# Project 001(C) Alternative Jet Fuel Supply Chain Analysis

## Purdue University

## Project Lead Investigator

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## University Participants

**Purdue University**

- Farzad Taheripour, Research Associate Professor
- FAA Award Number: 13-C-AJFE-PU, Amendments 25, 29, 34, 36
- Period of Performance: October 1, 2019 to September 30, 2020
- Tasks:

1. Lead: Taheripour; supported by Chepeliev and Stevenson—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: Taheripour; supported by Sajedinia, Aguiar, and Malina (Hasselt University) —Life cycle analysis (LCA) of alternative jet fuel pathways in coordination with the International Civil Aviation Organization's Committee on Environmental Protection Fuels Task Group (ICAO-CAEP-FTG). Work with the CAEP/FTG life cycle assessment group on issues such as system boundaries, induced land use change (ILUC), LCA methodology, and pathway greenhouse gas (GHG) emissions assessment.
3. Lead: Taheripour; supported by Sajedinia, Aguiar, and Chepeliev—Develop estimates of land use change (LUC) associated emissions for alternative jet fuels for the ICAO-CAEP-FTG. This task is closely related to Task 2,
4. Lead: Taheripour—Provide support for the other ASCENT universities on alternative jet fuel policy analysis.

## Project Funding Level

- Amendment 3: $250,000
- Amendment 6: $110,000
- Amendment 10: $230,000
- Amendment 15: $373,750
- Amendment 19: $400,000
- Amendment 29: $400,000
- Amendment 36: $523,000

Current cost sharing for this project year was from Alex Menotti from Neste US, Inc.

## Investigation Team

- Farzad Taheripour (PI): Research Associate Professor
- EhsanReza Sajedinia (PhD student Purdue University): stochastic techno-economic analysis and Global Trade Analysis Project (GTAP) ILUC analysis.
- Xin Zhao (former PhD student, Purdue University): stochastic techno-economic analysis and GTAP ILUC analysis. (Zhao graduated and left Purdue but still voluntarily contributes to the project)

- Jeremiah Stevens (MS student, Purdue University): stochastic techno-economic analysis. (Stevens graduated in December 2019, continued to work for the project as a consultant until August 2020, and still voluntarily contributes to project.)
- Maksym Chepeliev (PhD, Research Associate, GTAP Center): collaborates part time with the project.
- Angel H. Aguiar (PhD, Research Associate, GTAP Center): collaborates part time with the project.

## Project Overview

This project has five main components: First is advancement of stochastic techno-economic analysis (TEA) for aviation biofuel pathways. Second is life cycle and production potential analysis of alternative jet fuel pathways in coordination with ICAO CAEP-FTG. The third component also involves working with FTG, specifically on estimation of land use change (LUC) associated emissions for alternative jet fuels. The fourth is to provide support for the policy sub-group in FTG by providing policy guidelines to facilitate expansions in using sustainable aviation fuels. This task includes bridging existing TEA for alternative jet fuels with partial and general equilibrium economic models to develop alternative scenarios for alternative jet fuels in the fuels mix used by the industry. The fifth task supported "Farm to Fly 2.0" (F2F2). F2F2 was a collaboration of government and industry to enable commercially viable, sustainable alternative jet fuel supply chains in the U. S. at state and regional levels to support the goal of one billion gallons of alternative jet fuel production capacity and use by 2019. Purdue University provided necessary analytical support for this effort.

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

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### Objective

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 fuel 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 continued to work on alcohol-to-jet (ATJ) and the catalytic hydrothermolysis (CH) processes. We have also developed some harmonized TEA.

### Milestone(s)

We developed a new a stochastic TEA for a plant designed to use the CH technology to produce renewable diesel fuel, renewable jet fuel, and renewable naphtha from pennycress seed oil produced in Iowa and Indiana. In addition to the standard stochastic practices, this TEA considers uncertainty in biofuel policies and highlights the existing policies that can be altered to support production of alternative jet fuels. This research shows that with proper policies in place, producing alternative jet fuels could be commercially viable in the near future. This research has been fully and successfully conducted. We will continue to publish results of these case studies.

### Major Accomplishments

- An Excel-based framework has been developed to conduct stochastic TEA in combination with @Risk program.
- An archive from the exiting TEAs has been created and summarized in an Excel file for future uses.

### Publications

The following paper has been developed and presented:

Stevens J. and Taheripour F. (2020) "A stochastic techno-economic analysis of aviation biofuel production from pennycress seed oil," Selected paper *presented at the 2020 Agricultural & Applied Economics Association Annual Meeting, Virtual Meeting August 10-1, 2020.*

## Outreach Efforts
None

## Awards
None

## Student Involvement
Jeremiah Stevens, MS student, Purdue University

## Plans for Next Period
We will work on the publication of the result of the TEA of producing alternative jet fuels from pennycress.

# Task 2 – Life Cycle Analysis of Alternative Jet Fuel Pathways in Coordination with ICAO-AFTF-FTG
**Purdue University**

## Objective(s)
- Provide required data and analysis to support the low LUC risk practices adopted in CAEP.
- Provide required data and analysis to support the core LCA group with respect to ILUC for co-processing of esters and fatty acids in petroleum refineries and other tasks as needed.

## Research Approach
There are many varied assignments and pieces under this Task. We follow standard approaches to support FTG subgroups including core LCA, Technology Production Policy (TPP), Emission Reductions Accounting (ERA), and Sustainability subgroups. We use the GTAP-BIO model, collected data, and provided proper analyses to accomplish this Task.

Taheripour is co-chair of the FTG induced land use change (ILUC) group.

Taheripour collaborates with the LCA, TPP, ERA, and Sustainability subgroups of ICAO-CAEP-FTG.

## Milestones
Taheripour participated in the following FTG meetings: FTG3 in Dubai and virtual FTG4 and FTG5. Taheripour has been involved in many of the tasks and document preparation activities for the meetings. He responded to other subgroups requests for help and collaboration. He leads the efforts on ILUC modeling and the ILUC-related tasks associated with other subgroups. We developed a framework to examine regional ILUC and rank countries according to their LUC determinants. We collected data on LUC determinants and developed some primary analysis.

## Major Accomplishments
- We developed a template to collect information from the existing TEAs. Using this template and in collaboration with ASCENT projects, we collected and reviewed the existing TEA on alternative jet fuels and summarized and synthesized their findings, advantages, and limitations. The results of this work helped us to bridge the TEA approach with a modeling framework that aims to develop a supply schedule for alternative jet fuels. The results of this effort have been used by the FTG-TPP subgroup to help the ICAO-CAEP-FTG group to identify future research on supply of sustainable aviation fuels (SAFs), see CEAP/12-FTG/03-WP/10.
- We also developed two harmonized TEAs for: hydroprocessed esters and fatty acids (HEFA) from vegetable oils and ATJ from grain-based ethanol. These TEAs have been developed in collaboration with ASCENT projects.
- A dataset including historical observations on crop yields has been developed to support TPP subgroup projections. This dataset covers yield trends for maize, wheat, soybean, rapeseed, oil palm crop, sugar beet, and sugarcane for two time slices of 1961–2028 and 2000–2018. These crops are the main feedstocks for biofuel production. Data provided by the Food and Agricultural Organiztion (FAO) data have been used to determine yields for the 10 largest producers of each crop.

## Publications

Taheripour, F., & Tyner, W. E. (2020). US biofuel production and policy: implications for land use changes in Malaysia and Indonesia. *Biotechnology for Biofuels*, *13*(11), 17.

## Outreach Efforts

- Taheripour attended the CRC meeting and made a presentation on regional land use change values. The meeting was in Argonne National Laboratory, Lemont, IL, October 15-17, 2019.
- Taheripour attended the ASCENT Advisory Group Meeting and made a presentation on limiting deforestation from palm oil in Malaysia and Indonesia. The meeting was in Washington DC., October 22-23, 2019.
- Taheripour attended the virtual ASCENT Advisory Group Meetings in March 2020 and September 2020 and presented the following posters entitled:
    - Alternative Jet Fuel Supply Chain Analysis - CORSIA Fuels Support,
    - Land Use in Computable General Equilibrium models - CORSIA Support.

## Awards

None

## Student Involvement

EhsanReza Sajedinia, PhD student Purdue University
Jeremiah Stevens, MS student, Purdue University

## Plans for Next Period

We will continue to support FTG subgroups.

# Task 3 – Develop Estimates of Land Use Change Associated Emissions for Alternative Jet Fuels for the ICAO Fuels Task Group

Purdue University

## Objective(s)

- Computation of induced land use change emissions of alternative jet fuels for use in Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA).
- Improvements in GTAP-BIO model and its database and making proper modification in the Agro-ecological Zone Emission Factor (AEZ-EF) emissions model.
- Define and implement a method to determine regional ILUC values and rank countries according to their LUC determinants.

## Research Approach

We modify, update, and use the GTAP-BIO model to produce estimates of ILUC for FTG. We also collaborate with the International Institute for Applied Systems Analysis (IIASA) and Hugo Valin to evaluate the outcomes of GTAP-BIO and GLOBIOM models. We collect data and develop new approaches to assess issues related to ILUC emissions due to production of alternative jet fuels.

## Milestones

We added several new pathways to the GTAP-BIO model. We examined new regional ILUC values. We developed primary analyses to rank countries according to their land use change determinants and determine global ILUC values.

## Major Accomplishments

Most of the accomplishments under this Task are in the form of work progress of ICAO-CAEP-FTG. Some of the working papers and information papers we have produced over this period are listed in this section and in the overall publication list at the end of this report. In addition, an Excel-based model has been developed to estimate direct land use change (DLUC) emissions values.

## Publications

There have been several working papers and information papers produced for the AFTF/FTG work. In what follows, we only presented the working and information papers presented at FTG meetings:

- CAEP/12-FTG/03-WP/07: "Progress on Modelling of ILUC values for CORSIA LCA", Abu Dhabi, United Arab Emirates, February 2020.
- CAEP/12-FTG/03-WP/08: "Progress of ILUC Subgroup on Low LUC Risk Practices", Abu Dhabi, United Arab Emirates, February 2020.
- CAEP/12-FTG/03-WP/11: "Guidance document for calculation and submission of LCA data for new pathways", Abu Dhabi, United Arab Emirates, February 2020.
- CAEP/12-FTG/03-IP/04: "Possible methodologies to derive regional ILUC values based on current modelling", Abu Dhabi, United Arab Emirates, February 2020.
- CAEP/12-FTG/03-IP/05: "Land Use Change Emission Accounting in GLOBIOM and GTAP-BIO", Abu Dhabi, United Arab Emirates, February 2020.
- CAEP/12-FTG/03-IP/08: "Method proposed for DLUC values", Abu Dhabi, United Arab Emirates, February 2020.
- CAEP/12-FTG/04-WP/07: "Guidance on Direct Land Use change calculation for Sustainability Criterion 2.2", Virtual, June 2020.
- CAEP/12-FTG/04-WP/08: "Expanding Regional ILUC Values Coverage Based On Model Simulations", Virtual, June 2020.
- CAEP/12-FTG/04-IP/09: "Progress on ILUC values for additional SAF pathways", Virtual, June 2020.
- CAEP/12-FTG/04-IP/10: "Low LUC risk practices: scoping for case studies analysis", Virtual, June 2020.
- CAEP/12-FTG/05-WP/05: "Updated ILUC values for carinata oil HEFA", Virtual, July 2020.
- CAEP/12-FTG/05-WP/06: "Updated ILUC values for ETJ perennial grass pathways", Virtual, July 2020.
- CAEP/12-FTG/05-WP/07: "DLUC safeguard for unused land approach in LMP", Virtual, July 2020.
- CAEP/12-FTG/05-WP/08: "Revised guidance on Direct Land Use Change calculation", Virtual, July 2020.
- CAEP/12-FTG/05-IP/05: "Overview of ILUC modelling assumptions applied across pathways", Virtual, July 2020.

In addition to the above reports we have the following papers in press or already published:

- Zhao X. Taheripour F., Malina R. Tyner W. (2020) "Aviation biofuels: A viable and sustainable option to curb aviation emissions," Selected paper *presented at the 2020 Agricultural & Applied Economics Association Annual Meeting, Virtual Meeting August 10-1, 2020.*
- Taheripour F. Zhao X., Horridge M. Farrokhi F. Tyner W (2020: In press) "Modeling Land Use in Computable General Equilibrium Models: Preserving Physical Area of Land" (In press), *Journal of Global Economic Analyses.*

## Outreach Efforts

Taheripour attended several meetings to present the research outcomes on ILUC values, including:

- National Biodiesel Conference & Expo, Tampa, Florida, January 2020.
- GTAP 23nd Annual Conference on Global Economic Analysis, Virtual meeting, June 2020.
- AAEA Annual Meeting, Virtual, August 2020.
- EPA Brownbag seminar, September 10, 2020.

## Awards

- Farzad Taheripour, Award for Quality of Communication, The Agricultural and Applied Economic Association, 2020,
- Farzad Taheripour, Award for Outstanding Publication in the journal of *Environmental and Resource Economics* published in 2019, The European Association of Environmental and Resource Economics, 2020

## Student Involvement

EhsanReza Sajedinia, PhD student Purdue University

## Plans for Next Period

- We will continue working with ICAO on ILUC emission estimates including the following highlights:
- The current model uses a database which represent the world economy in 2011. We plan to update to this data base to 2014. This is a major task and requires new development.
- We will work to develop regional ILUC values.
- We are in the process of developing a method to rank countries according to their LUC determinant factors.

- We are now working on DLUC values.

## Task 4 – Provide Support for the other ASCENT Universities on Alternative Jet Fuels Policy Analysis

Purdue University

### Objective

To provide support for the other ASCENT universities on alternative jet fuels policy analysis.

### Research Approach

See Task 1

### Milestone(s)

See Task 1

### Major Accomplishments

See Task 1

### Publications

None

### Outreach Efforts

None

### Awards

None

### Student Involvement

Jeremiah Stevens, MS student, Purdue University

### Plans for Next Period

We will continue to collaborate with ASCENT as needed.

## Task 5 – Provide Support for the Farm-to-Fly Initiative as Needed

Purdue University

### Objectives

To provide support for the Farm-to-Fly (F2F2) 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.

### Milestones

There has been little activity under this Task in this reporting period.

### Major Accomplishments

None

## Publications
None

## Outreach Efforts
None

## Awards
None

## Student Involvement
None

## Plans for Next Period
Support for this effort has concluded.