Project 001(C) Alternative Jet Fuel Supply Chain Analysis

Purdue University

Project Lead Investigator

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University Participants

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- P.I.: Farzad Taheripour, Research Professor
- FAA Award Number: 13-C-AJFE-PU, Amendments 25, 29, 34, 36, 41
- Period of Performance: October 1, 2021to September 30, 2022
- Tasks:
    1. Develop techno-economic models for relevant pathways and identify key stochastic variables to model for assessing risk in conversion pathways, which 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)
    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

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- Farzad Taheripour (P.I.), research professor, works on all tasks.

- EhsanReza Sajedinia, PhD student, Purdue University: Stochastic techno-economic analysis (TEA) and Global Trade Analysis Project (GTAP) ILUC analysis, works on all tasks.
- Omid Karami, postdoctoral fellow (joined the research team in August 2021), works on all tasks.

GTAP Center

Maksym Chepeliev, PhD, research associate (collaborating part-time on the project) works on all tasks.
Angel H. Aguiar, PhD, research associate (collaborating part-time on the project) works on all tasks.
Kundu Debadrita. PhD student, research assistant (collaborating part time on the project), works on task 3.

Project Overview

This project has followed four main components in this performance time period. The first component is focused on advancing TEA for aviation biofuel pathways. The second component is concentrated 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.

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

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Objectives

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.

Milestones

Over this period, we continued to work on various analyses for various technologies at the global level. This research has been fully and successfully conducted. The results of these analyses helped to establish required cost structure of various global pathways to be used in the LUC assessments for Task 3.

Major Accomplishments

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

- Global value for soy oil hydroprocessed esters and fatty acids (HEFA) covering USA, Brazil, and Rest of South America;
- Global value for rapeseed oil HEFA covering Canada, EU27, Rest of Europe, and Commonwealth of Independent States;
- Global values for corn alcohol-to-jet (ATJ) and ethanol-to-jet (ETJ) covering USA, Brazil, Rest of South America, EU27, Rest of Europe, and Commonwealth of Independent States;
- Global values for sugarcane ATJ and ETJ and synthesized iso-paraffins (SIP) covering Brazil, Central America and Caribbean, Rest of South America, sub-Saharan Africa, India, Rest of South Asia, China, and Rest of Asia;
- Global value for sugar beet SIP covering USA, EU27, Rest of Europe, and Commonwealth of Independent States, Middle East and North Africa, and China;

- Global values for carinata and camelina oil HEFA covering USA, Canada, Brazil, Rest of South America, and European Union (ERU);
- Global values for miscanthus, switchgrass and poplar ATJ, ETJ, and Fischer-Tropsch (FT) covering USA, Brazil, and EU 27.

Publications

Peer-reviewed journal publications

Taheripour, F., Sajedinia, E., & Karami, O. (2022). Oilseed cover crops for sustainable aviation fuels production and reduction in greenhouse gas emissions through land use savings. Frontiers in Energy Research, 9(790421), 10. doi: 10.3389/fenrg.2021.790421

Outreach Efforts

Taheripour participated in ASCENT Advisory meetings in fall 2021 and spring 2022 and shared the findings of this research with the ASCENT community.

Awards

None.

Student Involvement

EhsanReza Sajedinia, current PhD student, Purdue University, full time assistantship (50%) for data collection and running simulations.

Plans for Next Period

We plan to work on TEAs to support calculation of LUC emissions associated with new SAF pathways. In particular, TEA of the use of renewable electricity for SAF production will be examined during the CAEP13 cycle to support FTG analyses.

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

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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.

Milestones

Taheripour participated in the CAEP12/FTG11 and CAEP13/FTG01 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 continued to examine regional and global ILUC values for each SAF and led a set of efforts to define a methodology to calculate direct land use change (DLUC) to support the FTG activities.

Major Accomplishments

A methodology has been defined and finalized to calculate DLUC to be used 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.

Publications

Written reports

International Civil Aviation Organization. (2022). CORSIA methodology for calculating actual life cycle emissions values, Section 8: CORSIA methodology for calculating direct land use change emissions values. https://www.icao.int/environmental-protection/CORSIA/Documents/CORSIA_Eligible_Fuels/ICAO%20document%2007%20-%20Methodology%20for%20Actual%20Life%20Cycle%20Emissions%20-%20June%202022.pdf

Outreach Efforts

Taheripour served 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 in 2021 and 2022. This committee has published the following comprehensive report on the LCA approach:

National Academies of Sciences, Engineering, and Medicine. 2022. Current Methods for Life-Cycle Analyses of Low-Carbon Transportation Fuels in the United States. Washington, DC: The National Academies Press. doi:10.17226/26402.

Taheripour attended the Commercial Aviation Alternative Fuels Initiative (CAAFI) Sustainable Aviation Fuels Summit & Biennial General Meeting Agenda (June 1-3, 2022) and updated the participants of this meeting regarding the efforts and findings of this research.

Taheripour attended the ASCENT Advisory Group meetings in fall 2021 and spring 2022 and discussed the findings of this task with members of this community.

Awards

None.

Student Involvement

EhsanReza Sajedinia, current PhD student, Purdue University, full time assistantship (50%) for data collection and running simulations.

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

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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.

Milestones

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

Peer-reviewed journal publications

Busch, J., Amarjargal, O., Taheripour, F., Austin, K. G., Siregar, R. N., Koenig, K., & Hertel, T. W. (2022). Effects of demand-side restrictions on high-deforestation palm oil in Europe on deforestation and emissions in Indonesia. *Environmental Research Letters*, *17*(1), 014035. doi:10.1088/1748-9326/ac435e

Taheripour, F., Sajedinia, E., & Karami, O. (2022). Oilseed cover crops for sustainable aviation fuels production and reduction in greenhouse gas emissions through land use savings. *Frontiers in Energy Research*, *9*(790421), 10. doi: 10.3389/fenrg.2021.790421

Published conference proceedings

Taheripour F., Kwon H., Mueller S., Emery I., Karami O., and Sajedinia E. (2022). Biofuels induced land use change emissions: The role of implemented emissions factors in assessing terrestrial carbon fluxes. *Global Trade Analysis Project 25th Annual Conference and 2022 AAEA Annual Meeting*.

Written reports

Malina R., Prussi M. and Taheripour F. (2022). *Method for establishing lifecycle greenhouse gas emission factors for sustainable aviation fuels*. In 2022 Environmental Report: Innovation for a Green Transition, International Civil Aviation Organization, Montreal QC, Canada.

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/11-WP/06 – "Revisions to methodology on Low Land Use Change (LUC) Risk Practices based on pilot applications", October 2021, Virtual
- CAEP/12-FTG/11-WP/09 – "Direct Land Use Change Emissions Methodology", October 2021, Virtual
- CAEP/12-FTG/11-WP/10 – "ILUC default values", October 2021, Virtual
- CAEP/12-FTG/11-IP/04 – "Foregone carbon sequestration accounting for Direct Land Use Change", October 2021, Virtual
- CAEP/12-FTG/11-IP/05 – "Updating the GTAP-BIO data base from 2011 reference year to 2014 reference year", October 2021, Virtual
- CAEP/12-FTG/11-FL/05 – "Proposal for carinata and camelina oil HEFA pathway characterization", October 2021, Virtual
- CAEP/13-FTG/01-WP/06 – "Approach to ILUC-Related CAEP/13 Work Plan Items", May 2022, Virtual

Outreach Efforts

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

- GTAP 25th Annual Conference on Global Economic Analysis, June 2022, Virtual
- AAEA Annual Meeting, Anaheim, California, July 31-August 2, 2022

Awards

None.

Student Involvement

EhsanReza Sajedinia, current PhD student, Purdue University, full time assistantship (50%) for data collection and running simulations.

Plans for Next Period

We will continue working with ICAO on ILUC emission estimates. In particular, we prepare to serve the FTG group during the CAEP13 cycle to accomplish the following tasks:

- Continue to carry out the computations of ILUC emissions associated with SAF production for requested world regions, for use in CORSIA
- Review the approach to ILUC in light of emerging scientific evidence and data
- Further examine assumptions in ILUC models, such as double cropping representation with a view to better reflect verified historical trends and market behavior
- Revisit the inclusion of foregone sequestration to the CORSIA DLUC methodology, based on the concrete certification experience and feedback from Sustainability Certification Schemes (SCSs)
- Develop pathway specifications for the pathways with negative ILUC emissions, to be verified by the SCSs during certification
- Monitor low-LUC-risk practices implemented for SAF production and incorporate lessons learned in the methodology, as appropriate
- Evaluate a potential inclusion of soil organic carbon and agricultural biomass sequestration at the project level, instead of the current approach that only accounts for changes in these sources as part of the ILUC
- Further explore the consequences of a potential inclusion of ILUC for biomass-derived process fuels (e.g., biomass used to generate electricity for the SAF conversion process)
- Develop sample calculations and/or methods for use in validating SCS tool calculations relating to LCA and DLUC to assist the Sustainability Certification Schemes Evaluation Group (SCSEG) in assessing SCS capabilities; this information could be made publicly available in the CORSIA supporting “LCA methodology” document

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

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Objective

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

Research Approach

See Tasks 1, 2, and 3.

Milestone(s)

See Tasks 1, 2, and 3.

Major Accomplishments

See Tasks 1, 2, and 3.

Publications

None.

Outreach Efforts

None.

Awards

None.

Student Involvement

None.

Plans for Next Period

None.