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 and production potential analysis of alternative aviation biofuel pathways in coordination with ICAO-AFTF. 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.
3. **Lead**: **Tyner; supported by Zhao, Taheripour, and post doc** – Develop estimates of land use change associated emissions for aviation biofuels for the ICAO Alternative Fuels Task Force.
4. **Lead: Tyner** - provide 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 is 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
David Cui – post doc, GTAP-BIO model modifications and simulations
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 to Be Modeled 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 Hydrothermolosis (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.
Two other papers on quantifying stochastic TEA were published. See publications below.

Major Accomplishments

See the publications section below.

Publications

Zhao, Xin, Guolin Yao, and Wallace E. Tyner. "Quantifying breakeven price distributions in stochastic techno-economic analysis." *Applied Energy* 183 (2016) 318-326.

Bann, Seamus J., Robert Malina, Pooja Suresh, Matthew Pearlson, Wallace E. Tyner, James I. Hileman, and Steven Barrett. "The costs of production of alternative jet fuel: A harmonized stochastic assessment." *Bioresource Technology* 227 (2017), 179-187.

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.

Outreach Efforts

Tyner made a presentation on stochastic TEA for aviation biofuels at the DOE workshop on aviation biofuels in Macon, GA

Awards

Tyner was named a fellow of the American Association for the Advancement of Science (AAAS) awarded in February 2017 at the AAAS meetings in Boston.
Tyner was named one of the top 100 people in the Advanced Bioeconomy by *Biofuels Digest*.

Student Involvement

Xin Zhao – PhD student, Purdue University

Elspeth McGarvey – MS student, Purdue University
Jeremiah Stevens – MS student, Purdue University
The students have worked on the stochastic techno-economic analysis and induced land use change.

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 of the quantitative potential for camelina based jet fuel.

Task #2: Life Cycle and Production Potential 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 model and have modified it to improve land allocation at the extensive and intensive margins (see task 4).

Milestone(s)
Tyner participated in the AFTF meetings in Montreal in October 2016 and February 2016. He has been involved in many of the tasks and document preparation for the meetings. In Montreal, Tyner and Zhao gave presentations on the improvements in induced land use change modeling and the work plan for the ILUC sub-group.

Major Accomplishments
AFTF is making progress on core LCA, induced land use change, and sustainability.

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

Outreach Efforts
None

Awards
See awards under Task 1

Student Involvement
Xin Zhao has been involved in the AFTF ILUC work

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 2017-2018.

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 preliminary 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.

Milestone(s)

None

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 2016/17 are listed in this section and in the overall publication list at the end of this report.

Publications

CAEP/11 ILUC Task Group. Development of Test Model Simulations to Be Used in Studying Induced Land Use Change from Aviation Biofuels Production. *CAEP/11-AFTF/2-WP/3.* Oct 2016.

CAEP/11 ILUC Task Group. Preliminary Simulation Test Results for Estimation of Land Use Change Emission Values for Aviation Biofuels Production. *CAEP/11-AFTF/3-WP/4.* Jan 2017.

CAEP/11 ILUC Task Group. Preliminary GTAP-BIO Simulation Results for Estimation of Land Use Change Emission Values for Aviation Biofuels Production. *CAEP/11-AFTF/4-WP/06.* May 2017.

CAEP/11 ILUC Task Group. Summary Comparison of GTAP-BIO and GLOBIOM Models and Results. *CAEP/11-AFTF/4-IP/07.* May 2017.

Taheripour, F., Cui, H., & Tyner, W. E. (2017). An Exploration of Agricultural Land use Change at the Intensive and Extensive Margins: Implications for Biofuels Induced Land Use Change. In Z. Qin, U. Mishra, & A. Hastings (Eds.), *Bioenergy and Land Use Change*: American Geophysical Union (Wiley).

Taheripour, F., Zhao, X., & Tyner, W. E. (2017). The impact of considering land intensification and updated data on biofuels land use change and emissions estimates. *Biotechnology for Biofuels*, *10*(1), 191.

Outreach Efforts

Xin Zhao made a poster presentation of the aviation biofuels induced land use change work at the April 2017 ASCENT meeting.

Xin Zhao presented our induced land use change work at the September 2017 ASCENT meeting.

Awards

See task 1.

Student Involvement

Xin Zhao – PhD student, Purdue University

Plans for Next Period
We will be producing induced land use change emission estimates for the AFTF April 2018 meeting.

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.

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. If desired, we can work 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
See task 1.

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

Perkis, David F., and Wallace E. Tyner. "Developing a Cellulosic Aviation Biofuel Industry in Indiana: A Market and Logistics Analysis." *Energy*, forthcoming 2017.

Zhao, Xin, Guolin Yao, and Wallace E. Tyner. "Quantifying breakeven price distributions in stochastic techno-economic analysis." *Applied Energy* 183 (2016) 318-326.

Bann, Seamus J., Robert Malina, Pooja Suresh, Matthew Pearlson, Wallace E. Tyner, James I. Hileman, and Steven Barrett. "The costs of production of alternative jet fuel: A harmonized stochastic assessment." *Bioresource Technology* 227 (2017), 179-187.

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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.

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CAEP/11 ILUC Task Group. Summary Comparison of GTAP-BIO and GLOBIOM Models and Results. *CAEP/11-AFTF/4-IP/07.* May 2017.

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."