Project 001(C) Alternative Jet Fuel Supply Chain Analysis

Purdue University

Project Lead Investigator

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University Participants

Purdue University

- PI: Farzad Taheripour, Research Associate Professor
- FAA Award Number: 13-C-AJFE-PU, Amendments 25, 29, 34, 36, 41
- Period of Performance: October 1, 2020 to September 30, 2021
- Task(s):

1. Develop techno-economic models for relevant pathways and identify key stochastic variables to model for assessing risk in conversion pathways, which work will lead to our capability to compare pathways, their expected economic cost, and the inherent uncertainty in each pathway (lead: Farzad Taheripour; supported by Chepeliev and Stevenson)
2. Perform a 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 emissions assessments (lead: Taheripour; supported by Sajedinia, Aguiar, and Malina [Hasselt University])
3. Develop estimates of land use change (LUC)-associated emissions for alternative jet fuels for the ICAO CAEP FTG, in close relation to Task #2 (lead: Taheripour; supported by Sajedinia, Debadrita, Aguiar, and Chepeliev)
4. Provide support for other ASCENT universities on alternative jet fuel policy analysis (lead: Taheripour)

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, 41: $523,000

Current cost sharing for this project year was provided by Sami Jauhiainen from Neste US, Inc.

Investigation Team

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

Omid Karami, postdoctoral fellow (joined the research team in August 2021)
Kundu Debadrita, PhD student, Purdue University: GTAP ILUC emissions analysis (collaborating part time with the project)
Maksym Chepeliev, PhD, research associate, GTAP Center (collaborating part time with the project)
Angel H. Aguiar, PhD, research associate, GTAP Center (collaborating part time with the project)

Project Overview

This project has five main components. The first component is focused on advancing TEA for aviation biofuel pathways, and the second centers on life cycle and production potential analysis of alternative jet fuel pathways in coordination with the ICAO CAEP FTG. The third component also coordinates with the FTG, with a specific focus on estimating LUC-associated emissions for alternative jet fuels. The fourth component aims to provide support for the policy subgroup of the FTG by providing policy guidelines to facilitate expansions in using sustainable aviation fuels (SAFs). This task includes bridging existing TEAs for alternative jet fuels with partial and general equilibrium economic models to develop alternative scenarios for alternative jet fuels in the fuel mix used by the industry. The fifth component supported "Farm to Fly 2.0" (F2F2) which was a collaboration between government and industry to enable commercially viable, sustainable alternative jet fuel supply chains in the United States, at state and regional levels, to support the goal of one billion gallons of alternative jet fuel production capacity and use by 2018. Purdue provided the analytical support necessary for this effort.

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

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Objective

This task aimed to develop TEAs for relevant pathways and identify key factors to model for assessing the feasibility of conversion pathways. This work will lead to our capability to compare pathways, their expected economic cost, and the inherent uncertainty in each pathway. This activity will help us to include new pathways in the GTAP-BIO model to assess their LUC impacts.

Research Approach

For each fuel pathway under evaluation, we collected the required data and developed the required analyses for both TEA and LCA to determine the cost structure of new pathways to be included in the GTAP-BIO model to support FTG tasks.

Milestone(s)

Over this period, we continued to work on various analyses for ethanol-to-jet (ETJ) and hydroprocessed ester and fatty acid (HEFA) pathways. This research has been fully and successfully conducted. We will continue to publish the results of our case studies.

Major Accomplishments

The following TEAs have been developed to support the inclusion of several new pathways in the GTAP-BIO database:

- Miscanthus ETJ, E.U. and U.S. cases;
- Switchgrass ETJ, U.S. case;
- Carinata oil HEFA, Brazil and U.S. cases;
- Camelina oil HEFA, Brazil and U.S. cases;
- Jatropha oil HEFA, India case; and
- Corn alcohol-to-jet (ATJ), Brazil case.

Publications

Taheripour, F., Scott, D., Hurt, C. A., & Tyner, W. E. (2021). Technological progress in US agriculture: Implications for biofuel production. Sustainable Agriculture Research, *10*(1), 61. https://doi.org/10.5539/sar.v10n1p61

Taheripour, F., Sajedinia, E., & Karami, O. (2021). Oilseed cover crops for sustainable aviation fuels production and reduction in greenhouse gas emissions through land use savings. Manuscript submitted for publication.

Outreach Efforts
Taheripour presented a paper at the National Biodiesel Board Sustainability Workshop, Virtual Meeting, 2021.

Awards
None.

Student Involvement
EhsanReza Sajedinia, PhD student, Purdue University

Plans for Next Period
We will work on publishing the results of our TEA for producing alternative jet fuels to support FTG analyses.

Task 2 - LCA of Alternative Jet Fuel Pathways in Coordination with ICAO Alternative Fuels Task Force (AFTF) FTG
Purdue University

Objectives
- Provide required data and analysis to support the low-LUC-risk practices adopted by CAEP
- Provide required data and analysis to support the core LCA group with respect to ILUC for coprocessing of esters and fatty acids in petroleum refineries and other tasks as needed

Research Approach
This task incorporates many varied assignments and components. We followed standard approaches to support FTG subgroups including the core LCA, Technology Production Policy (TPP), Emission Reductions Accounting (ERA), and Sustainability subgroups. Using the GTAP-BIO model, we collected data and provided appropriate analyses to accomplish this task.

Taheripour is co-chair of the FTG ILUC group.

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

Milestone(s)
Taheripour participated in the FTG6, FTG7, FTG8, FTG9, and FTG10 meetings and was involved in many of the tasks and document preparation activities for these meetings. He also responded to other subgroup requests for help and collaboration. He has led efforts in ILUC modeling and ILUC-related tasks associated with other subgroups. He developed a framework to examine regional and global ILUC values for each SAF and participated in developing a methodology to calculate Direct Land Use Change (DLUC) to support FTG activities.

Major Accomplishments
A methodology has been developed to calculate DLUC for use within the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) sustainability systems to evaluate the land use emissions of individual projects that will be launched by economic operators for SAFs. The methodology has been tested for several case studies. For each case study, an Excel file has been developed to be used by Sustainability Certification Schemes (SCS) in the future.

Publications
Prussi, M., Lee, U., Wang, M., Malina, R., Valin, V., Taheripour, F., Velarde, C., Staples, M. D., Lonza, L., & Hileman, J. L. (2021). CORSIA: The first internationally adopted approach to calculate life-cycle GHG emissions for aviation fuels. *Renewable and Sustainable Energy Reviews, 150*, 111398.

Outreach Efforts

Taheripour attended a Coordinating Research Council (CRC) meeting and gave a presentation on updates to the GTAP database: CRC Life Cycle Analysis Workshop, Virtual Meeting, 2021.

Taheripour attended virtual ASCENT Advisory Group meetings in April 2021 and October 2021 and presented the following papers:

- Estimating induced land use change emissions for sustainable aviation biofuel pathways, Alternative Jet Fuel Supply Chain Analysis - CORSIA Fuel Support.
- Oilseed cover crops for sustainable aviation fuel production and reduction in greenhouse gas emissions through land use savings, Alternative Jet Fuel Supply Chain Analysis - CORSIA Fuel Support.

Taheripour serves as a member of the Committee on Current Methods for Life Cycle Analyses of Low-Carbon Transportation Fuels in the United States of the National Academy of Sciences, Engineering, and Medicine.

Awards

None

Student Involvement

EhsanReza Sajedinia, PhD student, Purdue University
Kundu Debadrita, PhD student, Purdue University

Plans for Next Period

We will continue to support FTG subgroups, including the core LCA, TPP, and ERA subgroups, to accomplish the required LCAs for new SAF pathways. In addition, we will continue to develop required TEAs to include the cost structure of new SAF pathways in the GTAP-BIO database.

Task 3 - Develop Estimates of LUC-Associated Emissions for Alternative Jet Fuels for the ICAO FTG

Purdue University

Objectives

- Compute ILUC emissions of alternative jet fuels for use in CORSIA
- Improve the GTAP-BIO model and its database and make appropriate modifications to the agro-ecological zone emission factor 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 ILUC estimates for the FTG. We also collaborate with the International Institute for Applied Systems Analysis 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 the production of alternative jet fuels.

Milestone(s)

We added several new pathways to the GTAP-BIO model and examined new regional ILUC values. We also developed a methodology for estimating global ILUC values and assessed ILUC values for numerous SAF pathways.

Major Accomplishments

The primary accomplishments in this task are based on the work progress of ICAO CAEP FTG. Some of the working papers and information papers that we have produced over this period are listed in this section and in the overall publication list at the end of this report.

Publications

Several working papers and information papers have been produced based on our work for the AFTF/FTG. Working and information papers presented at FTG meetings include:

- CAEP/12-FTG/06-WP/06 – "Update on ILUC default values modelling for SAF pathways", November 2020, Virtual.
- CAEP/12-FTG/06-WP/08 – "Revised guidance on Direct Land Use Change calculation", November 2020, Virtual.
- CAEP/12-FTG/06-FL/04 – "Comparison of Proposed Methodology for Global ILUC", November 2020, Virtual.
- CAEP/12-FTG/08-WP/07 – "Update on ILUC default values modelling for SAF pathways", March 2021, Virtual.
- CAEP/12-FTG/08-WP/08 – "Methodology proposal on Direct Land Use Change calculation", March 2021, Virtual.
- CAEP/12-FTG/08-WP/04 – "Pilot application of the methodology on Low Land Use Change (LUC) Risk Practices", March 2021, Virtual.
- CAEP/12-FTG/09-WP/09 – "Methodology proposal on Direct Land Use Change calculation", May 2021, Virtual.
- CAEP/12-FTG/09-IP/02 – "ILUC Modelling Assumptions on Soil Organic Carbon Accounting", May 2021, Virtual.
- CAEP/12-FTG/09-WP/08 – "Update on ILUC modelling and low LUC risk", May 2021, Virtual.
- CAEP/12-FTG/10-WP/06 – "Methodology proposal on Direct Land Use Change calculation", July 2021, Virtual.
- CAEP/12-FTG/10-WP/07 – "Revisions to methodology on Low Land Use Change (LUC) Risk Practices based on pilot applications", July 2021, Virtual.
- CAEP/12-FTG/10-WP/05 – "Update on modelling of ILUC default values", July 2021, Virtual.

Zhao, X., Taheripour, F., Malina, R., Staples, M. D., & Tyner, W. E. (2021). Estimating induced land use change emissions for sustainable aviation biofuel pathways. *Science of The Total Environment, 779*(20), 146238.

Gao, Y., Zhang, X., Davidson, E., & Taheripour, F. (2021). The increasing global environmental consequences of a weakening US–China crop trade relationship. *Nature Food, 2* (8), 578-586.

Outreach Efforts

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

- GTAP 24th Annual Conference on Global Economic Analysis, Virtual June 2021,
- AAEA Annual Meeting, Virtual, August 2021, and
- EAAE Annual Meeting, Virtual, July 2021.

Awards

None.

Student Involvement

EhsanReza Sajedinia, PhD student, Purdue University
Kundu Debadrita, PhD student, Purdue University

Plans for Next Period

We will continue working with ICAO on ILUC emission estimates. In particular, the current model uses a database that represents the 2011 world economy. A new benchmark database that represents the 2014 world economy has been developed. We plan to use this database for ILUC assessment, which represents a major task and new development.

Task 4 - Provide Support for Other ASCENT Universities on Alternative Jet Fuels Policy Analysis

Purdue University

Objective

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

Objective
Provide support for the Farm-to-Fly initiative as needed

Research Approach
This task provides 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 during 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.