boundaries, induced land use change, LCA methodology, and pathway GHG emissions assessment.

Research Approach

There are many varied assignments and pieces under this task. For life cycle analysis, working with other team members, we use standard approaches for consequential LCA. For system boundaries, we have investigated the consequences of different approaches to defining system boundaries. For estimating induced land use change, we use the GTAP-BIO model and have modified it to improve land allocation at the extensive and intensive margins (see task 3).

In addition, Tyner has been working with Dr. Brad Saville on low-risk for induced land use change.

Tyner is co-chair of the AFTF induced land use change group.

Milestone(s)

Tyner and Zhao participated in the AFTF meetings in Brasilia in October 2017 and in Montreal in April and September 2018. They have been involved in many of the tasks and document preparation for the meetings. In Brasilia, Tyner and Zhao gave presentations on the improvements in induced land use change modeling and the work plan for the ILUC sub-group. In April in Montreal they provided a comparison of the GTAP-BIO and GLOBIOM models and the progress that had been made in reconciling differences between the two models. In September 2018, AFTF reached agreement on the approach to calculating induced land use change emissions that would be recommended to CAEP.

Major Accomplishments

AFTF has agreed on the induced land use change emissions to be included in CORSIA.

Publications

See the list is Task #3.

Outreach Efforts

None

Awards

None

Student Involvement

Xin Zhao has been involved in the AFTF ILUC work. He completed his PhD in August 2018.

Plans for Next Period

In the next period, we will be doing further model improvements and additional test simulations for multiple aviation biofuel pathways and regions. We have also been working with the International Institute for Applied Systems Analysis on comparing model results from their GLOBIOM model with GTAP-BIO. That work will continue in 2018-2019 assuming funding is available.

Task 3- Develop Estimates of Land Use Change Associated Emissions for Aviation Biofuels for the ICAO Alternative Fuels Task Force

Purdue University

Objective(s)

Develop estimates of land use change associated emissions for aviation biofuels for the ICAO Alternative Fuels Task Force

Research Approach

We use the updated and modified GTAP-BIO model to produce estimates of induced land use change for AFTF. We are also working with IIASA and Hugo Valin to evaluate differences between results obtained with GTAP-BIO and GLOBIOM. We reached concurrence in the September 2018 AFTF meeting on ILUC emissions for CORSIA.

Milestone(s)

See the milestone list under Task #2.

Major Accomplishments

Most of the accomplishments under this task are in the form of work progress of ICAO/CAEP/AFTF. Some of the working papers and information papers we have produced in 2017/18 are listed in this section and in the overall publication list at the end of this report.

Publications

There have been numerous working papers and information papers produced for the AFTF work:

CAEP/11-AFTF/05-WP/04 – "Updates on Preliminary GTAP-BIO and GLOBIOM Results for Aviation Biofuels Induced Land use change Emission Values," Brasilia, October 2017.

CAEP/11-AFTF/06-IP/04 – "GTAP-BIO Progress on Estimating Aviation Biofuel Induced Land Use Change Emission Values," Montreal, April 2018.

CAEP/11-AFTF/06-WP/03 – "Updates on Preliminary Aviation Biofuel Induced Land Use Change Emission Values from GTAP-BIO and GLOBIOM," Montreal, April 2018.

CAEP/11-AFTF/07-IP/05 – "GTAP-BIO Updates on Estimating Aviation Biofuel Induced Land Use Change Emission Values," Montreal, September 2018.

CAEP/11-AFTF/07-IP/06 – "Sensitivity Analysis for Key Data and Parameters in GTAP-BIO and AEZ-EF," Montreal, September 2018.

CAEP/11-AFTF/07-IP/07 – "Discussion of Creating Global or Regional Values for Aviation Biofuel Induced Land Use Change Emissions," Montreal, September 2018.

CAEP/11-AFTF/07-IP/08 – "Updates of Comparisons between GTAP-BIO and GLOBIOM for Aviation Biofuels Induced Land Use Change Emissions," Montreal, September 2018.

In addition, the following journal paper was published related to land use change research:

Chen, Rui, Zhangcai Qin, Jeongwoo Han, Michael Wang, Farzad Taheripour, Wallace E. Tyner, Don O"Connor, James Duffield (2018). "Life cycle energy and greenhouse gas emission effects of biodiesel in the United States with induced land use change impacts." *Bioresource Technology* 251, pp. 249-258, https://doi.org/10.1016/j.biortech.2017.12.031.

Outreach Efforts

Xin Zhao made a poster presentation of the aviation biofuels induced land use change work at the April 2018 ASCENT meeting.

Awards
None

Student Involvement
Xin Zhao – PhD student, Purdue University

Plans for Next Period
We will continue working with ICAO on induced land use change emission estimates assuming availability of funding.

Task 4- Provide Support for the other ASCENT Universities on Aviation Biofuels Policy Analysis
Purdue University

Objective(s)
To provide support for the other ASCENT universities on aviation biofuels policy analysis.

Research Approach
We develop spreadsheet models of various pathways incorporating risk analysis. The output of the risk analysis is the distribution of net present value (NPV), internal rate of return (IRR), and the probability the investment will lose money. Being able to provide a distribution of financial outputs is immensely valuable to private sector investors and other players. The analysis outputs can also be used to help target future research to areas where the research outcome could be expected to have a high payoff. We have been working with WSU on stochastic TEA and expect in the next year to work with WSU, PSU, Hawaii, and Tennessee on stochastic TEA and risk analysis.

Tyner has joined the Southeast Partnership for Advanced Renewables from Carinata (SPARC) project funded by USDA and will be working with them on stochastic TEA of different pathways.

In addition, we now can develop distributions of breakeven prices that reflect the uncertainty in the input distributions. A distribution of breakeven prices is a very effective way to communicate the relative level of pathway cost as well as its uncertainty.

Any of the stochastic techno-economic analyses can be used with policy overlays to conduct evaluations of alternative policy options. The stochastic models can also be used to examine the impacts of alternative feedstock contracting mechanisms for feedstocks without effective hedging alternatives available, such as the cellulosic feedstocks or new lipids such as pennycress. We have worked with the ICAO/AFTF policy sub-group to develop such policy case studies.

Milestone(s)
We have published papers on stochastic TEA (see the publications in task #1) and are now assisting researchers at other universities in doing this type of analysis using the approaches we have developed.

Major Accomplishments
We have provided guidance to ASCENT partners and have helped them to build stochastic TEA models for their pathways under investigation.

Publications
None

Outreach Efforts
None

Awards
None

Student Involvement
Elspeth McGarvey – MS student, Purdue University
Jeremiah Stevens – MS student, Purdue University

Plans for Next Period
We will be working with researchers at other universities to do stochastic TEA and to develop policy overlays for the models.

Task 5- Provide Support for the Farm to Fly Initiative as Needed
Purdue University

Objective(s)
To provide support for the Farm to Fly initiative as needed.

Research Approach
This activity is a general support for other initiatives. Our main role is to consult with other projects and activities and provide assistance as needed.

Milestone(s)
There has been little activity under this task in this reporting period.

Major Accomplishments
None

Publications
None

Outreach Efforts
None

Awards
See Task 1.

Student Involvement
None

Plans for Next Period
We will continue to be available to other projects and universities as needed in the regional and national analysis related to "Farm to Fly."