Project 001(B) Alternative Jet Fuel Supply Chain Analysis

University of Hawai‘i

Project Lead Investigator

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University Participants

University of Hawai‘i (UH)

- P.I.: Scott Q. Turn, Researcher
- FAA Award Number: 13-C-AJFE-UH, Amendment 005
- Period of Performance: October 1, 2015, to August 4, 2021
- Tasks:
  1.
     1.1 Inform regional supply chains.
     1.2 Identify supply chain barriers in the Hawaiian Islands.

- FAA Award Number: 13-C-AJFE-UH, Amendment 007
- Period of Performance: October 1, 2016, to August 4, 2021
- Tasks:
  2.
     2.1 Inform regional supply chains.
     2.2 Support Indonesian alternative jet fuel (AJF) supply initiatives.

- FAA Award Number: 13-C-AJFE-UH, Amendment 008
- Period of Performance: August 1, 2017, to August 4, 2021
- Tasks:
  3.
     3.1 National lipid supply availability analysis
     3.2 Hawai‘i Regional Project

- FAA Award Number: 13-C-AJFE-UH, Amendment 011
- Period of Performance: May 31, 2019, to August 4, 2021
- Task:
  4. Hawai‘i Regional Project

- FAA Award Number: 13-C-AJFE-UH, Amendment 013
- Period of Performance: June 5, 2020, to August 4, 2021
- Task:
  5. Hawai‘i Regional Project

- FAA Award Number: 13-C-AJFE-UH, Amendment 017
- Period of Performance: October 1, 2021, to September 30, 2022

- Task:
  6. Hawai‘i Regional Project

- FAA Award Number: 13-C-AJFE-UH, Amendment 019
- Period of Performance: December 22, 2022, to December 31, 2023
- Task:
  7. Hawai‘i Regional Project

- FAA Award Number: 13-C-AJFE-UH, Amendment 025
- Period of Performance: August 12, 2024, to August 11, 2025
- Task:
  8. Hawai‘i Regional Project

Project Funding Level

Under **FAA Award Number 13-C-AJFE-UH, Amendment 005**, the Alternative Jet Fuel Supply Chain Analysis–Tropical Region Analysis project received $75,000 in funding from the FAA and cost-share funding of $75,000 from the State of Hawai‘i.

Under **FAA Award Number 13-C-AJFE-UH, Amendment 007**, the Alternative Jet Fuel Supply Chain Analysis–Tropical Region Analysis project received $100,000 in funding from the FAA, cost-share funding of $75,000 from the State of Hawai‘i, and $25,000 of in-kind cost match in the form of salary support for Scott Turn from UH.

Under **FAA Award Number 13-C-AJFE-UH, Amendment 008**, the Alternative Jet Fuel Supply Chain Analysis–Tropical Region Analysis project received $125,000 in funding from the FAA and cost-share funding of $125,000 from the State of Hawai‘i.

Under **FAA Award Number 13-C-AJFE-UH, Amendment 011**, the Alternative Jet Fuel Supply Chain Analysis–Tropical Region Analysis project received $200,000 in funding from the FAA and cost-share funding of $200,000 from the State of Hawai‘i.

Under **FAA Award Number 13-C-AJFE-UH, Amendment 013**, the Alternative Jet Fuel Supply Chain Analysis–Tropical Region Analysis project received $200,000 in funding from the FAA and cost-share funding of $200,000 from the State of Hawai‘i.

Under **FAA Award Number 13-C-AJFE-UH, Amendment 019**, the Alternative Jet Fuel Supply Chain Analysis–Tropical Region Analysis project received $150,000 in funding from the FAA and cost-share funding of $150,000 from the State of Hawai‘i.

Under **FAA Award Number 13-C-AJFE-UH, Amendment 025**, the Alternative Jet Fuel Supply Chain Analysis–Tropical Region Analysis project received $150,000 in funding from the FAA and cost-share funding of $150,000 from the State of Hawai‘i.

Investigation Team

University of Hawai‘i

Dr. Scott Turn (P.I.; Hawa'ii Natural Energy Institute), All Tasks
Dr. Trevor Morgan (assistant researcher; Hawai‘i Natural Energy Institute), Tasks 1–3
Dr. Richard Ogoshi (assistant researcher; Department of Tropical Plant and Soil Sciences), Tasks 1 and 2
Dr. Adel H. Youkhana (junior researcher; Department of Tropical Plant and Soil Sciences), Tasks 1 and 2
Dr. Curtis Daehler (professor; Department of Botany), Task 1
Ms. Sharon Chan (junior researcher; Hawai‘i Natural Energy Institute), Tasks 2, 5, and 7
Mr. Gabriel Allen (undergraduate student; Department of Biochemistry, Task 2
Dr. Jinxia Fu (assistant researcher; Hawai‘i Natural Energy Institute), Task 3
Dr. Quang Vu Bach (assistant researcher; Hawai‘i Natural Energy Institute), Tasks 3,4, 6, and 8
Ms. Sabrina Summers (undergraduate student; Department of Bioengineering), Task 3
Ms. Sarah Weber (undergraduate student; Department of Molecular Biosciences and Biotechnology), Task 3

Mr. Taha Elwir (undergraduate student; Department of Chemistry), Task 3
Dr. Donna Lee (energy crop analyst, Hawai‘i Natural Energy Institute), Task 5 and 7
Dr. Elmar Villota (postdoctoral researcher, Hawai‘i Natural Energy Institute), Task 5 and 7

Other Lead Personnel

University of Tennessee
Prof. Tim Rials (co-P.I.)
Prof. Edward Yu (co-P.I.)

Washington State University (WSU)
Prof. Michael Wolcott (P.I.)
Prof. Manuel Garcia-Perez (co-P.I.)

Volpe National Transportation Systems Center
Kristin Lewis (principal technical advisor and P.I.)

The Pennsylvania State University
Prof. Lara Fowler (P.I.)

Project Overview

The research effort under **Task 1** has two objectives. The first objective is to develop information on regional supply chains for use in creating scenarios of future alternate jet fuel (AJF) production in tropical regions. Outputs from this project may be used as inputs to regional supply chain analyses being developed by the FAA and Volpe Center. The second objective is to identify key barriers in regional supply chains that must be overcome to produce substantial quantities of sustainable aviation fuel (SAF) in the Hawaiian Islands and similar tropical regions.

The project goals of **Task 1** are as follows:

- Review and summarize the following:
  - The available literature on biomass feedstocks for the tropics
  - The available literature on pretreatment and conversion technologies for tropical biomass feedstocks
  - The available literature on geographic information system (GIS) datasets available for assessing AJF production systems in the tropics
- Identify AJF supply chain barriers in the Hawaiian Islands.

The research effort under **Task 2** has two objectives. The first objective is to develop information on regional supply chains for use in creating scenarios of future SAF production in tropical regions. Outputs from this project may be used as inputs to regional supply chain analyses being developed by the FAA and Volpe Center. This objective includes the development of fundamental property data for tropical biomass resources to support supply chain analysis. The second objective is to support the memorandum of understanding between the FAA and the Indonesian Directorate General of Civil Aviation to promote the development and use of sustainable alternative aviation fuels.

The project goals of **Task 2** are as follows:

- Support the Volpe Center and Commercial Aviation Alternative Fuels Initiative (CAAFI) Farm to Fly 2.0 supply chain analysis.
- Use GIS-based estimates of fiber crop production potential to develop preliminary technical production estimates of jet fuel in Hawai‘i.
- Develop fundamental property data for tropical biomass resources.
- Transmit data and analysis results to other ASCENT Project 001 researchers to support the improvement of existing tools and best practices.
- Support Indonesian SAF supply initiatives.

The research effort under **Task 3** has two objectives. The first objective is to support a national lipid supply availability analysis that will inform industry development and guide policy. The second objective is to conduct a targeted supply chain analysis for a SAF production facility based on the Hawai‘i regional project.

The project goals of **Task 3** are as follows:

- Support ASCENT partners conducting the national lipid supply availability analysis by contributing information on tropical oilseed availability.
- Evaluate supply chains for targeted waste streams and purpose-grown crops in Hawai‘i to a location in the principal industrial park on the island of O‘ahu.

For the research effort under **Task 4**, the main objective is to conduct bench-scale testing of tropical feedstocks for use in targeted supply chain analysis for a SAF production facility based on the Hawai‘i Regional Project initiated under Amendment 008.

The project goals of **Task 4** are as follows:

- Survey bench-scale systems available for relevant SAF conversion technology options.
- Down-select from the available bench-scale systems to no more than two systems capable of conducting feedstock testing and quantifying product yields and contaminant concentrations.
- Conduct bench-scale feedstock tests and quantify product yields, quality, and contaminant concentrations.

The project goals of **Task 5** are as follows:

- Conduct tropical oil-to-SAF supply chain analyses.
- Develop management strategies for elements present in construction and demolition (C&D) waste that affect use in thermochemical-conversion-based SAF production pathways.

The project goals of **Task 6** are as follows:

- Explore the impacts of HB2386 on waste management in Hawai‘i and potential for waste-based SAF production systems.

The project goals of **Task 7** are as follows:

- Evaluate greenhouse gas (GHG) implications of tropical oil-to-SAF supply chains in Hawai‘i based on life cycle methods.

The project goals of **Task 8** are as follows:

- Evaluate GHG implications of waste management use for SAF production in Hawai‘i based on life cycle methods

Task 1.1 – Inform Regional Supply Chains

University of Hawai‘i

Objectives

This task included two activities: (1) reviewing the archival literature on existing tropical crops and potential new crops that could provide feedstocks for SAF production and (2) reviewing relevant pretreatment and conversion technology options and experiences with the feedstocks identified in (1).

Research Approach

Task 1.1

The archival literature was reviewed to construct an updated database of relevant citations for tropical crops; new potential energy crops were identified and added to the database. Available information on agronomic practices, crop rotation, and harvesting techniques was included. The database was shared to serve as a resource for the ASCENT Project 001 Team and Volpe Center analyses of regional supply chains.

Task 1.2

A database of relevant pretreatment and conversion technology options, and experiences with potential tropical feedstock materials, was assembled from the archival literature and from existing Project 001 Team shared resources. Of particular interest were inventories of material and energy flows associated with the pretreatment and conversion unit operations fundamental to the design of sustainable systems and underlying analyses. Pairings of pretreatment and conversion technology options provided a starting point for the evaluation of tropical biorefineries that can be integrated into the ASCENT Project 001 Team and Volpe Center activities.

Milestones

Task 1.1

- Identified a target list of databases to search for relevant literature.
- Provided an interim report summarizing progress in the literature search.

Task 1.2

- Identified a target list of databases to search for relevant literature.
- Provided an interim report summarizing progress in the literature search.

Major Accomplishments

This work has been completed. A report was produced for each of the two activities, and the two reports were combined into a manuscript published in the journal *Energy & Fuels* (Morgan et al., 2019).

Publications

Peer-reviewed Journal Publication

Morgan, T. J., Youkhana, A., Ogoshi, R., Turn, S. Q., & Garcia-Perez, M. (2019). Review of biomass resources and conversion technologies for alternative jet fuel production in Hawai‘i and tropical regions. *Energy & Fuels, 33(4*), 2699–2762. doi: 10.1021/acs.energyfuels.8b03001

Outreach Efforts

On February 21, 2018, the P.I. participated in a ThinkTech Hawai‘i broadcast focused on SAFs, with collaborators from WSU and CAAFI (https://www.youtube.com/watch?v=Ci4oWITPRKQ&feature=youtu.be).

Awards

None.

Student Involvement

None.

Plans for Next Period

None.

Task 1.2 – Identify Supply Chain Barriers in the Hawaiian Islands

University of Hawai‘i

Objective

The objective of this task was to identify key barriers in regional supply chains that must be overcome to produce substantial quantities of SAF in the Hawaiian Islands and similar tropical regions.

Research Approach

The UH developed the Hawai‘i Bioenergy Master Plan for the State of Hawai‘i (http://www.hnei.hawaii.edu/wp-content/uploads/Hawaii-Bioenergy-Master-Plan.pdf), which was completed in 2009. In that plan, UH was tasked with determining whether Hawai‘i had the capability to produce 20% of land transportation fuels and 20% of electricity from bio-based resources. To this end, the plan included assessments of (a) land and water resources that can support biomass feedstock production, (b) potential biomass resources and their availability, (c) technology requirements, (d) infrastructure requirements to support logistics, (e) economic impacts, (f) environmental impacts, (g) availability of human capital, (h) permitting requirements, and (i) limitations to developing complete value chains for biomass-based energy systems. In keeping with the stakeholder-driven development of the Hawai‘i Bioenergy Master Plan, barriers to the development of regional supply chains for ASCENT were identified through interactions with key stakeholder groups. Green Initiative for Fuels Transition Pacific (GIFTPAC) meetings are held quarterly and attended by biofuel development interests in Hawai‘i, including representatives of large landowners, producers of first-generation biofuels, petroleum refineries, electric utilities, the Hawai‘i State Energy Office, U.S. Pacific Command, biofuel entrepreneurs, county government officials, and UH. Additional stakeholders are invited as necessary to fill gaps in information and the value chain. These meetings serve as excellent opportunities to receive stakeholder input, identify barriers to supply chain development, and organize data collection efforts that span supply chain participants.

Milestones

- Introduced activities at the next regularly scheduled GIFTPAC meeting after contract execution
- Prepared an interim report outlining two tropical supply chain scenarios developed in consultation with the Project 001 Team, with input from GIFTPAC participants

Major Accomplishments

This task has been completed. A stakeholder meeting was held and documented in a report submitted to the FAA. The stakeholders identified barriers to SAF production in Hawai‘i and ranked the barriers in order of importance as follows:

1. Economic constraints (e.g., high costs of entry for production factors such as land) throughout the entire production chain;
2. Issues associated with access to capital, including high initial risks and uncertain returns on investment
3. Insufficient government support in the form of incentives and favorable policies to encourage long-term private investment;
4. Cost, availability, and competition for water;
5. SAF production technologies (emerging but not yet demonstrated to have full commercial viability); and
6. Insufficient or inadequate infrastructure (e.g., harbors, roads, fuel distribution infrastructure, irrigation systems) to support the entire production chain.

Several of these barriers also arise at locations in the continental United States; however, those related to water and infrastructure are unique characteristics of an island state.

Publications

None.

Outreach Efforts

This activity engaged stakeholders to identify barriers to SAF production in Hawai‘i. Preparation included reviewing stakeholder lists from previous activities. Facilitators appropriate to the stakeholder group were retained. The stakeholder meeting included a presentation of the scope and goals of the larger ASCENT program and other aspects of the UH ASCENT project.

Awards

None.

Student Involvement

None.

Plans for Next Period

This task is complete, but stakeholder outreach activities will continue under other tasks, as outlined below.

References

Hawai‘i Natural Energy Institute. (n.d.). *Hawai‘i Natural Energy Institute.* hnei.hawaii.edu

Task 2.1 – Inform Regional Supply Chains

University of Hawaiʻi

Objectives

To build on activities from fiscal year 2016, additional supporting analyses will be conducted for proposed supply chains in Hawaiʻi, including the following:

- Task 2.1.1 - Support the Volpe Center and CAAFI Farm to Fly 2.0 supply chain analysis
- Task 2.1.2 - Use GIS-based estimates of fiber crop production potential to develop preliminary technical production estimates of jet fuel in Hawaiʻi
- Task 2.1.3 - Develop fundamental property data for tropical biomass resources
- Task 2.1.4 - Transmit data and analysis results to support the improvement of existing tools (e.g., Policy Analysis System Model [POLYSYS]; https://bioenergykdf.net/content/polysys).

Research Approach

Task 2.1.2 has been conducted by using GIS data to identify areas suitable for purpose-grown crop production of feedstocks for SAF production in Hawaiʻi. The approach has used GIS layers for land capability class (LCC), slope, and zoning as preliminary screens for suitability. Lands are classified by the Natural Resources Conservation Service with ratings from 1 to 6. LCCs 1–3 are generally suitable for agricultural production, LCC 4 can be productive with proper management, and LCCs 5 or 6 can support less intensive production and may be suitable for forestry. The slopes of terrains affect aspects of production, including mechanization and erodibility. An elevation GIS layer was used to derive a slope layer. Zoning layers were acquired from Hawaiʻi state and county GIS offices. Only agricultural zoning was deemed suitable for this analysis.

The EcoCrop model was used to develop yield models for the crops selected in Task 1 according to annual rainfall and mean minimum monthly temperature data. EcoCrop includes model parameters on sugarcane, bana grass, five species of eucalyptus, *Gliricidia*, *Leucaena*, *Pongamia*, *Jatropha*, and sorghum. The parameters for sugarcane have been used to provide a base case assessment for comparison with historical sugarcane acreage and yield. Through sensitivity analysis, the model can be tuned to account for differences between parameters developed from global sugar production and a century of production experience in Hawaiʻi that has been refined through plant breeding to adapt sugarcane varieties to a wide variety of agro-ecosystems. The analysis has purposely avoided land-use conflict with food production by limiting suitability to areas capable of sustaining AJF feedstocks under rain-fed conditions. Areas suitable for SAF production that do not conflict with current agricultural land use (i.e., fallow land) have also been identified.

Pongamia (*Millettia pinnata*) was the initial focus of Task 2.1.3. *Pongamia* is an oilseed-bearing leguminous tree with production potential in Hawaiʻi and Florida. The tree produces pods containing oil-bearing seeds. Pods, oilseed cake, and oil were evaluated from trees growing on the island of Oʻahu. Fundamental measurements of chemical composition were conducted and reported. Torrefaction of pods as a coproduct in oil production has been conducted. An investigation of pretreatment methods to improve pod feedstock properties for thermochemical conversion applications has been completed.

Milestones

- Identified target opportunities to augment POLYSYS, the Alternative Fuel Transportation Optimization Tool (https://trid.trb.org/view/1376122), and conversion modules
- Reviewed previously developed GIS information layers for tropical fiber crops and identified updating requirements
- Conducted preliminary estimates of SAF technical potential in Hawaiʻi, according to previously developed GIS information layers

Major Accomplishments

The GIS-based analysis of SAF production potential is ongoing. The assessment of potential lands meeting the requirements for LCC, slope, and land-use zoning has been completed. The EcoCrop model was implemented to predict yield as a function of the minimum mean monthly temperature and annual rainfall. This process identified potential SAF feedstock crops for land areas capable of supporting their production under both rain-fed and irrigated conditions. This analysis provided information necessary for determining cropping patterns and assessing costs for transport to processing facility locations. The EcoCrop model's prediction of sugarcane potential was determined, and the results were compared with historical sugarcane acreage, both rain-fed and irrigated. The EcoCrop's upper and lower values for temperature and rainfall that support optimal sugarcane production were varied to calibrate the prediction against historical acreage. The difference between the EcoCrop values and those representative of conditions in Hawai'i is attributable to improvements due to plant breeding and unique combinations of environmental conditions (e.g., the relatively young volcanic soils present in high-rainfall areas on the island of Hawai'i that enable high drainage rates and accommodate sugar production).

Calibration of the EcoCrop model using historical sugarcane planted acreages was completed in 2018. This effort used a confusion matrix approach for validation (resulting in a kappa value >0.4) and demonstrated that the mean annual temperature was a better indicator of environmental capability than the minimum mean monthly temperature recommended by the EcoCrop developers. This effort highlights the need to adapt models to local conditions. Model predictions for suitable cropping are being compared with current land uses to provide another indicator of agreement.

The GIS analysis of SAF feedstock production potential has been completed. Statewide working maps for each of the species have been summarized in a draft report currently undergoing internal review (Chan et al., draft). This report will serve as the basis for a journal article publication.

Dr. Curtis Daehler (UH, Department of Botany) has completed a report assessing the invasiveness of *Pongamia*. Retrospective analyses have shown that predictive weed risk assessment systems correctly identify many major pest plants, but their predictions are not 100% accurate. The purpose of this study was to collect field observations of *Pongamia* planted around O'ahu to identify direct evidence of *Pongamia* escaping from plantings and becoming an invasive weed. Seven field sites were visited in various environments across O'ahu. Although some *Pongamia* seedlings were found in the vicinity of some *Pongamia* plantings, particularly in wetter, partly shaded environments, almost all observed seedlings were restricted to areas directly beneath the canopies of mother trees. This finding suggests a lack of effective seed dispersal away from *Pongamia* plantings. According to its current behavior in the field, *Pongamia* is not invasive or established outside of cultivation on O'ahu. Because of its limited seed dispersal and low rates of seedling establishment beyond the canopy, the risk of *Pongamia* becoming invasive can be mitigated through monitoring and targeted control of any rare escapes in the vicinity of plantings. Because seeds and seed pods are dispersed by water, future risks of *Pongamia* escape and unwanted spread can be minimized by avoiding planting at sites near flowing water, near areas exposed to tides, or on or near steep slopes. Although vegetative spread by root suckers was not observed around plantings on O'ahu, monitoring for vegetative spread around plantations is recommended; unwanted vegetative spread might become a concern in the future that could be addressed with localized mechanical or chemical control.

Pods, oilseed cake, and oil have been evaluated from a number of trees growing on the island of O'ahu. TerViva, a company pursuing *Pongamia* commercialization, provided material from orchards on O'ahu. Fundamental measurements of chemical composition were made for seeds, pods, extracted oil, and post-extraction seed material. The measured values included carbon, hydrogen, nitrogen, and sulfur elemental composition; energy content; volatile matter, fixed carbon, and ash content; and trace element composition. Oils were characterized for peroxide value, iodine value, fatty acid profile, free fatty acid content, flash point, density, viscosity, and phase transition temperatures. The chemical composition and fuel properties of the oilseed cake and the pod material were characterized. A manuscript summarizing the results of this effort has been published in the journal *ACS Omega* (Fu et al., 2021a).

Coproduct evaluation of *Pongamia* pod feedstock for thermochemical conversion has been conducted. Evaluation included both untreated pods and pods pretreated by a torrefaction process to improve their properties. Torrefaction produces a material with improved grindability, storage stability, diminished oxygen content, and microbial availability. The effects of process conditions on feedstock properties relevant to thermochemical conversion technologies, proximate and ultimate composition, heating value, and Hardgrove grindability index were measured. The chemical structure, reactivity, and changes in elemental composition of the torrefied materials were also investigated. A manuscript summarizing the results of this effort has been published in the journal *Fuel* (Fu et al., 2021b).

Pongamia seedpods are recognized as a potential feedstock for SAF production because of the relatively high oil content of the seeds. *Pongamia* pods are byproduct residues available after seed separation. Pods have high chlorine and potassium content that may be problematic in thermochemical energy conversion systems. Leaching experiments were performed to remove inorganic constituents of the pods and thereby decrease the potential for fouling, slagging, and agglomeration. A manuscript summarizing the results of this effort has been published in the journal *Fuel* (Fu et al., 2021c).

The state tree of Hawai'i, *Aleurites moluccanus* (commonly known as kukui and candlenut), is an oil-nut-bearing tree frequently found in the tropics. Nuts from a number of these trees growing on the island of O'ahu were collected, and the nutshell, oilseed cake, and oil components were fractionated and analyzed for common properties necessary for designing SAF production systems. Results were published in the journal *ACS Omega* (Fu et al., 2023).

Publications

Peer-Reviewed Journal Publications

Fu, J., Summers, S., Morgan, T. J., Turn, S. Q., & Kusch, W. (2021a). Fuel properties of pongamia (*Milletia pinnata*) seeds and pods grown in Hawaii. *ACS Omega*, *6*, 9222–9233. doi:10.1021/acsomega.1c00635

Fu, J., Summers, S., Turn, S. Q., & Kusch, W. (2021b). Upgraded pongamia pod via torrefaction for the production of bioenergy. *Fuel, 291,* 120260. doi: 10.1016/j.fuel.2021.120260

Fu, J., Allen, G., Weber, S., Turn, S. Q., & Kusch, W. (2021c). Water leaching for improving fuel properties of pongamia pod: Informing process design. *Fuel, 305,* 121480. doi: 10.1016/j.fuel.2021.121480

Fu, J., Weber, S., & Turn, S.Q. (2023). Comprehensive characterization of kukui nuts as feedstock for energy production in Hawai'i. *ACS Omega*. 8, 22567-22574.

Written Report

Chan, S., Ogoshi, R. & Turn, S. (2024, draft). Feedstocks for sustainable jet fuel production: An assessment of land suitability in Hawaii. A draft report has been prepared and a draft manuscript is under preparation for publication.

Outreach Efforts

Outreach in this task has focused on interactions with Terviva,® a startup company that has identified *Pongamia* germplasm production and marketing as the central focus of its business plan.

Chan, S., Ogoshi, R. & Turn, S. (2020, July 6-9). *Feedstocks for Sustainable Jet Fuel Production: An Assessment of Land Suitability in Hawaii* [Poster presentation]. 28th European Biomass Conference & Exhibition, Virtual.

Fu, J., Summers, S. & Turn, S. (2020, October 5-7). *Upgraded Millettia Pinnata Pod via Torrefaction for the Production of Bioenergy in Hawai'i* [Oral presentation]. 2020 Thermal & Catalytic Sciences Virtual Symposium, Virtual.

Turn, S. (2019, December 3). *Regional Supply Chain Analysis for Alternative Jet Fuel Production in the Tropics* [Poster presentation]. Hawai'i Aviation and Climate Action Summit, Honolulu, HI.

Fu, J., Allen, G., Weber, S., Turn, S. Q., & Kusch, W. (2021, August 22-26). *Water Leaching for Improving Fuel Properties of Pongamia Pods* [Oral and Virtual presentation]. American Chemical Society Fall 2021 National Meeting, Atlanta, GA, United States.

Fu, J., Summers, S. & Turn, S. (2021, April 5-16). *Upgraded Millettia Pinnata Pod via Torrefaction for the Production of Bioenergy in Hawai'i* [virtual and oral presentation]. American Chemical Society Spring 2021 National Meeting, Virtual.

Fu, J., Weber, S. & Turn, S. (2022, August 21-25). *Comprehensive Characterization of Kukui Nuts for Bioenergy Production in Hawaii* [Oral presentation]. American Chemical Society Fall 2022 National Meeting & Exposition, Chicago, IL, United States.

Awards

A poster entitled "Feedstocks for Sustainable Jet Fuel Production: An Assessment of Land Suitability in Hawai'i" (Chan et al., 2020) was presented at the European Biomass Conference & Exhibition held virtually July 6–9, 2020, and received the Best Visual Presentation Award.

Student Involvement

Three undergraduate students are involved in the project. Their primary responsibility is processing and analyzing samples of biomass materials selected for evaluation as potential SAF feedstocks. The *Pongamia* torrefaction work was the focus of an Undergraduate Research Opportunity Program project for Sabrina Summers, a bioengineering and chemistry double major. The results of her work were presented at the American Chemical Society Fall 2019 National Meeting in San Diego, California. The *Pongamia* pod leaching work was the focus of an Undergraduate Research Opportunity Program project for Gabriel Allen, a biochemistry major.

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Plans for Next Period
A report summarizing the GIS analysis of SAF feedstock production potential and a companion manuscript will be completed. Apart from this report and manuscript, this task is complete.

Task 2.2 – Support Indonesian AJF Supply Initiatives
University of Hawai‘i

Objective
This task supports the memorandum of understanding between the FAA and the Indonesian Directorate of General Civil Aviation to promote the development and use of sustainable alternative aviation fuels. Under the coordination of the FAA, efforts to establish points of contact and coordinate with Indonesian counterparts are ongoing.

Research Approach
To begin this process, the team will work with the FAA to establish points of contact to coordinate efforts with Indonesian counterparts. Members of the Indonesian Aviation Biofuels and Renewable Energy Task Force include Universitas Indonesia, Institut Teknologi Bandung, and Universitas Padjadjaran. A prioritized list of tasks will be developed in consultation with Indonesian counterparts, and data required to inform sustainability and supply analyses, and potential sources of information will be identified. The information collected may include Indonesian jet fuel use and resources for SAF production, airport locations, and annual and monthly jet fuel consumption patterns. Characterization of sustainable biomass resources with potential for use in producing SAF supplies may include developing preliminary GIS mapping information of their locations and distributions, and preliminary estimates of their technical potential.

Milestones
- Identified points of contact at Indonesian universities participating in the Aviation Biofuels and Renewable Energy Task Force
- Identified research needs and develop a project plan
- Developed data for potential projects

Major Accomplishments
The P.I. traveled to Jakarta, Indonesia, in the first week of August 2017 and met with the following individuals:
- Cesar Velarde Catolfi-Salvoni (International Civil Aviation Organization)
- Dr. Wendy Aritenang (International Civil Aviation Organization)
- Dr. Ridwan Rachmat (Head of Research Collaboration, Indonesian Agency for Agricultural Research and Development)
- Sylvia Ayu Bethari (Head of Aviation Fuel Physical and Chemical Laboratory, Research and Development Centre for Oil and Gas Technology)
- Dr. Ina Winarni (Forest Product Research and Development Center, Ministry of Environment and Forestry)
- Dr. SD Sumbogo Murti (Center of Technology Energy Resources and Chemical Industry, Agency for the Assessment and Application of Technology)

The activities of the tropical supply chain analysis effort were presented to the group, and a general discussion followed. From this introductory meeting, it was concluded that the Indonesian counterparts would seek agreement on how to move forward with future cooperation.

In November 2018, the P.I. traveled to Jakarta, Indonesia, and met with Dr. Wendy Aritenang of the International Civil Aviation Organization’s Jakarta office. The same trip included meetings with renewable energy researchers at Universitas Indonesia. After the meeting, Dr. Aritenang suggested several points of contact for future engagement: Frisda Panjaitan from the Palm Oil Research Institute and Tatang Soerawidjaja, Tirto Prakoso Brodjonegoro, and Imam Reksowardojo from the Bandung Institute of Technology.

In October 2022, the P.I. traveled to Jakarta, Indonesia, and met with Dr. Wendy Aritenang. The following day, the P.I. and Dr. Aritenang traveled to Bandung, West Java, Indonesia, to visit the Bandung Institute of Technology and met with faculty members Professor Adiwan Aritenang (Department Head of Regional Planning) and Professors Tatang Soerawidjaja, Tirto

Prakoso Brodjonegoro, and Iman Reksowardojo, from the Faculty of Industrial Technology, Bandung Institute of Technology. Ongoing UH ASCENT activities were presented, and the Bandung Institute of Technology researchers discussed their SAF-related research efforts.

Publications
None.

Outreach Efforts
Outreach efforts by the P.I. are described in the Major Accomplishments section above. In addition, the P.I. participated in the Asia Pacific Economic Cooperation event, "Energy Transition toward Carbon Neutrality, APEC BCG Economy Thailand 2022: Tech to Biz," in Bangkok, Thailand, and gave an oral presentation entitled "US Initiatives on Sustainable Aviation Fuel."

Awards
None.

Student Involvement
None.

Plans for Next Period
This activity is complete.

Task 3.1 – National Lipid Supply Availability Analysis
University of Hawai‘i

Objective
In this task, the team will support ASCENT partners working on a national lipid supply availability analysis by sharing data on tropical oilseed availability developed under previous years' activities.

Research Approach
This support will include estimates of *Pongamia* production capability in the state of Hawai‘i, in addition to assessments of waste cooking oil and tallow.

Milestones
Milestones will coincide with the schedule of the lead institution (WSU) for the national lipid supply analysis.

Major Accomplishments
Additional seeds and pods were collected from the *Pongamia* trees on the UH campus, Foster Botanical Garden, and Ke‘ehi Lagoon Beach Park. Large quantities (tens of kilograms) of material were acquired from TerViva's plantings on the O‘ahu North Shore for use in oil evaluation. Two oilseed presses were acquired, and safety documents were developed. Pods, oilseed cake, and oil were evaluated from a number of trees growing on the island of O‘ahu. Fundamental measurements of chemical composition were made for seeds, pods, extracted oil, and post-extraction seed material. The measured values included carbon, hydrogen, nitrogen, and sulfur elemental composition; energy content; volatile matter, fixed carbon, and ash content; and trace element composition. Oils were characterized for peroxide value, iodine value, fatty acid profile, free fatty acid content, flash point, density, viscosity, and phase transition temperatures. The development of coproducts from pods and oilseed cake was explored.

Areas in Hawai‘i with agricultural zoning suitable for rain-fed production of *Pongamia* have been identified. Conflicts with the current agricultural land use have been identified.

The waste oil resources in Hawai‘i are estimated to be on the order of 2–3 million gallons per year, according to the de facto population, and are directed to biodiesel production.

Publications

Peer-Reviewed Journal Publication

Fu, J., Summers, S., Morgan, T. J., Turn, S. Q., & Kusch, W. (2021). Fuel properties of pongamia (*Milletia pinnata*) seeds and pods grown in Hawaii. *ACS Omega, 6*(13), 9222–9233. doi:10.1021/acsomega.1c00635

Outreach Efforts

Data were presented at the April 2019 ASCENT review meeting in Atlanta, Georgia.

Awards

None.

Student Involvement

Three undergraduate students (Sabrina Summers, Sarah Weber, and Taha Elwir) are involved in the project. Their primary responsibility is processing and analyzing samples of biomass materials selected for evaluation as potential SAF feedstocks.

Plans for Next Period

This task is complete. Results will underpin future tasks.

Task 3.2 – Hawai‘i Regional Project

University of Hawai‘i

Objectives

A supply chain based on fiber feedstocks transported to a conversion facility located at the Campbell Industrial Park (CIP) on O‘ahu will be evaluated (Figure 1). The CIP is the current site of two oil refineries. C&D wood waste from the PVT Land Company’s landfill could provide a primary source of feedstock. Other sources will be evaluated from elsewhere on O‘ahu and outer islands, including municipal solid waste streams from outer islands and mining of current waste-in-place stocks. Waste streams and purpose-grown crops form the basis of a hub-and-spoke supply system, with the hub located on O‘ahu. Pipelines for jet fuel transport are in place from CIP to Daniel K. Inouye International Airport and the adjacent Joint Base Pearl Harbor-Hickam. Other coproduct offtakers for alternative diesel fuel include the Hawaiian Electric Company and several military bases, including Schofield Barracks (~50-megawatt alternative fuel-capable power plant under development) and Marine Corps Base Hawai‘i located in Kaneohe Bay. Hawai‘i Gas, a local gas utility, is also seeking alternative sources of methane if methane or feedstock suitable for methane production is available as a coproduct. Hawai‘i Gas currently offtakes feedstock (naphtha) from the refinery.

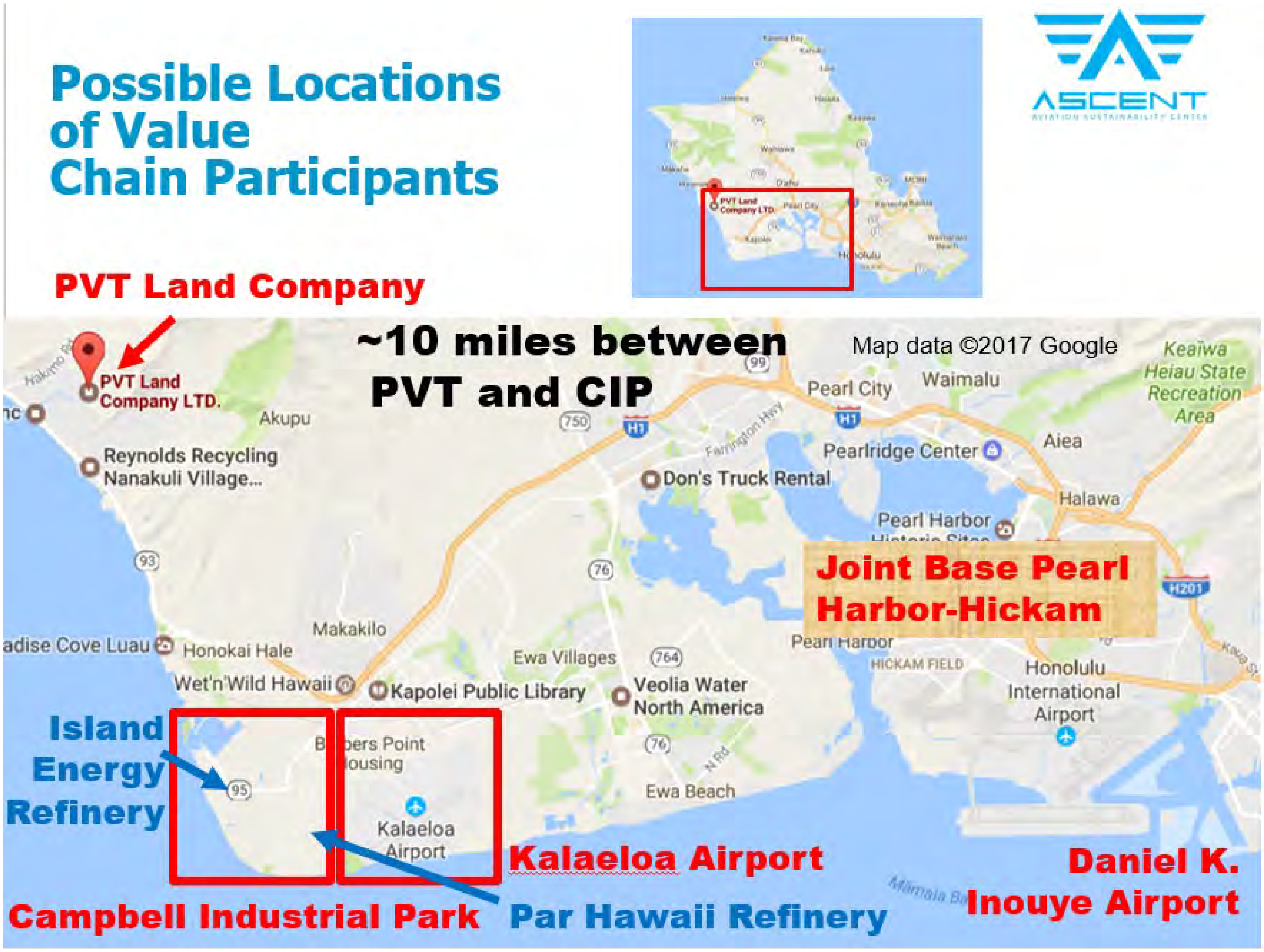

Figure 1. Possible Locations of Value Chain Participants for a Fiber-Based Alternative Jet Fuel Production Facility at the Campbell Industrial Park, O‘ahu.

Research Approach

Task 3.2.G1. Analyze feedstock-conversion-pathway efficiency, product slate (including coproducts), and maturation

To build on activities from previous years, additional supporting analyses will be conducted for proposed supply chains in Hawai‘i, as follows:

- Subtask 3.2.G1.1. Assess feedstock suitability for conversion processes (e.g., characterization, conversion efficiencies, and contaminants) (UH and WSU [Manuel Garcia-Perez])
- Subtask 3.2.G1.2. Acquire data on feedstock size reduction, particle size of materials, and bulk densities (UH, WSU [Manuel Garcia-Perez])
- Subtask 3.2.G1.3. Evaluate coproducts at every step of the supply chain (ASCENT Project 001 Team)

Task 3.2.G2. Assess the scope of techno-economic analysis (TEA) issues

This task will determine the current TEA status of targeted SAF production technologies that use fiber feedstocks as production inputs (UH, WSU [Manuel Garcia-Perez], Purdue University [Wally Tyner]).

Task 3.2.G3. Conduct a screening-level GHG life-cycle assessment (LCA)
This task will conduct screening-level GHG LCA on the proposed target supply chains and SAF conversion technologies.
Subtasks:

- Subtask 3.2.G3.1. Assess Massachusetts Institute of Technology (MIT) waste-based GHG LCA tools in the context of application to Hawai'i (MIT [Mark Staples])
- Subtask 3.2.G3.2. Assess requirements to link previously completed eucalyptus energy and GHG analysis to the edge of the plantation with available GHG LCA information for conversion technology options (MIT [Mark Staples], UH)
- Subtask 3.2.G3.3. Identify and fill information/data gaps

Task 3.2.G4. Identify supply chain participants/partners
Subtasks:

- Subtask 3.2.G4.1. Define C&D landfill case
- Subtask 3.2.G4.2. Identify eucalyptus in existing plantations, landowners, leaseholders/feedstock producers, harvesting contractors, truckers, etc. (UH)
- Subtask 3.2.G4.3. Define other feedstock systems as identified (ASCENT Project 001 Team)

Task 3.2.G5. Develop an appropriate stakeholder engagement plan
Subtasks:

- Subtask 3.2.G5.1. Review stakeholder engagement methods and plans from past work to establish baseline methods (UH, WSU [Season Hoard])
- Subtask 3.2.G5.2. Identify and update engagement strategies according to the updated Community Social Asset Modeling/Outreach support tool (UH, WSU [Season Hoard])

Task 3.2.G6. Identify and engage stakeholders
Subtasks:

- Subtask 3.2.G6.1. Identify stakeholders along the value chain and create a database based on value chain location (UH)
- Subtask 3.2.G6.2. Conduct a stakeholder meeting by using the instruments developed in Task 3.2.G5 (UH, WSU [Season Hoard])
- Subtask 3.2.G6.3. Analyze stakeholder response and feedback to the process (UH, WSU [Season Hoard])

Task 3.2.G7. Acquire transportation-network and other regional data needed for the Freight and Fuel Transportation Optimization Tool and other modeling efforts
Subtasks:

- Subtask 3.2.G7.1. Acquire necessary data to evaluate harbor capacities and current usage (UH, Volpe [Kristin Lewis], WSU [Michael Wolcott])
- Subtask 3.2.G7.2. Acquire data on inter-island transport practices (UH, Volpe [Kristin Lewis], WSU [Michael Wolcott])

Task 3.2.G8. Evaluate infrastructure availability
Subtasks:

- Subtask 3.2.G8.1. Evaluate inter-island shipping options and applicable regulation (UH, Volpe [Kristin Lewis], WSU [Michael Wolcott])
- Subtask 3.2.G8.2. Evaluate transport or conveyance options from conversion location to end users and applicable regulation (UH, Volpe [Kristin Lewis], WSU [Michael Wolcott])

Task 3.2.G9. Evaluate feedstock availability
Subtasks:

- Subtask 3.2.G9.1. Refine ground-truth prior evaluations of options for purpose-grown feedstock supply (UH)
- Subtask 3.2.G9.2. Conduct projections of future C&D waste supply and mining of waste-in-place on O'ahu, municipal solid waste, and mining of waste-in-place on other islands (UH)

Task 3.2.G10. Develop a regional proposal
This task will use the information collected in Tasks 3.2.G1–3.2.G9 to develop a regional project proposal.

Milestone
One milestone is associated with each of the subtask activities identified in the Research Approach section above.

Major Accomplishments
The characteristics of the feedstock generated at the landfill have been determined and summarized in a publication (Bach et al., 2021).

The elemental compositions of feedstock materials have been used as the basis for equilibrium analysis of gasification systems using oxygen, steam, and steam–oxygen mixtures to inform process design.

The material flows relevant to the screening-level GHG analysis of C&D waste as SAF feedstock have been assembled. Preliminary discussions of GHG analysis of C&D-based SAF systems with landfill operators have been initiated.

The plans for solid waste management from all counties in Hawai'i have been used to provide a broader picture of the waste stream composition, diversion, recycling practices, and planned uses.

Publications
Peer-reviewed journal publications

Bach, Q. V., Fu, J., & Turn, S. (2021). Construction and demolition waste-derived feedstock: fuel characterization of a potential resource for sustainable aviation fuels production. *Frontiers in Energy Research, 9,* 711808. doi: 10.3389/fenrg.2021.711808

Bach, Q. V. & Turn, S. (2024, draft). Fate of arsenic and other inorganic elements during gasification of construction and demolition wastes – thermochemical equilibrium calculations. Draft manuscript in process.

Outreach Efforts
Results of the fuel sampling, fuel analyses, and gasification equilibrium analyses were presented at the October ThermoChemical Biomass 2019 Conference in Chicago, Illinois.

Information from this task was included in the talk "Regional Supply Chain Analysis for Alternative Jet Fuel Production in the Tropics" presented at the Hawai'i Aviation and Climate Action Summit, December 3, 2019, at the Hawai'i State Capitol, Honolulu, Hawai'i.

Data acquired under this task were presented to the management of PVT Land Company and their consultants from Simonpietri Enterprises and T. R. Miles Technical Consultants, Inc.

A poster entitled "Construction and Demolition Waste as an Alternative Energy Source: Fuel Characterization and Ash Fusion Properties" was presented at the 2020 Thermal & Catalytic Sciences Virtual Symposium.

Discussion with Dr. Kristin Lewis and Volpe Center staff on the addition of Hawai'i transportation infrastructure to the Freight and Fuel Transportation Optimization Tool was initiated and deferred until a clearer definition of the system emerges.

As suggested by FAA management, UH worked with the Servicios y Estudios para la Navegación Aérea y la Seguridad Aeronáutica (SENASA) to identify a counterpart university in the Canary Islands, Spain. Universidad de la Laguna (ULL) was selected, and a memorandum of understanding was signed between UH and ULL. A nondisclosure agreement was subsequently signed among SENASA, ULL, UH, and the Spanish company Abengoa Energía, S.A. Regularly scheduled meetings have been held biannually with Professor Dr. Ricardo Guerrero Lemus from ULL to discuss common research themes and were continued in 2023.

Awards
None.

Student Involvement
Three undergraduate students (Sabrina Summers, Sarah Weber, and Taha Elwir) have been involved in sample preparation and in operating the laboratory analytical equipment used for sample analysis.

Plans for Next Period

Manuscripts covering the prediction of gasification product streams including contaminant concentrations will be completed and submitted. Comparative data from bench-scale gasification tests (see Task 4) at ThermoChem Recovery International facilities were received in October 2023. These data will be supplemented with the results of C&D waste sample analyses using a differential thermal analyzer paired with an inductively coupled plasma mass spectrometer (DTA-ICPMS) to provide information on the release of inorganic elements as a function of temperature. Contracting for DTA-ICPMS analytical services at the University of California, Davis, Interdisciplinary Center for Plasma Mass Spectrometry is underway. With these experimental data, the manuscripts will be completed. Note: Although this was anticipated to be completed in 2024, unresolved contracting issues between UH and the University of California, Davis, have delayed the DTA-ICPMS analysis and thus the manuscript preparation and the completion of this task.

References

Bach, Q. V., Fu, J., & Turn, S. (2021). Construction and demolition waste-derived feedstock: fuel characterization of a potential resource for sustainable aviation fuels production. *Frontiers in Energy Research, 9,* 711808. doi: 10.3389/fenrg.2021.711808

Task 4 – Hawai'i Regional Project

University of Hawai'i

Objective

This task builds upon results from the previous years' work under the Hawai'i Regional Project, with a focus on the data and analysis necessary to plan a project that uses C&D waste as feedstock for SAF production. The Task 4 objective is to use C&D feedstock characterization data and thermochemical equilibrium analysis from the previous years to conduct bench-scale gasification tests and to quantify the product gas yield, composition, and contaminant concentrations. These results will be compared with equilibrium prediction used to identify contaminants that must be addressed before end use and will provide the basis for designing contaminant control systems.

Research Approach

Bench-scale gasification tests will be conducted on samples of C&D wastes characterized in the earlier tasks, to measure product yields, identify contaminants, and investigate element partitioning between product phases.

The information gained from the tests will be used to identify opportunities to improve TEA, identify coproducts, inform supply chain participants and stakeholders, and identify necessary infrastructure improvements.

Milestones

- Identified and evaluated capabilities of experimental bench-scale facilities for gasifier tests
- Specified system performance parameters to be measured
- Specified techniques to sample and analyze contaminants
- Selected and engaged an experimental bench-scale facility for testing
- Prepared and shipped feedstock from Hawai'i to the experimental test facility
- Conducted tests, reduce data, and prepare a summary report of the results

Major Accomplishments

Operational measurements to be conducted as part of the bench-scale tests were summarized, and a test plan was developed; these were used as the basis for entertaining proposals for test services.

Through a competitively structured proposal process, ThermoChem Recovery International, Inc., was engaged to provide bench-scale test services for C&D waste feedstock and other opportunity fuels of relevance to Hawai'i and the tropics.

A synthetic C&D waste recipe was developed according to the results published in *Frontiers in Energy Research* (Bach et al., 2021). Component fractions in the recipe were determined by a least-squares approach to matching critical fuel characteristics, including volatile matter, fixed carbon, and ash content; higher heating value; and concentrations of the elements Na, Mg, Al, Si, P, S, Cl, K, Ca, Ti, Cr, Mn, Fe, Cu, Zn, As, Ru, and Pb. This recipe will enable a reproducible C&D waste fuel lot to be assembled and will aid in decreasing test-to-test variability.

In November and December 2021, tests were conducted in the bench-scale facility at the ThermoChem Recovery International facility in Durham, North Carolina. After shakedown testing was completed, two subsequent tests were conducted: (1) a test using *Leucaena leucocephela* stemwood and (2) a test using synthetic C&D waste. Test reports for the two bench-scale gasification tests at ThermoChem Recovery International facilities were finalized in October 2023.

Publications

Peer-reviewed journal publications

Bach, Q. V., Fu, J., & Turn, S. (2021). Construction and demolition waste-derived feedstock: fuel characterization of a potential resource for sustainable aviation fuels production. *Frontiers in Energy Research, 9,* 711808. doi: 10.3389/fenrg.2021.711808

Outreach Efforts

A presentation entitled “Hawai‘i Energy Crop and Urban Waste Feedstock Updates” was presented at the ASCENT Spring Meeting in Honolulu, Hawai‘i.

Awards

None.

Student Involvement

None.

Plans for Next Period

Planning for additional bench-scale tests at the Gas Technology Institute began in 2023. Moving the mini bench-scale gasifier unit between facilities at the Gas Technology Institute delayed the tests. As of November 2024, the Gas Technology Institute’s mini bench-scale unit has not been recommissioned. The principal investigator will re-evaluate the utility of the remaining tests and budgetary issues with the FAA program manager in early 2025.

Test results will be shared with stakeholder communities.

Task 5 – Hawai‘i Regional Project

University of Hawai‘i

Objective

Task 5.1: Tropical oil-to-SAF supply chain analysis

The goal of Task 5.1 is to develop a model for tropical oil supply chains for SAF and associated coproducts. Hawai‘i will be the initial focus, but the modeling tools will be developed for wider use in island settings.

Task 5.2: Contaminants in the gasification of C&D waste

The goal of Task 5.2 is to develop management strategies for elements present in C&D waste that affect its use as a feedstock for thermochemical conversion.

Research Approach

Task 5.1

Prior ASCENT EcoCrop GIS modeling activities identified the growing locations for *Pongamia*, kamani, croton, and *Jatropha*, according to suitable environmental conditions, geography, and zoning. If unavailable, the primary data on the chemical and physical characteristics of these tropical oils and their coproducts (e.g., pods/shell and oilseed cake) were acquired. The project will use these earlier results as the basis for developing supply chain models for AJF production. The model results will identify feedstock production areas as well as locations and scales of primary processing sites for shell and pod separation, oil extraction from seeds, and oil conversion to SAF. Potential sources of hydrogen from oilseed coproducts, other renewable resources, and fossil sources will be analyzed and included in the model. Options for points of production, SAF production technologies (e.g., Applied Research Associates [ARA], SBI BioEnergies [SBI], or Forge Hydrocarbons [Forge]), transportation strategies, and blend ratios at airports (or for specific end users, e.g., the military) across Hawai'i will affect model outcomes and will be evaluated. Options for coproducts such as animal feeds and high-value materials will be evaluated and incorporated into the model decision-making process. Criteria used to drive the model solution might include minimizing SAF production costs while meeting a minimum total production benchmark or a minimum blending rate for annual state jet fuel consumption. Other criteria, such as system resiliency to extreme weather events and climate change, provision of environmental services, and stakeholder acceptability, will also be of importance and will be used to evaluate model solutions.

Task 5.2

Thermochemical gasification of biorenewable resources is the initial conversion process for two entry points to AJF production: (1) synthesis gas used in the direct production of Fischer–Tropsch liquids and/or (2) green/renewable hydrogen used in biorefineries for hydrotreating lipids or in existing petroleum-refining activities for the production of hybrid jet fuel. Urban wood waste from C&D activities provides a reliable source of biorenewable material and requires a tipping fee for disposal, characteristics that enhance its attractiveness as feedstock. The negative aspects of C&D feedstock are its physical and chemical inhomogeneity. In the latter case, the inorganic elements present in the feedstock can negatively influence the gasification process (e.g., corrosion of, or accumulation on, reactor working surfaces, bed material agglomeration, catalyst deactivation, or pollutant emissions). Using data generated from previous ASCENT Project 001 tasks, this project will assess methods for managing contaminants in C&D feedstocks. This project will be based on gasification systems proposed for the production of synthesis gas/Fischer–Tropsch liquids and green hydrogen. The technology options for contaminant removal or conversion to benign forms will be assessed at each step in the conversion process, including presorting at the waste generation site, sorting/diversion at the C&D waste intake facility, removal by physical/chemical/other methods before gasification, in-situ reactor control methods, and gas cleanup. The technology options based on existing process industries and the scientific literature will be considered. Laboratory-scale testing of removal techniques will be conducted to provide a preliminary assessment of selected promising technology options. The integrated gasification process options and contaminant control options will be evaluated as complete systems to guide system design and to enable system comparisons. The risks associated with technology options will also be assessed to guide implementation and risk mitigation of the system as a whole. The impacts of processing scale (e.g., Mg waste/day) on the selection of technology options will also be assessed.

Milestones

Task 5.1.

- Established a model framework for an oilseed-based SAF supply chain in an island setting, using the scenario of Hawai'i.

Task 5.2.

- Conducted a review of options for managing contaminants along the supply chain and bench-scale tests to confirm the efficacy of options.

Major Accomplishments

On the basis of the *Pongamia* production areas identified by GIS analysis in Task 3 (described above), sites for processing *Pongamia* (pod and seed separation, oil extraction from seed) have been evaluated on each island. Candidate processing sites in the analysis included (a) brownfield sites with industrial zoning and (b) greenfield sites identified as lands with a slope of less than 5%, a contiguous area of 50 hectares, and agricultural zoning. The ArcGIS® "minimized impedance" and "origin-destination" analysis tools were used to determine transportation cost index values for all potential processing facility locations, using the *Pongamia* production estimates and the road network distances from production sites to candidate processing sites. Analyses were performed for each island and included four *Pongamia* production scenarios.

A cost of production analysis for *Pongamia* based on a 25-year orchard lifetime was completed. As *Pongamia* has not been grown commercially in Hawai'i, the analysis included assumptions about the cultural practices and input application rates. The analysis was summarized and shared with stakeholders and subject matter experts for review and comment. Feedback has been incorporated. Analysis has been extended to project a pathway for industry development assuming values for the number of trees planted per year and their cumulative productivity. The production scenarios are being used to explore

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processing facility scales and technology options that include the unit operations of drying, decortication, oil extraction, and distribution of oil and meal components to the refinery on O‘ahu and animal feeding locations across Hawai‘i, respectively. Discussions with equipment vendors for drying, decortication, and oil extraction equipment have been productive. Permission to include vendor data as part of techno-economic analyses remains to be resolved.

In an earlier review, camelina (*Camelina sativa*) was not previously identified as a candidate oil seed crop for production in Hawai‘i but is nonetheless being pursued as a cover crop in rotation with food crops such as onions, lettuce, etc. In response to interest in producing camelina, UH developed new GIS analysis approaches to evaluate potential production areas. Unlike annual and perennial crops, camelina matures in ~90 days requiring that the growing season be matched to shorter time windows of temperature and rainfall availability. Hawai‘i’s varied climates, both geographically and seasonally, would require intensive management if grown under rainfed conditions and could require shifting production locations throughout the year. Use of camelina as a cover crop with irrigated food production could alleviate the need to match the plant growth requirements with monthly rainfall. Results of the UH analysis has been used by Pono Pacific to target production areas, engage growers for planting camelina trials, and discuss policy with state executive and legislative branches. The analysis also underpinned a proposal to the U.S. Department of Energy program, Regional Resource Hubs for Purpose-Grown Energy Crops with Pono Pacific and Hawai‘i Agriculture Research Center.

Kukui (*Aleurites moluccanus*) is the Hawai‘i State tree and bears a nut whose kernel contains 60% extractable oils. Previous work has characterized the fuel properties of the oil, meal, and nut fractions. Kukui is extensively distributed across the Hawai‘i landscape zoned for conservation, but little has been done to explore agricultural zoning areas suitable for production. A GIS-based assessment of kukui production using the Eco-Crop model has been initiated.

Elemental analyses of C&D waste from earlier tasks were used as inputs for the thermochemical equilibrium calculation in FACTSage™ 8.0 under different gasification conditions (e.g., bed material, oxidizer, etc.). The results show that the predictions of H_2, CO, and CO_2 in product gas are in good agreement with literature data. In addition, gasification in steam yields the highest H_2 content while that in oxygen yields the lowest. The elements As, Br, Cl, K, Mn, Mo, Na, Pb, S, and Zn were found in the gas phase at different concentrations depending on the feedstock composition and gasification conditions. Some elements (Br, Cl, K, Pb, and Zn) appear to be more volatile than others (As, Na, and S). The elements Ca, Si, P, Ti, Cr, Fe, Ni, Cu, Sr, Ru, and Ba were primarily presented in solid and/or slag phases. Olivine bed material captured a portion of arsenic during the gasification process due to the presence of nickel in its chemical composition. Arsenic species in the product gas stream are predicted to deactivate Fe- and Co-based Fischer-Tropsch catalysts in downstream processes. It is possible to remove arsenic compounds by cooling hot product gas; however, cooling may also result in the condensation of high molecular weight organic compounds (tar). Copper and nickel can be employed as arsenic sorbents with sorptive capacity directly linked to the metals’ mass.

Publications

None.

Outreach Efforts

The results of feedstock analyses have been shared with personnel from Par Hawai‘i, the refinery located on the island of O‘ahu, and with Pono Pacific, a land management company engaged in sustainable agricultural development. Par Hawai‘i has announced plans to produce SAF in partnership with Hawaiian Airlines. Pono Pacific is pursuing oilseed production to supply Par Hawai‘i with lipids for SAF production via the production pathway for hydroprocessed esters and fatty acids. Mitsubishi Corporation (Americas) personnel interested in SAF-related investment opportunities in Hawai‘i have requested briefings on oil seed opportunities. Outreach has also included staff from the Hawai‘i State Energy Office’s Energy Efficiency and Renewable Energy (EERE) branch and Decarbonization Program.

A presentation entitled “Hawai‘i Energy Crop and Urban Waste Feedstock Updates” was presented at the ASCENT Spring Meeting in Honolulu, Hawai‘i.

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A poster entitled "Thermochemical Equilibrium Prediction of Ash Behavior during Gasification of Construction and Demolition Waste" was presented at the conference TC Biomass: The International Conference on Thermochemical Conversion Science: Biomass & Municipal Solid Waste to RNG, Biofuels & Chemicals on September 10–12, 2024, Westin Hotel, Itasca, Illinois.

A poster entitled "Alternative Jet Fuel Supply Chain Tropical Region Analysis, Pongamia Supply Chain Optimization" was presented at the ASCENT Fall Meeting in Alexandria, Virginia.

Awards

None.

Student Involvement

None.

Plans for Next Period

Task 5.1

The costs for *Pongamia* delivered to the processing site gate and costs of *Pongamia* processing options will be used with TEA spreadsheets (hydro-processed esters and fatty acids, etc.) developed by WSU collaborators to provide estimates of SAF production costs according to supply chain scenario assumptions. This effort was begun in this reporting period and discussions with equipment vendors are expected to be completed in 2025. In this reporting period, Dr. Kristin Lewis, Dr. Kevin Zhang, and Dr. Alex Oberg from the Volpe Center have engaged on the logistic analysis for this project and Kristin Brandt and Dane Camenzind have engaged on project TEA. These collaborations are expected to continue in 2025.

Task 5.2

A review of additional options for managing contaminants in the gasification process will be conducted. The results of the equilibrium analysis, literature review and contaminant measurements from the bench-scale gasification tests in Task 4 may be used to target bench-scale contaminant control tests. The principal investigator will re-evaluate the utility of the bench scale tests and budgetary issues with the FAA program manager in early 2025.

Task 6 – Hawai'i Regional Project

University of Hawai'i

Objective

The task activities in Year 6 will explore the impacts of Hawai'i State Legislative Bill HB2386 on waste management and the potential for waste-based SAF production systems. HB2386 requires 0.5-mile buffer zones around waste and disposal facilities (including landfills) and restricts facilities from land with conservation-district zoning.

Research Approach

The goal of this task is to assess and evaluate the impacts of HB2386 on waste management strategies in Hawai'i. HB2386 was disruptive to disposal practices for C&D waste on the island of O'ahu, and its impacts are currently not fully understood. The aims of Task 6 are to collect updated waste generation data, elucidate how HB2386 will affect current management strategies, and develop scenarios for waste-based SAF production under the new regulatory environment. The impacts of HB2386 on the capacity to perform landfill mining will also be considered. A preliminary assessment of restricted and unrestricted sites for waste and disposal facilities will be reviewed and refined as necessary.

Milestone

- Evaluated the impacts of removing or diminishing the role of an active C&D landfill as a supply chain participant.

Major Accomplishments

An assessment of available data on urban waste flows across the state has been completed. Sources have included county solid waste management plans, annual reports by county solid waste management offices, and annual legislative reports prepared by the state solid and hazardous waste management branch. Based on these data, estimates of solid waste production across the state have been assembled. Waste composition data available at the county level has been used to generate production estimates of combustible and noncombustible fractions as well as biogenic and nonbiogenic fractions. The enactment of HB2386 has restricted expansion of the existing C&D landfill on O'ahu and delayed the siting of new landfills on the islands of O'ahu and Kaua'i. Six scenarios for managing waste across the state as an integrated system have been developed. Three of the scenarios split the waste resource between the existing Covanta Honolulu Resource Recovery Venture (H-POWER) waste to an energy plant on O'ahu and a waste-to-SAF production plant using gasification and Fischer-Tropsch technology. The other three scenarios assume that the H-POWER waste-to-energy plant is decommissioned and all of the state's waste is delivered to a larger SAF production facility. Diverting food waste and plastics from the waste streams were also included as scenario options; food waste has alternative use as animal feed or for anaerobic digestion feedstock and plastics are nonbiogenic. Estimates of production potential from the six waste utilization scenarios were completed. Scenarios where H-POWER was decommissioned yielded the highest SAF production values ranging from 38 to 45 million gallons annually. Diverting food waste and plastics from the material fueling the SAF process accounts for the difference of 7 million gallons per year. The scenario with the lowest SAF production potential, 18 million gallons per year, was the result of diverting waste to H-POWER and excluding both food waste and plastics.

Publications
None.

Outreach Efforts
A poster entitled "Municipal Solid Waste (MSW)-based SAF (Alternative Jet Fuel Supply Chain Tropical Region Analysis)" was presented at the ASCENT Fall review meeting in Alexandria, Virginia.

Awards
None.

Student Involvement
None.

Plans for Next Period
In the coming period, possible waste separation locations that meet HB2386 requirements will be identified and used to refine analyses. The preliminary findings will be shared with the waste management community and state and county energy office staffs to garner feedback and refine scenario assumptions.

Task 7 – Hawai'i Regional Project
University of Hawai'i

Objective
Activities proposed for Task 7 will continue to develop the information needed for the Hawai'i Regional Projects begun in previous years. These activities will support efforts by the State of Hawai'i and Hawai'i energy service providers to reduce GHG emissions. Task activities will explore the GHG intensity of *Pongamia* as a feedstock producer in Hawai'i regional pathways.

Research Approach
The goal of this task is to assess and evaluate the GHG implications of a *Pongamia*-based feedstock supply chain for SAF production. Based on analyses from previous years, life cycle inventories (LCIs) for *Pongamia* production, oil extraction, and oil conversion to SAF will be completed. The LCIs will be used to conduct GHG assessments of *Pongamia*-based SAF production systems. Different *Pongamia* land use scenarios, extraction options, and conversion technologies can be considered and compared.

Milestone
- Produced a complete set of LCIs for the *Pongamia* production system.

Major Accomplishments
Production scenarios developed in Task 5 have been used to identify inputs for orchard production of *Pongamia*. This includes material and energy requirements for nursery production of saplings, site preparation, planting and stand establishment, cultural practice (fertilization, weed control, and pruning), harvesting, and orchard removal at the end of productive life. The basis for transport of harvested material between the orchard and processing sites have been established.

Publications
None.

Outreach Efforts
None.

Awards
None.

Student Involvement
None.

Plans for Next Period
Drying, decortication, and oil extraction scenarios currently under development in Task 5 will provide the basis for material and energy flows for *Pongamia* processing. Data for oil and byproduct transport from processing sites to refining assets on O‘ahu and animal production facilities will be finalized.

Task 8 – Hawai‘i Regional Project
University of Hawai‘i

Objective
Activities proposed for Task 8 will continue to develop the information needed for the Hawai‘i Regional Projects begun in previous years. These activities will support efforts by the State of Hawai‘i and Hawai‘i energy service providers to reduce GHG emissions. Task activities in Year 8 will focus on waste-based feedstocks that address MSW and construction and demolition waste currently generated and disposed in landfills across the state.

Research Approach
The goal of this task is to assess and evaluate the GHG implications of waste based SAF production in Hawai‘i. Based on analyses from Task 6, waste production across the state will be considered as a single resource to be managed for SAF production. Available data on waste generation by island, waste composition by island, transportation requirements, and conversion technologies will be used as the basis for developing scenarios for SAF production given existing waste management practices. These scenarios will be used to evaluate GHG intensity of SAF production scenarios.

Milestone
- Developed scenarios for waste-to-SAF production options based on available county and state data reporting.

Major Accomplishments
An assessment of available data on urban waste flows across the state has been completed. Six scenarios for managing waste across the state as an integrated system have been developed. Three of the scenarios split the waste resource between the existing H-POWER waste to an energy plant on O‘ahu and a waste-to-SAF production plant using gasification and Fischer-Tropsch technology. The other three scenarios assume that the H-POWER waste-to-energy plant is decommissioned and all of the state’s waste is delivered to a larger SAF production facility. Based on these six scenarios of waste management for SAF production, preliminary estimates of GHG intensity were developed based on the contributions from feedstock transportation, fuel production, ash disposal, SAF production, and combustion of nonbiogenic components. The scenario that eliminated the use of the existing H-POWER waste-to-energy plant and diverted food waste and mixed plastics from the feedstock stream yielded the lowest GHG intensity, 32 g CO_2e/MJ. The highest value, 53 g

CO_2e/MJ of SAF, corresponded to the scenario where H-POWER was operated, food waste was diverted, and mixed plastics were included in the feedstock steam.

Publications
None.

Outreach Efforts
A poster entitled “MSW-based SAF (Alternative Jet Fuel Supply Chain Tropical Region Analysis)” was presented at the ASCENT Fall review meeting in Alexandria, Virginia.

Awards
None.

Student Involvement
None.

Plans for Next Period
Preliminary findings will be shared with the waste management community and state and county energy offices’ staff to garner feedback and refine scenario assumptions.