Project 001(C) Alternative Jet Fuel Supply Chain Analysis

Purdue University

Project Lead Investigator

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University Participants

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- Wallace E. Tyner, James and Lois Ackerman Professor
- FAA Award Number: 13-C-AJFE-PU
- Period of Performance: July 14, 2014 – August 31, 2017
- Task(s):

1. **Lead: Tyner; supported by post doc and 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 and Malina (MIT))** – 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 Taheripour** – Work with the CAEP/AFTF market based measures group to develop a methodology for applying market based measures for an aviation biofuels system.
4. **Lead: Tyner; supported by Taheripour and post doc** – Develop a new version of the GTAP-BIO model capable of handling land use changes on the intensive margin and of balancing extensive and intensive margin changes.

Project Funding Level

Amendment 3 - $250,000, Amendment 6 - $110,000, Amendment 10 - $230,000, Amendment 15 - $373,750. 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
Guolin Yao – PhD student Purdue University - stochastic techno-economic analysis
Luis Pena Levano – PhD student Purdue University – GTAP-BIO intensification

Project Overview

This project has four 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 on the market based measures activity. This component includes life cycle analysis issues such as co-product allocation and land use change. The fourth component involves developing a new version of GTAP-BIO that does a better job of handling intensification in estimating land use change. Historical data suggests that changes at the intensive margin have been quite important in some regions over the past decade.

Task 1

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) process. We have also developed some new approaches to stochastic TEA.

Milestone(s)

The alcohol to jet paper was presented at the annual meetings of the US Association of Energy Economics: Yao, Guolin, Mark D. Staples, Robert Malina, and Wallace E. Tyner. “Stochastic Techno-economic Analysis of Alcohol-to-Jet Fuel Production.” Paper presented at the annual meetings of the U.S. Association of Energy Economics, Pittsburg, PA, October 25-28, 2015.
The research also has been submitted to a journal.

Two other papers on quantifying stochastic TEA were published. See publications below.

Major Accomplishments

We had two presentations at the USAEE meetings in 2015 plus two published journal papers in 2015/16 and a poster at the ASCENT meeting in March 2015.

Publications

Zhao, Xin, Tristin R. Brown, and Wallace E. Tyner. “Stochastic techno-economic evaluation of cellulosic biofuel pathways.” *Bioresource Technology* 198 (2015), pp.755-763.

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

Outreach Efforts

Tyner made a presentation on stochastic TEA for aviation biofuels at the DOE workshop on aviation biofuels in Macon, GA
He also made a presentation for a NAS committee on aviation biofuels.

Awards
Tyner was named a fellow of the American Association for the Advancement of Science (AAAS) to be 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
Guolin Yao – PhD student, Purdue University
Elspeth McGarvey – MS student, Purdue University
The students have worked on the stochastic techno-economic analysis.

Plans for Next Period
We will continue stochastic TEA, with the next pathway to be completed being the Catalytic Hydrothermolosis (CH) process.

Task 2
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 2015 and June 2016. He has been involved in many of the tasks and document preparation for the meetings. In Montreal, he gave presentations on the improvements in induced land use change modeling and the work plan for the ILUC sub-group.

Major Accomplishments
The ILUC work plan has been approved by AFTF. Tyner is now co-lead of the ILUC task with Brad Saville of the University of Toronto.

Publications
de Carvalho Macedo, I., Andre M. Nassar, Annette L. Cowie, Joaquim E.A. Seabra, Luisa Marelli, Martina Otto, Michael Q. Wang, and Wallace E. Tyner. *Greenhouse Gas Emissions from Bioenergy (chapter 17)*, in *Bioenergy and Sustainability: bridging the gaps*, G.M. Souza, et al., Editors. 2015, Scientific Committee on Problems of the Environment (SCOPE): Paris. p. 582-616.

Outreach Efforts
N/A

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 test simulations for multiple aviation biofuel pathways and regions. The basic objectives are to determine if there are significant regional differences for any given pathway and to determine the extent to which emissions change as the size of test shocks increase.
Following the February AFTF meeting, additional GTAP simulations will be accomplished.

Also, beginning in 2017, there will be collaborative work with the International Institute for Applied Systems Analysis on comparing model results from their GLOBIOM model with GTAP_BIO.

Task 3
Purdue University

Objective(s)
Work with the CAEP/AFTF market based measures group to develop a methodology for applying market based measures for an aviation biofuels system.

Research Approach
We have not worked much on this task, as tasks 1, 2, and 4 were deemed to be more urgent. We have begun working some with the policy sub-group in AFTF.

Milestone(s)

Major Accomplishments
Most of the accomplishments under this task are in the form of work progress of ICAO/CAEP/AFTF. The group is making significant progress under the leadership of James Hileman and Maria del Mar Rica Jimenez.

Publications
none

Outreach Efforts
N/A

Awards
See task 1.

Student Involvement
No graduate students are involved in this task.

Plans for Next Period
This task in not included in the 2016-17 statement of work.

Task 4
Purdue University

Objective(s)
Develop a new version of the GTAP-BIO model capable of handling land use changes on the intensive margin and of balancing extensive and intensive margin changes.

Research Approach
We began the research by examining the changes in cropland cover and harvested area around the world. If the changes in harvested area are roughly equal to changes in cropland cover, then all the land use change is at the extensive margin. However, if the changes in harvested area are greater than the changes in cropland cover, then there has been intensification (e.g., double cropping) in that region. Using FAO data we estimated the changes over the period 2003-13 by region. We then made changes in the GTAP-BIO by introducing an intensification parameter that varies by region. We then calibrated the values for this parameter by region from the historical data. Finally, test simulations were done to determine how well the results matched historic data.

Milestone(s)
The modeling changes and preliminary results were presented at the June 2016 AFTF meeting in Montreal.

Major Accomplishments
Improving GTAP-BIO to do a better job on intensification and the extensive/intensive margin was a major accomplishment. Also, we updated the GTAP data base from 2004 to 2011.

Publications
Taheripour, F., Cui, H., & Tyner, W. E. (2016). 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)

This work also has been submitted to a journal.

Outreach Efforts
Tyner gave a presentation on this research at the DOE Aviation Biofuels workshop in Macon, GA.

Awards
See task 1.

Student Involvement
Luis Pena Levano was involved in this research.

Plans for Next Period
We continue to refine some aspects of the model and parameters. We will be using the model to do test simulations for the February 2017 AFTF meeting in Montreal and also for simulations for the June meeting in Washington, DC.