Project 001(F) Alternative Jet Fuel Supply Chain Analysis

Massachusetts Institute of Technology
Hasselt University

Project Lead Investigators

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University Participants

Massachusetts Institute of Technology (MIT)

- P.I.: Dr. Florian Allroggen
- FAA Award Number: 13-C-AJFE-MIT, Amendment Nos. 003, 012, 016, 028, 033, 040, 048, 055, 058, 067, 082, 088, 096, 115, 132, 135, 142, and 143
- Period of Performance: August 1, 2014, to August 31, 2027
- Tasks (for reporting period October 1, 2024, to September 30, 2025):
  1. Support and provide leadership for United States (U.S.) participation in the International Civil Aviation Organization (ICAO) Committee on Aviation Environmental Protection (CAEP) to enable appropriate crediting of the use of sustainable aviation fuels (SAF) under the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)
  2. Support U.S. participation in the ICAO CAEP by establishing default values and other lifecycle assessments for use under CORSIA
  3. *(omitted, led by Hasselt University)*
  4. Support knowledge sharing and coordination across all ASCENT Project 001 universities working on SAF supply chain analyses.

Hasselt University (UHasselt or UH, through subaward from MIT)

- P.I.: Prof. Robert Malina
- FAA Award Number: MIT Subaward Purchase Order No. 753374
- Period of Performance: September 1, 2016, to September 30, 2026
- Tasks (for reporting period October 1, 2024, to September 30, 2025):
  1. Support and provide leadership for U.S. participation in ICAO CAEP to enable appropriate crediting of the use of SAFs under CORSIA
  2. Support U.S. participation in the ICAO CAEP by establishing default values and other lifecycle assessments for use under CORSIA
  3. Contribute to the development of fuel production assessment for CORSIA-eligible fuels (CEF)
  4. *(omitted, led by MIT)*

Project Funding Level
$4,560,000 FAA funding and $4,560,000 matching funds. Sources of match are approximately $723,200 from MIT, plus 3rd party in-kind contributions of $809,000 from Byogy Renewables, Inc., and $1,038,000 from Oliver Wyman Group, and $1,155,000 from NuFuels LLC, and $401,000 from Savion Aerospace Corp., and $433,800 from Earth Force Technologies.

Investigation Team
Massachusetts Institute of Technology
Dr. Florian Allroggen (P.I.), All MIT tasks
Dr. Raymond L. Speth (co-P.I.), MIT Task 1
Dr. Niamh Keogh (research scientist), MIT Task 1 & 2
Tae Joong Park (graduate research assistant), MIT Tasks 1 & 2

Hasselt University
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Dr. Alessandro Martulli (postdoctoral associate), All UHasselt Tasks

Project Overview
The overall objectives of ASCENT Project 001 are to (a) derive information on regional supply chains to explore scenarios for future SAF production and (b) identify supply-chain-related obstacles to commercial-scale production in the near term and to larger-scale adoption in the longer term. For the reporting period, the MIT/UHasselt team contributed to these goals by (a) providing leadership in the ICAO CAEP Core LCA (CLCA) subgroup of the Fuels Task Group (FTG), now ICAO CAEP Working Group 5 (WG5), which has been tasked with calculating life-cycle greenhouse gas (GHG) emissions associated with the use of SAF, (b) performing core life-cycle GHG emission analyses to enable the inclusion of additional SAF pathways under CORSIA or to verify CLCA values calculated by other institutions, (c) contributing to SAF availability assessments, and (d) contributing to knowledge transfer among the A01 team.

Task 1 – Support and Provide Leadership for U.S. Participation in ICAO CAEP to Enable Appropriate Crediting of the Use of SAFs under CORSIA
Massachusetts Institute of Technology
Hasselt University

Objectives
The overall objective of this task is to provide leadership and support to the FAA in its engagement with the ICAO CAEP FTG (now WG5) to maintain and further develop CORSIA. The specific focus of the work during this reporting period was to (a) finalize amendments to the CORSIA actual value method for including fuels produced from with high electricity inputs and/or with atmospheric or waste gas carbon sources, (b) support finalizing documents for the CAEP 13 meeting, and (c) support development of the work program for WG5 for the CAEP 14 cycle.

Research Approach
To achieve the goals outlined above, the team continued to co-lead the CLCA subgroup of the FTG, now WG5. Prof. Malina acted as a co-lead of the CLCA subgroup and Dr. Allroggen leads the ad-hoc group (AHG) to develop methods for fuels with significant electricity input, which also covered carbon sourcing methods. Prof. Malina's role ensures that Prof. Malina remains a focal point of CLCA research and that specific research tasks can be guided efficiently and effectively; Dr. Allroggen's role ensures leadership on developing novel methods for fuels that were previously not captured in CORSIA. Research conducted in support of the leadership roles is discussed below.

Actual Value Method for Including Fuels Produced with High Electricity Inputs and from Atmospheric or Waste Gas Carbon Sources
Based on research reported during previous reporting periods, the MIT team helped finalize the methods proposal for fuels produced with high electricity inputs and from atmospheric or waste gas carbon sources. Specific text proposals were revised and discussed within FTG:

- For electricity sourcing, key amendments include the addition of a novel electricity sourcing method, which is now included in Section 10 of the Actual Value document. This section discusses the required sourcing documentation, as well as additionality, deliverability, temporal matching, and sustainability certification requirements for electricity sourced for CEF production. Taken together, these elements are meant to replicate chain of custody considerations. They were considered necessary to (a) provide a technology-neutral assessment methodology and (b) avoid concerns at the grid level, especially for impacts and grid stability. A detailed discussion of the underlying rationale can be found in the report for the previous reporting period.
- For carbon sourcing, the MIT team helped finalize new provisions that allow the use of atmospheric and waste gas carbon sources under the actual value document. Key edits include required revisions of the system boundary (now included in Section 2.2.1) and detailed provisions on how waste and residue gases of fossil and biogenic origin can be utilized (now in Section 2.4). Furthermore, a definition and criteria to identify waste and residue gases were included in Section 4 of the document. A detailed discussion of the underlying rationale can be found in reports for the previous reporting periods.

During the CAEP 14 cycle, the MIT team has begun supporting the work of the electricity AHG by researching the sensitivity of default LCA values to electricity carbon intensities. This included understanding when contributions of electricity could vary significantly from default assumptions. Initial analyses show substantial variability in this sensitivity across the default pathways. While electricity contributions to the default value for most pathways do not vary by more than 4g carbon dioxide equivalent (CO_2e) per MJ of fuel within reasonable ranges of electricity carbon intensity (CI) (see Figure 1), some pathways, including mostly ethanol-to-Jet (ETJ) pathways, can produce significant deviations.

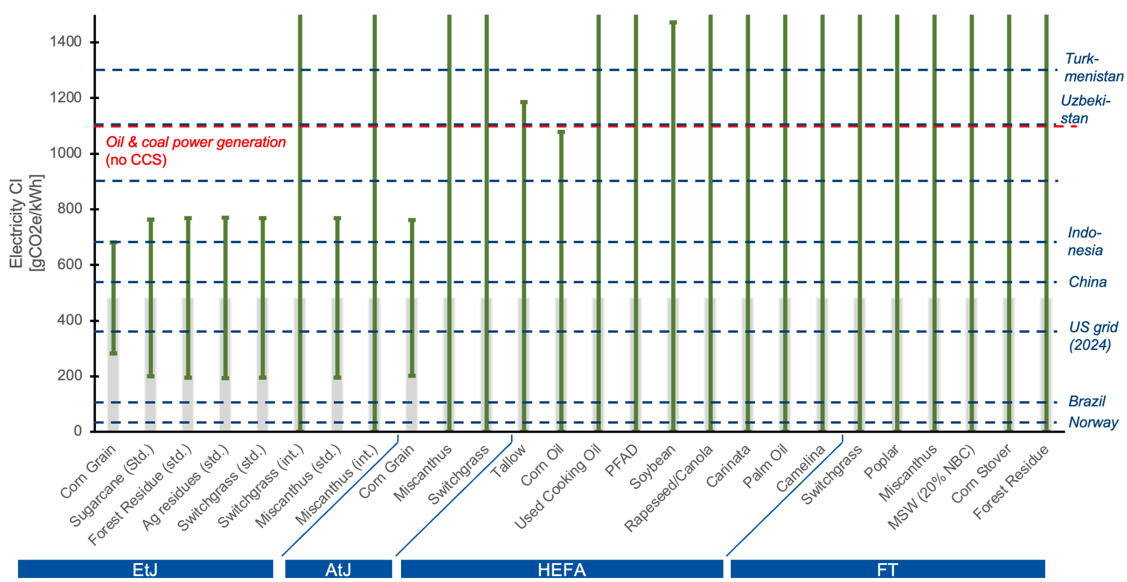

Figure 1. Ranges of electricity carbon intensity, which maintains electricity contribution within 4 gCO_2e per MJ of fuel of the default assumption. Default assumption grid assumption for the analysis is shown in the gray bar.

Support Finalizing Documents for the CAEP 13 Meeting

In wrapping up the CAEP 13 cycle, the MIT team supported finalization of documents for presentation to the CAEP 13 meeting. This included reviewing overview and status papers on FTG's work during the CAEP 13 cycle, as well as reviewing and finalizing concrete amendment proposals brought forward by FTG (see above as an example for the electricity and carbon sourcing method) and talking points for the U.S. team at the CAEP 13 meeting. Furthermore, the MIT team discussed inputs with FAA to help formulate the U.S. positions and leadership role of the U.S.

Support Development of the Work Program for WG5 for the CAEP 14 Cycle
During the CAEP 13 meeting, WG5 was established to take over the tasks of the FTG during the CAEP 14 cycle. WG5 was tasked with further advancing the methods to assess CEFs for consideration under CORSIA. During this reporting period, the MIT team supported development of a work program for the CAEP 14 cycle for WG5. In particular, the team co-led development of the work program for the CLCA group. This included identification of pathways for developing default LCA values (see below) and discussion and prioritization of areas to enhance methods (including further refinements on how electricity is considered in LCA values). The MIT team supported WG5 leadership to develop specific proposals for workplans; it further supported the US delegation in ensuring that U.S. priorities are reflected in the work plans.

Milestones

- UHasselt and MIT have brought forward analyses to support progress in the areas outlined above. The results have been presented to the FTG and WG5 during FTG and WG5 meetings and numerous CLCA subgroup and expert meetings.
- UHasselt and MIT experts participated in and contributed to FTG and WG5 meetings, including CAEP13/FTG9 as well as CAEP14_WG5_1 (May 2025), and CAEP13_WG5_2 (October 2025).

Major Accomplishments

- The CORSIA Actual Value document has been amended with proposed methods on electricity sourcing and use of additional carbon sources.
- Detailed work plans for the CAEP 14 cycle have been developed and presented to WG5.

Publications

- CAEP14_WP5_1_WP03: Update of the work of the CLCA subgroup
- CAEP14_WP5_2_WP09: Update of the work of the CLCA subgroup
- CAEP14_WP5_2_WP13: Proposal to the WG5 Board on feedstock classification
- CAEP14_WP5_2_WP20: Work Program of the Electricity Sourcing AHG in the CAEP 14 cycle.

Outreach Efforts

- Communicated progress on this task during weekly briefing calls with the FAA and other U.S. delegation members to the FTG and WG5, as well as during numerous FTG and WG5 teleconferences between meetings.
- Participated in and contributed to FTG meetings (UHasselt and MIT experts), including CAEP13/FTG9 as well as CAEP14_WG5_1 (May 2025) and CAEP13_WG5_2 (October 2025).
- Led an AHG to prepare concrete proposals for revision of the actual value document to enable the use of additional carbon sources and significant electricity use.

Student Involvement

Tae Joong Park (graduate student, MIT) was involved in this task.

Plans for Next Period

Subject to additional funding of the project, continue work in WG5, including:

- Calculate and propose default CLCA values for additional pathways.
- Continue to lead the CLCA Subgroup (Prof. Malina) and the Electricity Sourcing AHG (Dr. Allroggen).

Task 2 – Support U.S. Participation in ICAO CAEP by Performing CLCA to Establish Default Values for Use Under CORSIA

Massachusetts Institute of Technology
Hasselt University

Objectives

During the CAEP/11, CAEP/12, and CAEP/13 cycle, the MIT ASCENT Project 001 team took leadership in applying the agreed-upon CLCA method to establish default CLCA values for CEFs. However, the list of pathways is not exhaustive, and further CLCA analysis is required to enable the inclusion of SAF technologies nearing commercialization. During the current reporting period, the team supported the calculation of palm oil mill effluent (POME) hydroprocessed ester and fatty acid (HEFA) fuel default LCA value using the U.S.-developed Greenhouse gases, Regulated Emissions, and Energy use in Technologies (GREET) model.

Research Approach

CLCA of HEFA fuel from POME

The team estimated the life cycle GHG emissions of HEFA from POME. The feedstock is a palm oil mill effluent which is included in the positive list of wastes, residues and by products of the palm oil industry. The system boundaries of calculations as well as the specific data sources used for the calculation are summarized in Table 1. The results are shown in Table 2.

Table 1. General assumptions for estimating the core life-cycle analysis emissions of hydroprocessed ester and fatty acid (HEFA) fuels from palm oil mill effluent (POME). CORSIA: Carbon Offsetting and Reduction Scheme for International Aviation; GREET: greenhouse gases, regulated emissions, and energy use in transportation, ICAO: International Civil Aviation Organization, SAF: sustainable aviation fuel.

Stage	Modeling assumptions
Feedstock collection and pre-treatment	Feedstock is assumed to be collected from the POME pond by pump (electricity use). Steam, electricity and various chemicals are used as inputs in the pre-treatment stage. As this step is assumed to take place in Malaysia, the electricity grid mix and the natural gas emission factors of Malaysia are used. Data on the electricity grid mix for Malaysia are sourced from Ember-energy (2023). Electricity use is taken from Sharvini et al. (2020). The natural gas emission factors are computed assuming a 99% offshore gas production in Malaysia.
Feedstock transportation	The POME oil is assumed to be transported first by truck (315 km) to Port Klang from where it is transported to the Port of Rotterdam by ocean tanker (14985 km). Electricity input for the pumping is included.
Fuel production	Hydrogen requirements for POME oil were adjusted from those for soybean hydrogen consumption using the molar stoichiometry of the hydroprocessing reactions. The fatty acid composition of POME oil is taken from data submitted to ICAO. Other energy and utility inputs taken from other HEFA fuels considered under CORSIA. As the SAF production step is assumed to take place in Europe, electricity grid mix and adjusted natural gas emission factors of Europe are used. The natural gas emission factor for Europe is computed in GREET assuming a 33% imported liquified natural gas (LNG).
Fuel transportation and distribution	According to default data from the GREET model, 63%, 8% and 29% of the fuel were assumed to be transported 80 km by truck, 837 km by barge, and 1288 km by rail, respectively. Back-haul is assumed to be empty.

Table 2. Estimated greenhouse gas (GHG) emissions from palm oil mill effluent (POME) sustainable aviation fuel (SAF) production. Data in g CO_2e/MJ_{SAF}.

Stage	POME
Feedstock collection and pre-treatment	3.23
Feedstock transportation	3.71
SAF production	9.83
SAF transportation	0.38

A sensitivity analysis was conducted around key parameters in order to understand the need for clarification in the pathway specification column of the default value table in the ICAO Document “CORSIA Default Life Cycle Emissions Values For CORSIA Eligible Fuels.” (ICAO, 2025) The results are detailed in Table 3 and Table 4.

Table 3. Sensitivity analysis results for power, coal, and natural gas (NG) requirements.

Variation in g-CO_2e/MJ	-20%	-10%	Baseline	+10%	+20%
Power requirements	-0.17	-0.09	17.15	+0.09	+0.17
NG requirements	-1.44	-0.72	17.15	+0.72	+1.44

Table 4. Sensitivity analysis results for power, coal, and natural gas requirements. GHG: greenhouse gas.

g-CO_2e/MJ	Natural Gas (baseline)	Coal	Solar	Nuclear
GHG emission	17.15	21.80 (+4.65)	12.89 (-4.27)	12.93 (-4.22)

Milestones

- Documented research performed in working papers and information papers submitted to the FTG and WG5.
- Discussed the work outlined above with various technical experts.

Major Accomplishments

Inclusion of POME HEFA pathway in CORSIA

Publications

Written report

CAEP14/WG05_02/WP14: Proposal to the FTG Board on a default LCA value for POME HEFA.

Student Involvement

None.

Outreach Efforts

- Communicated progress on this task during weekly briefing calls with the FAA and other U.S. delegation members to the FTG and WG5, as well as during numerous FTG and WG5 teleconferences between meetings.
- Participated in and contributed to FTG meetings (UHasselt and MIT experts), including CAEP13/FTG9 as well as CAEP14_WG5_1 (May 2025) and CAEP13_WG5_2 (October 2025).

Plans for Next Period

Continue to perform attributional CLCA to establish default values for use under CORSIA, subject to additional funding of the project.

References

Ember-energy. (2023). *Electricity Data Explorer*. https://ember-energy.org/data/electricity-data-explorer/?data=co2_intensity&fuel=total&entity=Malaysia

ICAO. (2025). *CORSIA supporting document: CORSIA eligible fuels – Life cycle assessment methodology* (Version 7). International Civil Aviation Organization. https://www.icao.int/sites/default/files/environmental-protection/CORSIA/Documents/CORSIA%20Eligible%20Fuels/CORSIA_Supporting_Document_CORSIA-Eligible-Fuels_LCA_Methodology_V7.pdf

Sharvini, S. R., Noor, Z. Z., Chong, C. S., Stringer, L. C., & Glew, D. (2020). Energy generation from palm oil mill effluent: A life cycle assessment of two biogas technologies. *Energy, 191*, 116513. https://doi.org/10.1016/j.energy.2019.116513

Task 3 – Contribute to the Development of the Fuel Production Assessment for CEFs

Hasselt University

Objective

The objective of this task is to contribute to the development of the fuel production assessment for CEFs to the year 2030 and beyond, based on detailed information gathered in a fuel production database. During the reporting period, the team worked jointly with researchers from Washington State University to maintain and update the SAF production analysis database used for the WG5 fuel projections. Three work streams were developed: (1) update of the SAF short-term production projections, (2) revision of the methodology for developing the short-term production projections, and (3) publish SAF production development trajectories in the peer reviewed literature.

Research Approach

Update of the SAF Short-term Production Projections

In line with previous projections, the projection analysis considers a set of four production scenarios (Low, Moderate, High, and High+). The different scenarios are representative of more pessimistic or optimistic expectations on the development of the SAF market in the short-term. Table 5 details the scenario definitions. While not explicitly modeled, the gradient of parameters chosen in the scenarios with regard to success rates and product slate assumptions is reflective of different levels of policy support for SAF deployment through 2030 (Table 6).

Table 5. Definition of short-term scenarios. *Note*: Code 1: Company has SAF production plans, Code 2: SAF production mentioned but no specific plans & process relevant to SAF, Code 3: process relevant to SAF, but no SAF production plans mentioned; Maturity levels A (very high), B (high), C (moderate) and D (low) are considered. SAF: sustainable aviation fuel.

Scenario	Code	Maturity	Facility Jet Fuel Ratio	A	B	C
Low	1	A,B	Actual or low %	25%	10%	0%
Moderate	1-2	A,B,C	Actual or low %	50%	25%	10%
High	1-3	A,B,C	Actual or high % for 1-2 Actual or low % for 3	75%	50%	25%
High +	1-3	A,B,C	High %	75%	50%	25%

Table 6. Policy-mapping of scenarios. SAF: sustainable aviation fuel.

Scenario	Implicit SAF Policy landscape
Low	No policy support for SAF
Moderate	Some level of policy support for SAF, but lower than for road transportation biofuels
High	Level-playing field between SAF and road transportation biofuels
High+	SAF-emphasis in policies

The updated projections employ the International Air Transport Association SAF production estimate as starting point. For 2024, this value amounted to 1 million tonnes (Mt). Notably, the difference between the actual 2024 SAF production value and the estimates from the database and scenario definition is significantly larger in the High and High+ scenarios. This difference is primarily due to the inclusion of production volumes from facilities that use a technology that can be used for SAF production, but whose operators have not announced that they will actually produce SAF. In 2024, such facilities account for 40% and 79% of the projected production for the year 2024 in the High and High+ scenarios, respectively.

The use of actual production data for the baseline year (2024) results in a sharp increase between actual SAF production in 2024 and projected production in 2025 for the High and High+ scenarios (825% and 1,721% production growth between 2024 and 2025 for the High and High+ scenarios, respectively). This rapid increase is unlikely to occur. While keeping the projected 2030 values from the two scenarios as-is, we smoothen the ramp-up to the 2030 values using a market diffusion approach previously used for the FTG fuel projections. The diffusion model scales the curve to align with actual production in 2024 and scenario-based estimates for 2030, providing a modified projection of SAF production from 1 Mt/year in 2024 to the maximum production level for 2030 using data derived from scenario definition and database data for the High and High+ scenarios.

Table 7 shows the updated annual results for the four scenarios through 2030 using the short-term production database without adjustments to the High and High+ scenarios. For the four scenarios (Low, Moderate, High, and High+), SAF volumes in the year 2030 range from 2.29 Mt in the Low scenario, to 32.13 Mt in the High+ scenario.

Table 7. Annual global (domestic and international) sustainable aviation fuel (SAF) production by scenario (2024 - 2030), without adjustments for the High and High+ scenarios. Data in million tonnes per year (Mt/year).

Year	Low	Moderate	High	High+
2024	1	1	1	1
2025	1.21	3.17	9.25	18.21
2026	1.56	4.17	12.27	21.25
2027	2.05	5.46	16.60	25.63
2028	2.05	5.91	19.83	28.87
2029	2.13	6.17	20.40	29.43
2030	2.29	6.85	23.09	32.13

Revision of the Methodology for SAF Short-term Production Projections
In April 2025, following the release of the latest production projections, the need to revise the projection methodology was highlighted. In July 2025, a review and potential revision of the short-term production projection methodology was proposed. Three main limitations in the current short-term production projections methodology were identified: (1) definition of short-term production projections scenarios, (2) maturity level definition, and 3) discrepancy between two data types, production and capacity volumes.

The definition of the current short-term production projections scenarios results in significant volume disparities between the High/High+ and the Low/Moderate scenarios. This is primarily due to the inclusion of facilities which use a technology that can be used for SAF production, but whose operators have no announced intentions to produce SAF (code 3 facilities). Moreover, the disparity is amplified by the assumed jet fuel production in the overall output. The High and High+ scenarios apply a high jet fuel ratio (for code 1 and 2 facilities), while the Low and Moderate scenarios assume a low jet fuel ratio when actual SAF production data are unavailable. The suggested revision of the short-term production projections scenarios definition includes two changes: (1) excluding all facilities that use a technology that can be used for SAF production, but whose operators have not announced that they will produce SAF, and (2) adjusting the assumed jet fuel ratio.

Concerns associated with the maturity level definition focus on the imbalanced distribution of entries across the different maturity levels. The suggested revision is to revise the categorization criteria by focusing on the individual facility rather than the production company. For example, instead of “Company has a plant under construction” the criteria could be reframed as “Facility under construction.”

The third limitation concerns the discrepancy between actual production and announced capacity data used in the short-term production projections. Current projections rely on announced capacity volumes. However, actual production data reveal that realized production levels are often considerably lower than the projected volumes from capacity announcements. This results in a discontinuity between historical production and forward projections. The suggested adjustment to address this limitation is to use actual production data for the first year of the short-term production projections, while adopting the 2030 capacity-based forecast as the final value across all scenarios. The interpolation between these points would follow the smoothing method already applied in the High and High+ scenarios in the last short-term production projections.

SAF Production Development Trajectories
The team published two papers in the peer reviewed literature that provide insights into the short- and medium-term projections for SAF production. One paper focuses on global and European trajectories, while another paper discusses the U.S. trajectories.

Milestone
Updated SAF short-term production projections and methods.

Major Accomplishments
- Developed the SAF production relational database in SQL (structured query language).
- Published overviews of SAF development trajectories in the peer reviewed literature.

Publications
ICAO papers
- CAEP14_WG5_PlenaryMeeting 1_WP01: SAF Short-term Production Projections Update, April 2025
- CAEP14_WG5_1_IP09: SAF Short-term Projections Update, May 2025
- CAEP14_WG5_1_IP08: SAF Short-term Production Projections Methodology Updates, October 2025

Peer-Reviewed Journal Publications
Martulli, A., Brandt, K., Allroggen, F., & Malina, R. (2025). The potential scale-up of sustainable aviation fuels production capacity to meet global and EU policy targets. *Nature Communications, 16*, 11619. https://www.nature.com/articles/s41467-025-66686-9
Brandt, K., Martinez-Valencia, L., Camenzind, D., Martulli, A., Malina, R., Allroggen, F., & Wolcott, M. (2025). Pragmatic assessment of meeting the 2030 U.S. sustainable aviation fuel goals. *Biomass and Bioenergy, 206*, 108516. https://doi.org/10.1016/j.biombioe.2025.108516

Outreach Efforts
Communicated progress on this task during weekly briefing calls with the FAA and other U.S. delegation members to the FTG and WG5, as well as during numerous FTG and long-term global aspirational goal (LTAG) teleconferences.

Awards
None.

Student Involvement
None.

Plans for Next Period
- Continue the revision of the SAF short-term production projections methodology and provide a revised methodology during CAEP14/W03 meeting in March 2026.
- Provide a new update of the SAF short-term production projections during a plenary meeting of WG5 scheduled for May 2026.

Task 4 – Support Knowledge Sharing and Coordination Across All A01 Universities Working on SAF Supply Chain Analyses
Massachusetts Institute of Technology

Objective
The objective of this task is to provide support for coordination of work by all ASCENT Project 001 universities on SAF supply chain analysis. The sharing of methods and results decreases the replication of work on similar topics among ASCENT Project 001 universities.

Research Approach
The MIT A01 team performed several functions to accomplish this task. Specifically, the team participated in bi-weekly ASCENT Project 001 coordination teleconferences, which served as a venue to discuss progress in various grant tasks and learn about the activities of other ASCENT universities.

Milestone
Presented current research to other ASCENT universities.

Major Accomplishments
Participated in bi-weekly ASCENT Project 001 coordination teleconferences and presentation of current research to other ASCENT universities.

Publications
None.

Outreach Efforts
Participated in bi-weekly ASCENT Project 001 coordination teleconferences and presentation of current research to other ASCENT universities.

Awards
None.

Student Involvement
None.

Plans for Next Period
Continue to engage in bi-weekly teleconferences and other events to disseminate MIT's ASCENT Project 001 work.