Project 001(F) Alternative Jet Fuel Supply Chain Analysis

Massachusetts Institute of Technology

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University Participants

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- PI: Professor Steven R. H. Barrett
- FAA Award Number: 13-C-AJFE-MIT, Amendment Nos. 003, 012, 016, 028, 033, 040, 048, 055, 058, and 067
- Period of Performance: August 1, 2014 to August 10, 2021
- Tasks (those listed here are for the reporting period October 1, 2019 to September 31, 2020):
    1. Support 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), especially as it relates to assessments for low-carbon aviation fuels (LCAF).
    2. Support U.S. participation in ICAO CAEP by carrying out core life cycle analysis (CLCA) to establish default values for use under CORSIA, especially for SAF produced from co-processing of biogenic feedstocks with fossil feedstocks.
    3. *Omitted; Task led by Hasselt University Team.*
    4. Develop methods for probabilistic life-cycle analyses of SAF.
    5. Support knowledge-sharing and co-ordination across all ASCENT Project 01 universities' work on SAF supply-chain analyses.

Hasselt University (through subaward from MIT)

- PI: Robert Malina
- Period of Performance: September 1, 2016 to January 31, 2021
- Tasks (those listed here are for the reporting period October 1, 2019 to September 31, 2020):

1. Support U.S. participation in ICAO CAEP to enable appropriate crediting of the use of SAF under CORSIA especially as it relates to feedstock classification and pathway definitions.
2. Support U.S. participation in ICAO CAEP by carrying out CLCA to establish default values for use under CORSIA, especially for SAF produced using the ethanol-to-jet (ETJ) conversion technology.
3. Contribute to the development of the fuel production assessment for CORSIA-eligible fuels out to the year 2035/
4. *Omitted; Task led by MIT.*
5. *Omitted; Task led by MIT.*

Project Funding Level

FAA provided $3,135,000 in funding and matching funds of $3,135,000 have be contributed by: approximately $497,000 from MIT, plus third-party in-kind contributions of $809,000 from Byogy Renewables, Inc., $1,038,000 from Oliver Wyman Group, and $791,000 from NuFuels LLC.

Investigation Team

Principal Investigator:	Prof. Steven Barrett (MIT) (all MIT tasks)
Principal Investigator (Hasselt Subaward):	Prof. Robert Malina (Hasselt University) (all Hasselt University tasks)
Co-Principal Investigator:	Dr. Florian Allroggen (MIT) (all MIT tasks) Dr. Raymond Speth (MIT) (Task 4)
Postdoctoral Associates:	Hakan Olcay (Hasselt University) (all Hasselt University tasks) Gonca Seber (Hasselt University) (all Hasselt University tasks) Katrijn Gijbels (Hasselt University) (all Hasselt University tasks)
Research Specialist:	Matthew Pearlson (MIT) (Tasks 1 and 4)
Graduate Research Assistants:	Tae Joong Park (MIT) (Task 2) Walter Kelso (MIT) (Tasks 1 and 4)

Project Overview

The overall objectives of ASCENT Project 01 (A01) are to (i) derive information on regional supply chains to explore scenarios for future sustainable aviation fuel (SAF) production, and (ii) identify supply chain-related obstacles to commercial-scale production in the near term, and larger-scale adoption in the longer term.

For the assessment year (AY) 2019/20, the MIT/Hasselt University team contributed to these goals by: (1) providing leadership in the context of the International Civil Aviation Organization Committee for Aviation Environmental Protection (ICAO CAEP) core life cycle analysis (CLCA) task group of the Fuels Task Group (FTG), which is mandated to calculate lifecycle greenhouse gas (GHG) emissions associated with SAF use under the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA); (2) carry out CLCA analyses to enable the inclusion of additional SAF pathways under CORSIA; (3) contribute to the methodological development and analysis of SAF availability out to 2035 in the context of the Technology, Production & Policy (TPP) task group of FTG; (4) develop probabilistic estimates of life cycle GHG emissions for a number of SAF pathways; and (5) provide support for coordination of the A01 team.

Task 1 – Co-lead and Support U.S. Participation in ICAO-CAEP to Enable Appropriate Crediting of the Use of SAF Under CORSIA

Massachusetts Institute of Technology
Hasselt University

Objectives

The overall objective of this task is to provide support to the FAA in their engagement with the ICAO CAEP FTG (during CAEP/12). The specific focus of the work during this reporting period was to (1) refine feedstock classifications; and (2) support the discussion leading toward the development of a CLCA method for LCAF.

Research Approach

In order to achieve the goals outlined above, the team continued to co-lead the Core LCA Task Group of FTG. Prof. Malina acted as a co-lead. This role ensures that Prof. Malina can act as a focal point of CLCA research, so that the specific research tasks can be guided efficiently and effectively. The following research has been conducted in support of the leadership role:

Feedstock classifications

During CAEP/11, the Alternative Fuels Task Force (AFTF) established a process for defining feedstocks as either primary, residues, wastes, or by-products. An initial list of feedstocks in each of these categories was agreed upon. However, it was recognized that the list is incomplete. Under the leadership of the co-lead of the core LCA group, Professor Malina, FTG continuously updates this list during CAEP/12.

Pathway definitions

Under the leadership of the core LCA task lead, Professor Malina, a review of assumptions made in the development of default core LCA values has been conducted. This review aimed to understand if Sustainable Certification Schemes (SCS) require additional guidance on the applicability of a certain default value. The results of this assessment will be discussed at the FTG/6 meeting (AY20–21).

It was found that the publicly available ICAO document "CORSIA SUPPORTING DOCUMENT CORSIA Eligible Fuels – Life Cycle Assessment Methodology" already contains definitions within the sections for the different CORSIA-eligible fuels. For example, these sections contain definitions of the feedstocks for which default core LCA values have been calculated (a definition of used cooking oil, corn oil, palm fatty acid distillate (PFAD), etc.). These sections can be used as a concise source of reference and guidance by the SCS. Based on an analysis of how much the assumptions incorporated into the default pathway influence LCA calculations, several additional clarifications have been recommended to ensure that default values are applied appropriately to a SAF pathway. Recommendations included facility type definitions for the ethanol-to-jet (ETJ) pathway, definitions of open and closed pond palm hydroprocessed esters and fatty acids (HEFA) pathways and updated definitions of agricultural residue pathways, specifically with regard to additional nutrient replacement requirements on the primary crop.

Assessment of LCAF

In preparation of the FTG/04 Meeting, MIT outlined potential technologies and practices to produce LCAF and quantified potential cost and GHG emission impacts. The work was conducted in collaboration with Argonne National Laboratory (ANL). MIT evaluated renewable electricity use at the crude oil field, while ANL evaluated renewable hydrogen use at the refinery, and carbon capture and sequestration (CCS) at the refinery.

More specifically, MIT analyzed the costs and potential reduction of lifecycle impacts associated with electrification of oil field operations and on-site production of electricity from renewable sources. The Uthmaniyah oil field (1.6 million barrels of crude daily output from 472 producing wells) located in Eastern Saudi Arabia was chosen for the case study. The LCA results are presented in terms of the amount of GHG emissions for each megajoule (MJ) of oil produced (gCO_2e/MJ). The techno-economic analysis (TEA) results are presented in terms of change in minimum selling price per barrel of crude oil produced when LCAF technologies are implemented. GHG abatement costs are derived from the TEA and LCA results.

Electricity demand at oil field

MIT analyzed the potential for electrification and on-site production of renewable electricity (i.e., solar electricity) to meet electricity demand at the Uthmaniyah oil field. The electricity requirements and emissions at the field were computed using the Oil Production Greenhouse gas Emissions Estimator (OPGEE) model. OPGEE is a peer-reviewed, publicly available, and editable LCA tool for the measurement of GHG emissions from the production, processing and transport of crude petroleum. Specifically, OPGEE v2.0b and inputs for the Uthmaniyah field from Masnadi et al., (2018) were used.

In the baseline scenario, in which no additional processes at the field are electrified, 463 MWh of electricity are used daily in the field, mainly for water treatment, pumps, and air coolers for gas processing. When the downhole pumps are powered by 600 hp electric motors instead of natural gas (NG) engines, the daily electricity required at the field increases to 4.931 GWh.

Power generation and storage system sizing

The assumed power generation system is composed of a photovoltaic (PV) array consisting of monocrystalline solar modules. Complete specifications for the PV system follow Almarshoud (2016). Global Horizontal Irradiance (GHI) and temperature data are available in 5-minute intervals from the Solar Village in Saudi Arabia for the year 2002 (NREL, n.d.). The PV system is sized such that it produces enough electric energy during the daytime to meet instantaneous electricity demand from the oil field and charge an energy storage system (i.e., a battery system) which covers the night-time electricity demand of the field. The system is sized under four assumptions for back-up power. Under the worst-case sizing assumption, electricity production meets daily electricity demand in the oil field on all days using the year-2002 irradiance data. Under the 1st percentile case, the PV array is sized to meet electricity demand on 99% of the days (361 days). On the remaining days of the year, electricity is imported from the grid. The 5th and 10th percentile case are defined accordingly.

The electricity storage system is sized to store the electric energy to sustain night-time operations of the oil field and is composed of lithium-ion batteries. Based on the specifications of the battery system and the night-time electricity requirements at the field, the required minimum battery storage capacity is found to be 3.6 GWh.

Costs of PV and battery system

Discounted cash flow analysis is used to determine the increase in jet fuel selling price associated with electrification of oil well operations (i.e., downhole pumps) and production of renewable electricity at the well. The analysis is run over a 20-year period which reflects the assumed lifetime of the PV system. All costs are adjusted to year-2020 USD and are allocated to products by output volume.

Capital cost, construction labor cost, land cost and operation cost for the PV and inverter system are taken from Apostoleris et al., (2018). A Weighted Average Cost of Capital (WACC) of 7.5% is assumed, in line with the current WACC of large petrochemical companies. Utility scale lithium-ion battery storage capital, installation labor, and structural balance of system costs are taken from Fu et al., (2018), fixed and operating costs are from Mongrid (2019), and future capital cost reductions are from Cole and Frazier (2019). Labor costs are reduced by 50% relative to U.S. benchmarks due to lower labor costs in Saudi Arabia (Apostoleris et al., 2018).

Lifetimes and costs for electric motors and gas-powered engines are taken from Frazier (2014). Additionally, excess natural gas, which was previously used for combustion, and excess generated electricity is exported from the field at market value.

Minimum selling price impacts

Table 1 shows the increase in selling price per barrel of crude oil input for the four PV sizing scenarios, both with and without the additional revenue streams from selling excess natural gas and electricity.

Table 1. MSP impacts for PV array sizing assumptions ($/bbl of crude oil)

PV Sizing Assumption	**MSP Impact** *[USD per barrel of crude oil]*	**MSP revenue adjustments ***		**Net-cost-based MSP impact** *[USD per barrel of crude oil]*
		Natural Gas Sales *[USD per barrel of crude oil]*	***Electricity Sales*** *[USD per barrel of crude oil]*	
Worst Case	1.13	*0.03*	*0.50*	0.60
1st Percentile	0.53	*0.03*	*0.15*	0.35
5th Percentile	0.36	*0.03*	*0.05*	0.28
10th Percentile	0.32	*0.03*	*0.02*	0.27

* Note that the cost estimate disregards potential investments required for connecting the oil field to the grid

Life cycle GHG analysis of renewable electricity at the oil field

Well-to-refinery emissions at the oil field are modeled with OPGEE v.2.0b using the implemented assumptions for the Uthmaniyah oil field. Table 2 shows the break-down of well-to-refinery emissions for the baseline case, and the worst-case PV sizing scenario. In the renewable electricity scenario, combustion emissions are reduced due to the elimination of the natural gas engines, and offsite emissions are reduced because electricity is produced from renewable sources.

Table 2. Breakdown of Well-to-Refinery Emissions

GHG Emissions Source	**Baseline** *(gCO_2e/MJ)*	**Renewable Electricity** *(gCO_2e/MJ)*
Combustion	0.58	0.29
Venting and Flaring	2.41	2.40
Land Use	1.14	1.14
Transport	1.27	1.26
Small Source	0.50	0.50
Offsite Emissions	0.25	0.21
Total	**6.16**	**5.80**

Additionally, the sensitivity of the lifecycle emissions reductions to the PV sizing assumption are calculated because smaller PV systems will require additional back-up power with non-zero emissions index. As shown in Table 3, this impact was found to be small.

Table 3. Potential well-to-refinery carbon intensity (CI) reduction for PV array sizing assumptions

PV Sizing Assumption	**Average Daily CI (gCO_2e/MJ)**
Worst Case	5.80
1st Percentile	5.80
5th Percentile	5.80
10th Percentile	5.81
CI Reduction from Baseline	**0.35-0.36**

Abatement costs

The results from the cost and emissions analysis are combined to derive the abatement cost of one unit of CO_2-equivalent emissions. The results are shown in Table 4. Additionally, Table 4 shows the impact of natural gas and electricity exports on the cost of avoided CO_2 in the renewable electricity scenario.

Table 4. Costs of avoided CO_2 for PV array sizing assumptions ($/tonne CO_2 avoided)

PV Sizing Assumption	**CO_2e abatement costs, *no additional energy export revenue*** *(in USD per tCO_2e)*	**CO_2e abatement costs, *net impact after energy export revenue*** *(in USD per tCO_2e)*
Worst Case	547	290
1st Percentile	258	171
5th Percentile	176	138
10th Percentile	159	132

Summary of results

Table 5 provides a summary of the MIT results from above, as well as the results for the other LCAF technologies assessed by ANL.

Table 5. Summary of case study results

LCAF Technologies	**Reductions in CI** *[gCO_2e/MJ]*	**Changes in cost** *[$/gal]*	**Abatement cost** *[$\$/tCO_2e$]*
Renewable energy use at oil field [*Uthmaniyah oil field*]	0.35 – 0.36	0.006 – 0.013[a]	132 - 290
Carbon capture in the refinery	3.86	0.09	171
Hydrogen from renewable sources in the refinery	0.54	0.014	190

[a] *Calculated as net change in minimum selling price for jet fuel after additional revenue streams from additional sales of natural gas and electricity.*

Milestones

The work described above has been documented in numerous Working Papers and Information Papers submitted to the FTG. This includes FTG/02 (Montreal, September 2019), FTG/03 (Abu Dhabi, February 2020), FTG/04 (Virtual, June 2020), and FTG/05 (Virtual, July 2020). Team members from Hasselt University and MIT participated in and contributed to all meetings.

Major Accomplishments

The MIT and Hasselt University team accomplished the following under this task:

1. As co-lead of the FTG-CLCA Task Group, Prof. Malina drafted CLCA progress reports to all FTG meetings during the current reporting period and co-led several Task Group meetings.
2. The team submitted Information Paper (IP08) to FTG/04, which summarized the findings of the analysis on LCAF. The LCAF abatement cost analysis will allow assessments of economic viability and will facilitate comparisons between LCAF and biofuels.
3. The team contributed to the FTG report to SG2020/2, outlining the progress made within the core LCA and TPP tasks.

Publications

CAEP/12-FTG04-IP08. Potential LCAF Technologies and Practices. June 2020.
CAEP/12-FTG/02-WP/06. Summary of the work of CLCA-TG since FTG/01. September 2019.
CAEP/12-FTG/03-WP/04. Summary of the work of CLCA-TG since FTG/02. February 2020.
CAEP/12-FTG/04-WP/05. Summary of the progress of the Core LCA Subgroup since FTG/03. June 2020.
CAEP/12-FTG/05-WP/02. Summary of the progress of the Core LCA Subgroup since FTG/04. July 2020.

Outreach Efforts

Progress on these tasks was communicated during weekly briefing calls with the FAA and other U.S. delegation members to FTG, as well as during numerous FTG teleconferences between meetings.

Awards

None.

Student Involvement

During the reporting period, the MIT graduate student involved in this task was Walter Kelso.

Plans for Next Period

In the coming year, the MIT ASCENT Project 1 team will continue its work in FTG. Default core LCA values will be calculated and proposed for additional pathways. Prof. Robert Malina will continue to lead the core LCA Task Group. Work on pathway definitions and LCAF are currently expected to be the focus of attention. The work of the core LCA Task Group during CAEP/12 will be summarized in a series of working and information papers presented to FTG.

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

Massachusetts Institute of Technology
Hasselt University

Objective

During AY 2019/20, the team carried out attributional CLCA to establish or validate default values for use under CORSIA. During the CAEP/11 cycle, the MIT ASCENT Project 1 team took leadership in applying the agreed-upon CLCA method to establish default CLCA values for 26 unique pathways. However, the list of 26 pathways is not exhaustive, and further CLCA analysis is required to enable inclusion of SAF technologies that are nearing commercialization. During the current reporting period, the team supported the calculation of default CLCA values for fuels which are produced from co-processing of biogenic feedstocks and fossil feedstocks in conventional refineries. In addition, the team contributed towards the verification of a set of eight ethanol-to-jet production pathways.

Research Approach

Co-processing

Co-processed fuels are produced by upgrading biogenic feedstocks to jet fuel alongside petroleum feedstock in existing refineries. In their current specification (ASTM D1655-20, A.1.2.2 (ASTM International, 2020)), ASTM allows co-processed jet fuels to be produced by co-processing mono-, di-, triglycerides, free fatty acids, and fatty acid esters as biogenic feedstocks at up to 5% inputs by volume through either hydrocracking or hydrotreating and fractionation. For our initial analyses, we limited the scope of pathways under investigation to hydroprocessing via hydrotreater or hydrocracker, dependent upon the biogenic feedstocks and petroleum derived distillates used. A simplified refinery configuration example using middle distillates and a hydrotreater is shown in Figure 1.

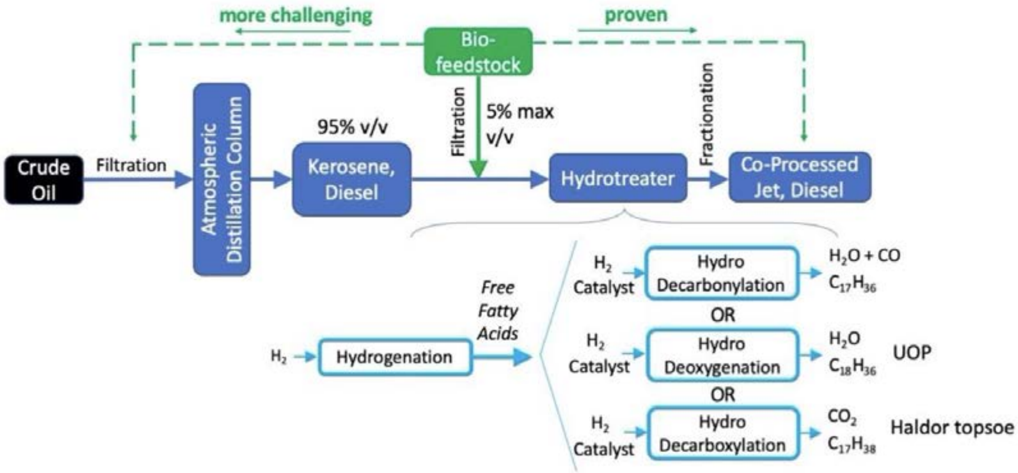


Figure 1. Illustration of co-processing of HEFA bio-feedstock with middle distillates.

The initial list of feedstocks (Table 6) follows the HEFA SAF feedstocks for which CLCA values have been published (ICAO, 2019). Co-processing is not limited to these feedstocks and the analysis can be expanded to include other feedstocks.

Table 6. List of HEFA feedstocks to be considered for co-processing

Feedstock	Type	Details
Used cooking oil (UCO)	Waste	Cooked vegetable oil
Tallow	By-product	Fats from cattle slaughtering
Palm fatty acid distillate		Stripped from crude palm oil during refined palm oil production
Corn oil		Extracted from distillers dry grains/solubles
Oil crops	Main	Soybean, canola/rapeseed, camelina
Palm oil		Closed (w/methane capture) or open pond (w/o methane capture)
Brassica Carinata		Primary summer crop in US/Canada

Conceptual questions for calculating the lifecycle emissions of jet fuel produced from co-processing

LCA analysis of co-processed fuels was found to require addressing the following four conceptual questions:

1. *Process yield/bio-yield calculations*: The goal of the yield analysis is to determine both the total output fuel volume and biogenic fuel volume which results from the addition of biogenic feedstock into the refinery. The potential approaches for the analysis include: a mass balance approach that accounts for process efficiencies; an energy balance which assumes the input feedstock fractions to apply to the outputs; and carbon dating.
2. *GHG emissions savings*: A potential approach for analyzing the lifecycle emissions of co-processed fuels is to analyze the incremental changes of GHG emissions as compared to a refinery configuration without co-processing of biogenic feedstocks. GHG emissions savings are then calculated as the sum of the changes in GHG output associated with inputs such as natural gas, hydrogen, or electricity, with by-products or waste streams, and with the emissions of petroleum-derived fuels. We note that the CORSIA CLCA method assumes combustion emissions of the biogenic fuel portion to be zero (ICAO, 2019).
3. *Eligible SAF volume*: In the regulatory framework, the regulator needs to determine which portions of fuel are considered as the eligible SAF volume. The conceptual options include the (estimated) biogenic portion of the fuel output or the total fuel output (including both the petroleum-derived and biogenic fractions).
4. GHG allocation: Since refineries produce multiple products, GHG emissions need to be allocated to the different products. This step can be completed through (1) proportional attribution following mass or energy of the output fuel portion; (2) carbon dating to directly measure biogenic content in the output fuel; or (3) free attribution which allocates the carbon saving to any chosen portion of the output fuel.

Fuels produced through co-processing are considered in existing regulatory frameworks including the California Low Carbon Fuel Standard (LCFS). For yield calculations under the LCFS, fuel producers can apply carbon dating, a total or carbon mass balance-based method, and an input biogenic energy content method (CARB, 2017A; CARB, 2017B). For computing CI, a default value approach is used which relies on average refining emissions of conventional fuel production, output energy content allocation, or hybrid marginal allocation by calculating the energy use difference between baseline and co-processing production. Other methods not outlined by CARB may also be allowed but are subject to approval (California LCFS, 17 CCR §95491 (d) (C)). CARB requires both the biogenic and total output fuel CIs to be reported (California LCFS, 17 CCR §95488.4). Other regulatory frameworks that include co-processed fuels include the International Sustainability & Carbon Certification System (ISCC) which suggests using an energy balance and/or carbon dating approach for yield analyses (ISCC, 2016).

During the reporting period, MIT conducted an analysis of the sensitivity of CLCA values to the different conceptual choices outlined above. The analyses are illustrative in nature and do not provide guidance on the expected lifecycle values for co-processed fuels. The work was conducted on the basis of two publications: Bezergianni et al., (2014), which showed laboratory experimental results of co-processing heavy atmospheric gas oil (HAGO) with UCO at 4.8% v/v, and Garrain et al., (2014), which showed refinery experimental results of co-processing diesel distillate with soybean oil at 9.6% v/v. We assumed that the soybean/diesel case would still provide valuable insight despite exceeding the ASTM limit of 5% v/v biogenic input feedstock. Both studies present data for producing co-processed renewable diesel, and we assumed no additional resource use for upgrading to jet fuel.

The HAGO/UCO case resulted in a lifecycle impact of 7.8 gCO_2e/MJ for the 0.039 kg biogenic portion and 84.8 gCO_2e/MJ for the 0.788kg entire jet fuel output. This result confirms that the definition of the eligible fuel will have significant impacts on the availability and lifecycle impact associated with the eligible fuel. We note that only one output fuel is reported in Bezergianni et al., thus only this single set of values is presented. A summary of the results for the soybean/diesel case is shown in Table 7. The results confirm the high sensitivities to the different conceptual choices outlined above.

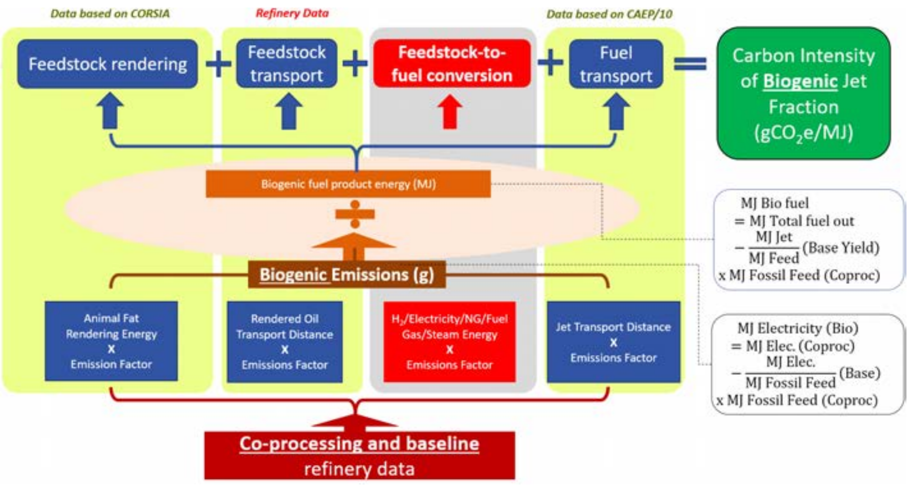
Table 7. LCA sensitivities and associated eligible fuel volumes for the diesel/soybean case, jet only

GHG allocation approach	Eligible fuel	Eligible fuel mass (kg)	Lifecycle emissions (gCO_2e/MJ)
Energy-based	All co-processed jet fuel	42,735	86.7
Energy-based	Biogenic diesel portion only	3,519	60.5
Total-mass-based	All co-processed jet fuel	42,735	86.6
Total-mass-based	Biogenic diesel portion only	3,519	60.3
Carbon-mass-based	All co-processed jet fuel	42,735	88.1
Carbon-mass-based	Biogenic diesel portion only	3,519	72.0
Free attribution to Jet	All co-processed jet fuel	42,735	86.4
Free attribution to Jet	Biogenic diesel portion only	3,519	57.8

Two approaches for computing the lifecycle impacts of co-processed fuels

We outlined two approaches to perform the default CLCA value calculations:

- *Bottom-up approach*: This method calculates CIs from detailed process data for each well-to-wake process step. The approach is similar to the approaches for SAF pathways described in ICAO (2019). An example process diagram for the biogenic portion of a fuel produced from co-processing tallow is shown in Figure 2. During the reporting period, MIT supported ANL in setting up a linear programming study to help obtain the data for a bottom-up assessment from refinery modeling.



$$\text{MJ Bio fuel} = \text{MJ Total fuel out} - \frac{\text{MJ Jet}}{\text{MJ Feed}}(\text{Base Yield}) \times \text{MJ Fossil Feed (Coproc)}$$

$$\text{MJ Electricity (Bio)} = \text{MJ Elec. (Coproc)} - \frac{\text{MJ Elec.}}{\text{MJ Fossil Feed}}(\text{Base}) \times \text{MJ Fossil Feed (Coproc)}$$

Figure 2. Bottom-up approach outline for calculating carbon intensity of biogenic jet fraction.

- *Top-down approach*: This method relies on (published) CI data for certain process steps, which are adjusted to reflect the specific conditions of the production process under investigation. As such, it does not derive CIs from detailed process data (e.g., GHG emissions associated with heavy duty truck transport of fuel). For example, existing data from existing SAF assessments could be combined with data from an approved application to the Californian LCFS for producing co-processed renewable diesel using tallow at BP Cherry Point, WA (CARB, 2019). The resulting calculation method is outlined in Figure 3. Due to a lack of published data, this method was determined to be viable for validating results from a detailed bottom-up analysis only.

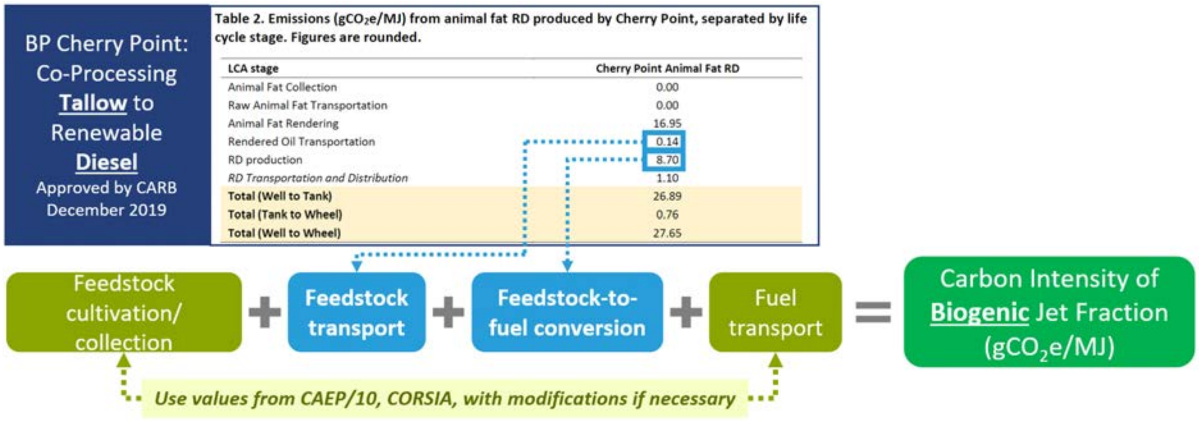


Table 2. Emissions (gCO_2e/MJ) from animal fat RD produced by Cherry Point, separated by life cycle stage. Figures are rounded.

LCA stage	Cherry Point Animal Fat RD
Animal Fat Collection	0.00
Raw Animal Fat Transportation	0.00
Animal Fat Rendering	16.95
Rendered Oil Transportation	0.14
RD production	8.70
RD Transportation and Distribution	1.10
Total (Well to Tank)	26.89
Total (Tank to Wheel)	0.76
Total (Well to Wheel)	27.65

Figure 3. BP Cherry Point tallow co-hydrotreating report data and top-down approach outline.

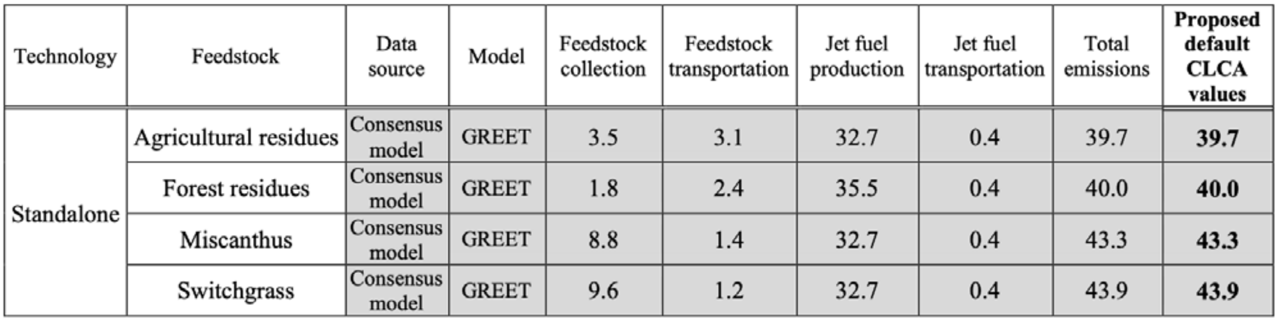
CLCA Validation and verification

The Hasselt University (UHasselt) team served as the verifier for a set of eight new core LCA pathways based on (EtJ) conversion technologies. Separate default core LCA values were calculated for four types of feedstocks and two distinct conversion technologies (integrated EtJ and stand-alone EtJ process).

Core LCA values for EtJ pathways from agricultural residues, forest residues, miscanthus, and switchgrass were modelled and the resulting default CLCA values were proposed at FTG/4 initially. Because the heat integration assumption in ethanol and jet fuel production changes the CLCA values significantly, two sets of default CLCA values for the standalone (without heat integration) and integrated (with heat integration) pathway were proposed. The CLCA TG used the same inputs and outputs of the EtJ process for calculating the approved default CLCA values of the approved corn grain EtJ pathway.

Since FTG/3, the core LCA modelling groups, including Hasselt University, reviewed the standalone EtJ process through an extensive literature review and collected a life-cycle inventory of the EtJ process from various research papers. With the literature review, detailed analyses, and discussion among the modeling group and industry, the CLCA modeling group has included the dataset provided by LanzaTech and two more life-cycle inventories. The modelers used the average datasets for the standalone pathways within the Greenhouse Gases, Regulated Emissions, and Energy Use in Technologies (GREET) model. The calculations have been verified by Hasselt University and approved by the modelling team from the three institutions. Table 8 shows the approved default core LCA values for the four standalone EtJ pathways.

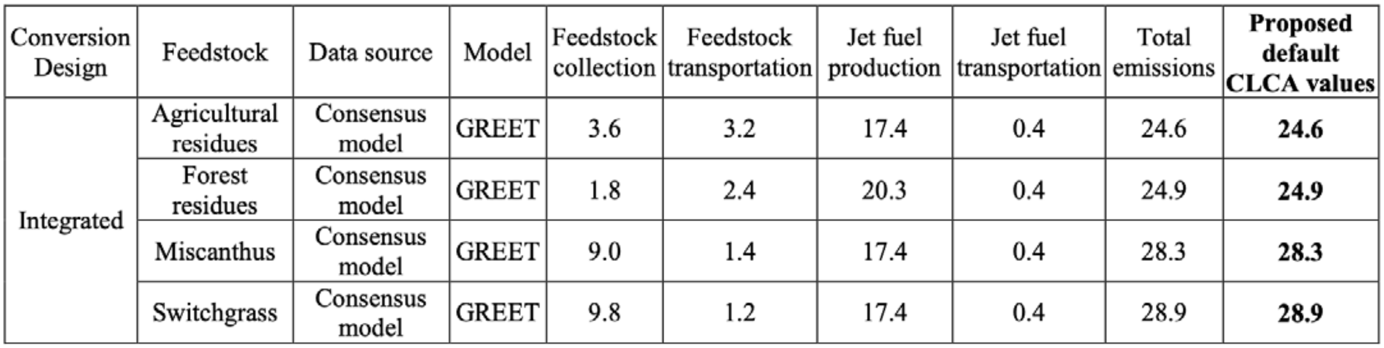
Table 8. Default CLCA values for FTG approval for the standalone EtJ pathways



Technology	Feedstock	Data source	Model	Feedstock collection	Feedstock transportation	Jet fuel production	Jet fuel transportation	Total emissions	**Proposed default CLCA values**
Standalone	Agricultural residues	Consensus model	GREET	3.5	3.1	32.7	0.4	39.7	**39.7**
	Forest residues	Consensus model	GREET	1.8	2.4	35.5	0.4	40.0	**40.0**
	Miscanthus	Consensus model	GREET	8.8	1.4	32.7	0.4	43.3	**43.3**
	Switchgrass	Consensus model	GREET	9.6	1.2	32.7	0.4	43.9	**43.9**

In order to guarantee consistency in the final results, the CLCA values of the four EtJ pathways with the integrated design were recalculated, using the appropriate parts of the agreed-upon life-cycle inventories for the standalone design pathways. ANL was the modeler of this pathway, with UHasselt serving as verifying institution. Table 9 shows the approved default core LCA values for the integrated EtJ pathways.

Table 9. Default CLCA values for FTG approval for the integrated EtJ pathways



Conversion Design	Feedstock	Data source	Model	Feedstock collection	Feedstock transportation	Jet fuel production	Jet fuel transportation	Total emissions	**Proposed default CLCA values**
Integrated	Agricultural residues	Consensus model	GREET	3.6	3.2	17.4	0.4	24.6	**24.6**
	Forest residues	Consensus model	GREET	1.8	2.4	20.3	0.4	24.9	**24.9**
	Miscanthus	Consensus model	GREET	9.0	1.4	17.4	0.4	28.3	**28.3**
	Switchgrass	Consensus model	GREET	9.8	1.2	17.4	0.4	28.9	**28.9**

Milestone

The work described above has been documented in numerous Working Papers and Information Papers submitted to the FTG. This includes paper for FTG/02 (Montreal, September 2019), FTG/03 (Abu Dhabi, February 2020), FTG/04 (Virtual, June 2020), and FTG/05 (Virtual, July 2020). Team members from Hasselt University and MIT participated in and contributed to all meetings. In addition, progress on the co-processing analysis was presented at the Spring ASCENT meeting (Virtual, March 2020).

Major Accomplishments

The MIT and Hasselt University team accomplished the following under this task:

1. The team submitted and presented working paper WP/06 to FTG/02.
2. The team submitted and presented information paper IP/07 and working paper WP/04 to FTG/03, which summarize approaches and challenges for CLCA analyses of co-processed fuels.

3. The team submitted and presented information paper IP/07 and working paper (WP/05) to FTG/04, which proposed the bottom-up and top-down approach for calculating CLCA values for co-processed fuels.
4. The team submitted and presented working paper WP/02 to FTG/05, which reported progress towards working with fuels industry experts towards obtaining data and better understanding of methods.
5. The team presented “Updates on Lifecycle Analysis: Methods for Analyzing Co-processing and for Systematically Capturing Uncertainty” at the Spring ASCENT meeting.

Publications

Written reports

CAEP/12-FTG/02-WP/06. Summary of the work of CLCA-TG since FTG/01. September 2019.
CAEP/12-FTG/03-IP/07. Summary of the work of CLCA-TG on co-processing since FTG/02. February 2020.
CAEP/12-FTG/03-WP/04. Summary of the work of CLCA-TG since FTG/02. February 2020.
CAEP/12-FTG/04-IP/07. Summary of progress since FTG/03 on calculating LCA values for fuels produced through co-processing of biogenic feedstock with petroleum feedstock. June 2020.
CAEP/12-FTG/04-WP/05. Summary of the progress of the Core LCA Subgroup since FTG/03. June 2020.
CAEP/12-FTG/05-WP/02. Summary of the progress of the Core LCA Subgroup since FTG/04. July 2020.

Presentations

Project 1 ASCENT Spring Meeting. "Updates on Lifecycle Analysis: Methods for Analyzing Co-processing and for Systematically Capturing Uncertainty," March 2020.

Outreach Efforts

Progress on these tasks was communicated during weekly briefing calls with the FAA and other U.S. delegation members to FTG, as well as during numerous FTG teleconferences between meetings. Furthermore, the team collaborated extensively with experts from the fuels industry for obtaining reliable data to model LCA values for co-processed fuels. In addition, MIT presented its work under Project 1 to ASCENT at the bi-annual meeting in Spring 2020 (virtual meeting, March 31–April 1) in the form of a presentation.

Awards

None

Student Involvement

TJ Park, Master’s degree student at MIT, performed most of the analysis on co-processing.

Plans for Next Period

The team will continue to carry out attributional CLCA to establish default values for use under CORSIA. More specifically, the team expects to support efforts to determine CLCA values for co-processed fuels and for novel fuel pathways (e.g., catalytic thermolysis), as well as establishing additional default core LCA values for pathways such as jatropha HEFA, for example.

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Task 3 – Contribute to the Development of the Fuel Production Assessment for CORSIA-eligible Fuels out to the Year 2035

Hasselt University

Objective

The UHasselt team aimed to contribute to the development of the fuel production assessment for CORSIA-eligible fuels out to the year 2035. The results of this scenario exercise will then be extrapolated to 2050 and fed into the CAEP Modelling and Databases Group (MDG) process. During the reporting period, this work was accelerated and re-scoped to inform efforts under ICAO's Long-Term Aspiration Goals (LTAG) Task. The research will be completed jointly with researchers from Washington State University and Purdue University.

Research Approach

The work for this task focused on two items:

1. The development of a set of techno-economic models for representative SAF pathways that can be used to estimate capital costs and financial public support needs in the 2035 fuel production scenarios and during the ramp-up; and
2. A comprehensive update of the short-term production database, which will be used to develop an intermediate waypoint (year 2025) for the short-term production scenarios.

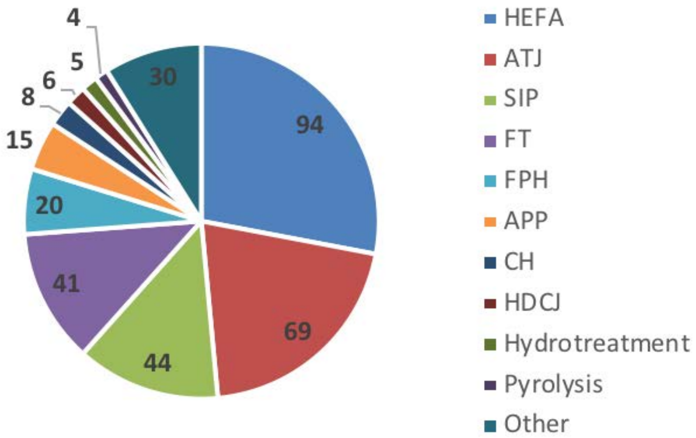
Techno-economic models for scenario development

UHasselt and Purdue University conducted a review of the archival literature and SAF-specific research projects. A total of 56 distinct studies were identified that contained 336 different cases. A case refers to one or more combinations of different parameters for which a (MSP) or net present value (NPV) is estimated in a reference paper. These parameters differ by case and may include process types, feedstocks, co-products, plant sizes, financial assumptions, plant location, etc.

A database was built that captures assumptions and parameter estimates as presented in the studies reviewed. Assumptions and parameters include but are not limited to: feedstock (type and amount), fuel production process, location of plant, location of feedstock sourcing, plant capacity, co-products, discount rate, reference year, plant life, equity/loan fraction, inflation rate, depreciation late, loan interest rate, base year, internal rate of return.

Not all parameters have yet been filled in for the 336 cases. However, based on initial assessment, assumptions differ significantly across the studies. The 336 cases were compared based on the reference year (year that fuel production is assumed to start), feedstock considered, and the fuel production pathways considered.

Five pathways account for almost 80% of all cases (Figure 4). In particular, the HEFA process is the one most frequently reported pathway (94 cases), followed by alcohol-to-jet (ATJ) (69 cases), synthesized iso-paraffins from hydroprocessed fermented sugars (SIP) (44 cases), Fischer-Tropsch processing (FT) (42 cases), and fast pyrolysis and hydroprocessing (FPH) (20 cases).



Note: Numbers on the chart represent the number of corresponding conversion pathways reported in the constructed dataset. The following abbreviations are used on the figure: Hydroprocessed esters and fatty acid (HEFA), Alcohol-to-jet (ATJ), Synthesized iso-paraffins (SIP), Fischer-Tropsch (FT), Fast pyrolysis and hydroprocessing (FPH), Aqueous-phase processing (APP), Catalytic hydrothermolysis (CH), Hydrotreated depolymerized cellulosic jet fuel (HDCJ).

Figure 4. Pathways considered in TEA studies (frequency)

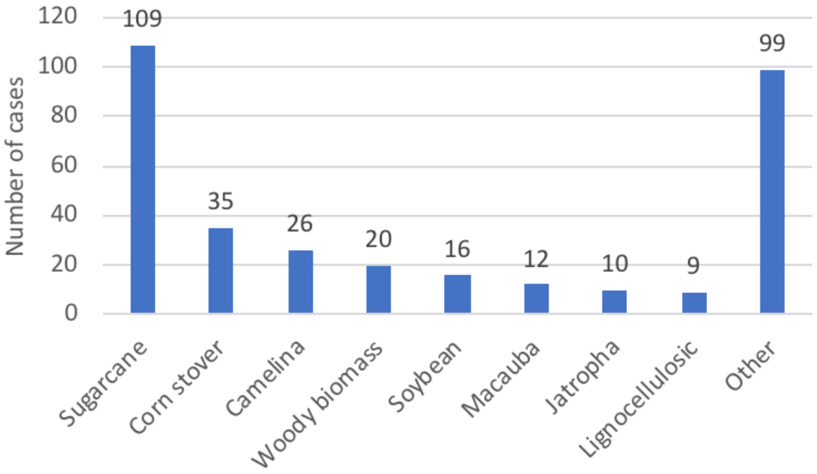


Figure 5. Feedstocks considered in TEA studies (frequency)

Over 30% of the analyzed cases use sugarcane as an input feedstock, followed by corn stover (10% of all cases) and camelina (8%) (Figure 5). The set of the feedstock inputs is highly diversified, representing over 50 varieties. Note that the high number of sugarcane cases is driven by several sugarcane studies assessing multiple cases.

The reported studies rely on different reference years, spanning from 2007 to 2018 (Figure 6). There are 13 cases with non-identified reference year. To make these cases comparable within our dataset, we assumed that the reference year is three years prior to the publication year.

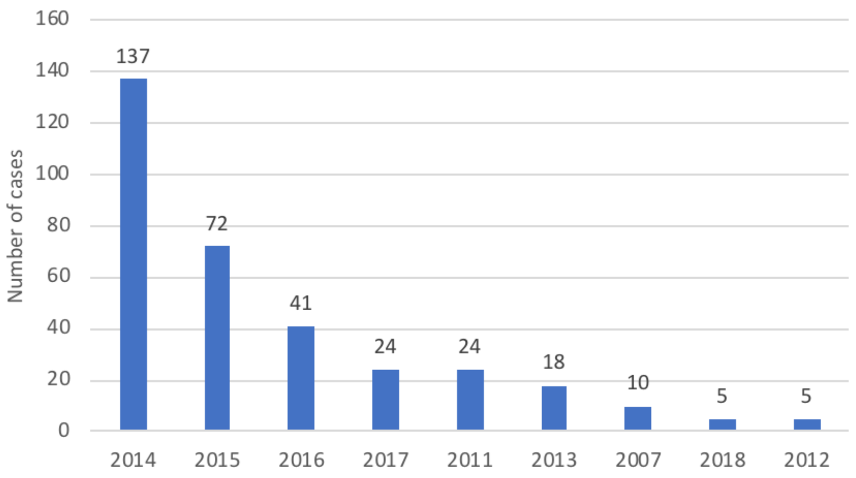


Figure 6, Reference years of TEA studies considered.

Based on the comprehensive literature review, a set of spreadsheet models has been developed for three ASTM-approved fuel pathways: HEFA, FT, and ATJ. Feedstocks considered include vegetable and waste oils, municipal solid waste, forest and agricultural residues, and bulk ethanol and isobutanol. A subset of the models is available to FTG experts in the ICAO portal. The models estimate the financial viability for a specific fuel pathway. They account for capital expenses, operating expenses and revenue streams from co-products in order to estimate the minimum selling price of the fuel pathway under a set of user-determined financial assumptions. The current model parameters reflect the state of the knowledge from the archival literature.

The models also have the capability to quantify the impact of a set of policies (e.g., loan guarantee, capital grant, feedstock subsidy, fuel production) on the financial viability of different fuel pathways. The policy impact calculated by the model builds upon the results of a previous AFTF analysis conducted by MIT, Purdue University, and UHasselt as documented in CAEP/11-AFTF/07-IP/14. The models, in their current form, represent U.S. production characteristics. However, production characteristics in other world regions will be different from the U.S., and the U.S. results from the tool are not representative of other parts of the world. Table 10 contains a list of parameters that can be assumed to be dependent on the location of the CORSIA eligible fuel (CEF) production.

Each Excel file, which was developed under the leadership of the Washington State University team, is a combination of multiple feedstocks and conversion pathways and includes both capital and operating costs. Inside battery limit (ISBL) equipment costs were determined from literature, Aspen modeling, and quotations. The ISBL equipment costs were increased using ratio factors to cover all other capital costs.

Table 10. Proposal for location-specific parameters in the techno-economic models

OPERATING EXPENSES	CAPITAL EXPENSES	FINANCIAL ASSUMPTIONS	
feedstock - purchase and transport	construction	corporate tax rate	property insurance
utility prices, e.g. electricity, natural gas, hydrogen	installation	inflation	local taxes
consumables	land value	depreciation schedule	equity
labor wages and burden	region factor for purchases	discount rate	loan interest rate
REVENUE			loan term (yrs)
Distillate co-product prices			

The outputs of the analysis are minimum selling price (MSP) values for the applicable fuel. In addition, capital costs, operating costs and fuel volumes are calculated. The capital costs are presented as equipment costs, equipment cost totals by manufacturing area, total direct costs (TDC), fixed capital investment (FCI), and total capital investment (TCI). Operational costs are reported as single line items, manufacturing area totals, variable and fixed costs. The details allow users to focus on costs that are most relevant for a given process and feedstock combination for each region, country, or specific location. All fuel distillate values are linearly related to jet fuel MSP using relationships developed by historical fuel cost data available from the U.S. Energy Information Administration. World-region relationships can be added as an option if FTG decides to pursue this option and if the necessary data is obtained.

Users can input a variety of information to tune the analysis to a specific world region, facility scale, and yield. Economic parameters (discount rate, inflation, percent equity, depreciation schedule, etc.), cost parameters (electricity, natural gas, hydrogen, etc.), technical data/assumptions (feedstock, yield, distillate split, etc.) and policy impact (output subsidies, feedstock subsidy, capital grant, etc.) can be altered.

Short-term production database

The short-term production projections database has been updated and revised for the current timeframe (2020–2025). Furthermore, it has been reorganized for ease of management and scenario filtering. It includes six sheets: Announcements & Projections; Codes, ASTM Spec, Facility Type; Conversions & Jet Fuel Ratios; Maturity Definitions; Scenario Definitions; and Updates. The “Announcements and Projections” sheet is organized alphabetically by company, with a single row for each known facility. The database currently includes 131 companies/ventures and 247 facilities. Drop-down menus are used in columns C (Code), L (ASTM specification), and P (Facility Type) to ensure consistency of entries. The “Code” in column C helps to track whether the company has indicated specific plans to produce jet fuel (code 1, green), has indicated jet as a possible product (2, blue), has a process that is compatible with producing jet fuel but no announced intent (3, purple), has a process that provides an intermediate for jet fuel (4, peach), if the company is defunct (5, grey), etc. Total fuel production is entered in original units in column U and then harmonized to kilotonnes/year (kt/y) in column V. If a specific jet fuel production quantity has been announced for the facility, it is included in column W. Alternatively, default product slate values for low and high SAF production are calculated in columns Y and Z, respectively, utilizing the default product slates found on the “Conversions & Jet Fuel Ratios” sheet. Defunct companies are kept on the list to avoid re-researching the same companies later (but these will be excluded from scenario analyses). The goal is to have all projections referenced with a link or other public information in column N. Currently, placeholder columns for low, medium, and high production scenarios are in columns AA to AY. These will be populated during the CAEP/12 cycle based on decisions regarding maturity and scenario definitions (see 2.7 and 2.8 below).

The “Codes, ASTM Spec, Facility Type” sheet provides the definitions for three of the drop-down columns in the Announcements & Projections sheet. The “Conversions & Jet Fuel Ratios” sheet provides conversion factors for various units of production (e.g., millions of gallons or liters per year, cubic meters, etc.) into kt/y, and provides default low and high jet fuel product slates for various processes to populate the low/high jet fuel entries in the Announcements & Projections sheet. It is planned to align the jet fuel conversion factors and product slate ratios between the techno-economic analyses for the various processes and the short-term database assumptions.

The “Maturity Definitions” sheet provides criteria for assessing company maturity as an element that will be used to determine inclusion in future production scenarios. The CAEP/10 analysis used the technology maturity (i.e., a fuel being qualified under ASTM, under evaluation, or not yet in process) and company maturity (experience producing fuel, financial backing, etc.) as criteria for inclusion in various production scenarios. Draft CAEP/12 criteria for assessing maturity are included; however, these maturity criteria have not yet been discussed/developed by the TPP subgroup and are provided solely as an example to aid FTG in understanding how maturity criteria will be developed during the CAEP/12 cycle. Further development of maturity definitions and their application to producers is planned by the TPP sub-group.

The “Scenario Definitions” sheet provides a set of potential rules for inclusion of companies and extent of commercial deployment success that take into account the industry-wide challenges of bringing company plans to fruition. An initial table of scenario definitions is included; however, these scenario definitions have not yet been discussed/developed by the TPP subgroup and are solely provided as an example to aid FTG in understanding how scenarios will be developed during the CAEP/12 cycle. Further development is planned.

The “Updates” sheet provides space for proposed modifications to the Announcements & Projections sheet. The use of the Updates sheet allows TPP to vet changes before they are made and track changes over time. It also ensures that all entries made into the Announcements & Projections sheet can be made consistently using the revised format.

Milestone

The work described above has been documented in several Working Papers submitted to the FTG. This includes papers submitted to FTG/02 (Montreal, September 2019), FTG/03 (Abu Dhabi, February 2020), and FTG/04 (Virtual, June 2020). Team members from Hasselt University and MIT participated in and contributed to all meetings.

Major Accomplishments

- The team presented the comprehensive literature review at the FTG/3 meeting.
- The team presented and led a discussion on the spreadsheet TEA models at the FTG/4 meeting.
- A subset of the spreadsheet TEA models is available for FTG-internal use at the ICAO portal.

Publications

Written reports

CAEP/12-FTG/02-WP/09: Potential Methodology for the Fuel Production Evaluation Task
CAEP/12-FTG/03-WP/10: Summary of the progress on inventory of techno-economic analyses on sustainable aviation fuel
CAEP12/FTG04/WP03: Update on fuel production assessment and TEA
CAEP12/FTG04/IP05 TPP Short Term Projections Database

Awards

None

Student Involvement

None

Plans for Next Period

The team will draft year-2035 fuel production scenarios based on using a market diffusion approach on the production ramp-up contained within the short-term production database and will bring forward scenario results at the Spring 2020 FTG meeting. The team will also provide guidance for MDG and LTAG TG on 2050 production scenarios.

Task 4 – Develop Methods for Probabilistic Life-cycle Analyses and Probabilistic Techno-economic Analyses of SAF

Massachusetts Institute of Technology

Objective

Previous studies have shown that there is significant variability and uncertainty in the life cycle emissions of renewable drop-in fuels (e.g., Sills et al., 2012, Fortier 2014). Variability has been addressed by calculating local sensitivities and by generating a deterministic range of estimates including maximum, minimum, and most likely values (e.g., Staples et al. 2014, Stratton et al., 2011, Seber et al. 2014, Galligan 2018, Rosen 2017). Uncertainty has been quantified for selected pathways (Suresh et al., 2018), however a probabilistic quantification of uncertainty across a number of AJF pathways has not been carried out.

Similarly, MIT previously conducted stochastic TEA studies for a wide set of feedstock-to-fuel pathways to convert biomass or industrial and household wastes into alternative aviation fuel in the U. S. The resulting literature (e.g., Bann et al., 2017; Yao et al., 2017; Suresh et al., 2018; Pearlson et al., 2013, Seber et al., 2014; Bond et al., 2014; Staples et al., 2014) shows that alternative aviation fuels will remain more expensive to produce than conventional jet fuel in the short- to medium-term, but also highlights the range of potential cost outcomes.

These existing TEA and LCA studies have evaluated nationwide uncertainty but did not intend to capture or disentangle this this nationwide uncertainty from regional variability in key inputs. The latter variability manifests itself in factors such as yield, utility prices, and emissions factors, and capital area cost factors. Under this task, we develop a high-resolution stochastic TEA and LCA model to disentangle the impacts of regional variability and nationwide uncertainty in key input parameters on costs and lifecycle impacts. The results of a combined probabilistic LCA would help researchers, policymakers, technology developers, and investors to evaluate the risks and likely emissions outcomes of AJF production and use in a systematic way. In addition, disentangling variability from uncertainty would guide decisionmakers in choosing the most efficient implementation strategies.

Research Approach

High Resolution Feedstock Availability

MIT has previously investigated the production potential of SAF in 2050 in the U. S. across scenarios assuming different economic, climate, and land use assumptions (Galligan 2018). This high-resolution feedstock availability model coupled with regional stochastic LCA and TEA modeling enables the proposed work.

County level crop availability is determined using 2035 land use projections and future crop yield assumptions. Land use patterns in the U.S. in 2035 are modeled with a spatial resolution of 250 meters by the U.S. Geological Survey FORE-SCE project under Intergovernmental Panel on Climate Change (IPCC) Special Report Emissions Scenarios (SRES) A1B, A2, B1, and B2 (Sohl et al., 2014). Land use changes for crop cultivation is considered on the following land classifications: mechanically disturbed lands, barren, grassland, shrubland, herbaceous and woody wetland, and hay and pasture land. For all crops except switchgrass and miscanthus, historical U.S. Department of Agriculture (USDA) county level yield data is extrapolated to 2035 and capped by the agro-climatically attainable yield from the Global Agro-Ecological Zone (GAEZ) version 3.0 model (Fischer, 2012). County level switchgrass and miscanthus yields in 2035 are drawn from the baseline scenario in the 2016 Billion Ton Report (Langholtz, Stokes, and Eaton, 2016).

Crop residue availability is determined using present day crop-specific land cover data, 2035 cropland area, residue quantity per unit crop yield, and sustainable residue removal rates. Crop-specific land cover data is used to determine the distribution of crops on cropland in each county in 2035 and is assumed equal to the crop distribution in 2019 (USDA National Agricultural Statistics Service Cropland Data Layer, 2019). The residue quantity per unit crop yield is available for each crop from Lal (2005), and county level sustainable crop residue removal rates are available from Muth et al., (2013).

Forest residue availability is taken from 2035 county level results from the baseline scenario in the 2016 Billion Ton Report.

Waste products evaluated include animal fats, waste grease, and municipal solid waste (MSW). Waste grease production is available on a per capita basis from Wiltsee (1998), while animal fat production on a per capita basis is calculated using 2017 USDA census data, 2017 USDA animal slaughter data and animal byproduct fractions (USDA, 2018). Municipal solid waste availability is calculated on a per capita basis in 2035 with data from Hoornweg (2012), and 2017 discard fractions from the U.S. Environmental Protection Agency (EPA, 2019). County level population projections in 2035 are available from Hauer (2019) for the five Shared Socioeconomic Pathways (SSP). The SSP data is mapped to the SRES scenarios according to Riahi et al., (2017) for consistency with the USGS FORE-SCE land use models.

Stochastic Life Cycle Assessment

The stochastic LCA model builds off deterministic LCA models which quantify GHG emissions along the AJF supply chain from feedstock cultivation and collection to transportation and combustion. Key stochastic inputs for each step in the LCA model are shown in Table 11.

Table 11. Stochastic LCA inputs

Life Cycle Step	Stochastic Inputs
Feedstock cultivation	▪ Crop yield ▪ Soil nutrient requirements
Feedstock harvesting, collection, and recovery	▪ Cultivation energy ▪ Electricity emissions factor
Feedstock transportation	▪ Transportation distance ▪ Transportation fuel emissions factor
Feedstock pre-processing and fuel conversion	▪ Energy utility requirements ▪ Feedstock-to-fuel conversion efficiency ▪ Utility emissions factors
Fuel transportation	▪ Transportation distance ▪ Transportation fuel emissions factor

The LCA method uses energy allocation for allocating emissions among energy products along the conversion process. The calculated LCA values include emissions generated during ongoing operational activities and emissions embedded in all utilities used. Preliminary stochastic LCA results for the corn grain iso-butanol ATJ pathway in the year 2018 are shown in Figure 7 for a sample of ten U.S. states, along with preliminary stochastic LCA results when U.S.-wide uncertainty is evaluated. The results assume that all life cycle steps occur within the same U.S. state.

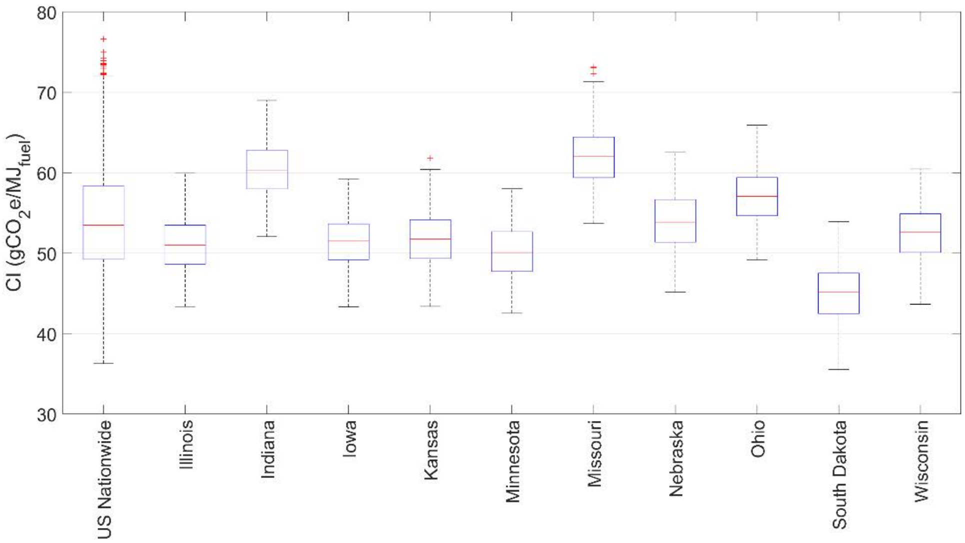


Figure 7. Preliminary regional stochastic LCA for corn grain iso-butanol ATJ.

Preliminary results indicate that regional stochastic LCA modeling can reduce life cycle emissions uncertainty for the ATJ pathway by capturing regional variability in key inputs. Further development of the stochastic LCA modeling is ongoing for all feedstocks and pathways.

Stochastic Techno-Economic Analysis

The stochastic TEA model and stochastic LCA model use harmonized inputs where appropriate, including feedstock yield, chemical and utility requirements, and transportation distance and method. Key stochastic inputs for each step in the TEA model are shown in Table 12.

Table 12. Stochastic TEA inputs

Life Cycle Step	Stochastic Inputs
Feedstock cultivation	▪ Crop yield ▪ Soil nutrient requirements ▪ Fertilizer and chemical costs
Feedstock harvesting, collection, and recovery	▪ Cultivation energy ▪ Utility and labor costs
Feedstock transportation	▪ Transportation distance ▪ Transportation fuel costs
Feedstock pre-processing and fuel conversion	▪ Energy utility requirements ▪ Feedstock-to-fuel conversion efficiency ▪ Utility and chemical emissions costs ▪ Refinery capital costs ▪ Non-fuel product prices
Fuel transportation	▪ Transportation distance ▪ Transportation fuel costs

Milestone

The team briefed FAA on progress during the ASCENT meetings in Spring and Fall 2020.

Major Accomplishments

MIT has developed the framework for harmonized regional stochastic LCA and TEA models. Further development of the TEA and LCA models and integration with regional feedstock availability will occur in the next period.

Publications

N/A

Outreach Efforts

MIT presented the work under this task at the biannual meeting in Spring 2020 (virtual meeting, March 31–April 1) in the form of a presentation. During the ASCENT Fall 2020 meeting (virtual meeting, September 29–30), MIT provided an update through a poster presentation.

Awards

None

Student Involvement

The MIT graduate students involved in this task was Walter Kelso.

Plans for Next Period

MIT will further develop methods for probabilistic life-cycle analyses and probabilistic techno-economic analyses. More specifically, the MIT team will disentangle uncertainty from stochasticity by using a higher-resolution LCA model. This high-resolution approach will provide insights in the regional variability of lifecycle emissions for different SAF pathways in the U.S. and the associated risks by area. This data will further be combined with a regionalized stochastic TEA model (Bann et al., 2017) and previous work on U.S.-specific assessments of long-term SAF availability (Galligan 2018) to obtain a holistic assessment of U.S.-sourced SAF availability in 2035. The results will guide researchers, policymakers, technology developers, and investors in prioritizing geographic areas of SAF development and in better understanding the risks and uncertainties associated with specific choices.

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Task 5 – Support Coordination of All A01 Universities' Work on SAF Supply-chain Analyses

Massachusetts Institute of Technology

Objective

The objective of this task is to provide support for coordination of all ASCENT Project 1 (A01) Universities' work on SAF supply-chain analysis. The sharing of methods and results decreases the replication of A01 Universities' work on similar topics.

Research Approach

The MIT A01 team performed several functions to accomplish this task.

- Participated in the bi-weekly A01 coordination teleconferences, which were used as a venue to discuss progress on various grant tasks and learn about the activities of other ASCENT universities. The team also presented current research on co-processing to the A01 universities.
- Contributed to efforts for developing a special journal issue on SAF based on the research conducted under A01.

Milestone

The MIT ASCENT A01 team presented current research to other ASCENT universities.

Major Accomplishments

The major accomplishments associated with this task include participation in bi-weekly A01 coordination teleconferences; presentation of current research to other ASCENT universities; and contribution to the development of a journal special issue.

Publications

N/A

Outreach Efforts

See above.

Awards

None

Student Involvement

N/A

Plans for Next Period

Continued engagement in bi-weekly teleconferences and other events to disseminate MIT's A01 work. In particular, the MIT team expects to contribute to a collection of articles on SAF development.