Project 001(B) Alternative Jet Fuel Supply Chain Analysis

University of Hawaii

Project Lead Investigator

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University Participants

University of Hawaii
- 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
- Task 1:
    1. Informing regional supply chains
    2. Identification of supply chain barriers in the Hawaiian Islands

University of Hawaii
- P.I.: Scott Q. Turn, Researcher
- FAA Award Number: 13-C-AJFE-UH, Amendment 007
- Period of Performance: October 1, 2016 to August 4, 2021
- Task 2:
    1. Informing regional supply chains
    2. Support of Indonesian alternative jet fuel supply initiatives

University of Hawaii
- P.I.: Scott Q. Turn, Researcher
- FAA Award Number: 13-C-AJFE-UH, Amendment 008
- Period of Performance: August 1, 2017 to August 4, 2021
- Task 3:
    1. National lipid supply availability analysis
    2. Hawaii regional project

University of Hawaii
- P.I.: Scott Q. Turn, Researcher
- FAA Award Number: 13-C-AJFE-UH, Amendment 011
- Period of Performance: May 31, 2019 to August 4, 2021
- Task 4: Hawaii regional project

University of Hawaii
- P.I.: Scott Q. Turn, Researcher
- FAA Award Number: 13-C-AJFE-UH, Amendment 013
- Period of Performance: June 5, 2020 to August 4, 2021
- Task 5: Hawaii regional project

University of Hawaii

- P.I.: Scott Q. Turn, Researcher
- FAA Award Number: 13-C-AJFE-UH, Amendment 017
- Period of Performance: October 1, 2021 to September 30, 2022
- Task 6: Hawaii 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 Hawaii.

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 Hawaii, 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 Hawaii.

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 Hawaii.

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 Hawaii.

Under **FAA Award Number 13-C-AJFE-UH, Amendment 017**, the Alternative Jet Fuel Supply Chain Analysis–Tropical Region Analysis project received $100,000 in funding from the FAA and cost-share funding of $100,000 from the State of Hawaii.

Investigation Team

Lead
Scott Turn, University of Hawaii, P.I.

Other Lead Personnel
Tim Rials, Professor, and Burt English, Professor (University of Tennessee co-P.I.s)
Manuel Garcia-Perez, Professor (Washington State University [WSU] co-P.I.)
Kristin Lewis, Principal Technical Advisor (Volpe National Transportation Systems Center P.I.)
Michael Wolcott, Professor (WSU P.I.)
Lara Fowler, Professor (The Pennsylvania State University P.I.)

UH Investigation Team
Under **FAA Award Number 13-C-AJFE-UH, Amendment 005**, Task 1 and Task 2:
Dr. Scott Turn, Researcher, Hawaii Natural Energy Institute, UH
Dr. Trevor Morgan, Assistant Researcher, Hawaii Natural Energy Institute, UH
Dr. Richard Ogoshi, Assistant Researcher, Department of Tropical Plant and Soil Sciences, UH
Dr. Adel H. Youkhana, Junior Researcher, Department of Tropical Plant and Soil Sciences, UH

Under **FAA Award Number 13-C-AJFE-UH, Amendment 007**, Task 1 and Task 2:
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Ms. Sharon Chan, Junior Researcher, Hawaii Natural Energy Institute, UH
Mr. Gabriel Allen, Undergraduate Student, Biochemistry Department, UH

Under **FAA Award Number 13-C-AJFE-UH, Amendment 008**, Task 1 and Task 2:
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Under **FAA Award Number 13-C-AJFE-UH, Amendment 011**, Task 1:
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Under **FAA Award Number 13-C-AJFE-UH, Amendment 013**, Task 1 and Task 2:
Dr. Scott Turn, Researcher, Hawaii Natural Energy Institute, UH
Ms. Sharon Chan, Junior Researcher, Hawaii Natural Energy Institute, UH

Under **FAA Award Number 13-C-AJFE-UH, Amendment 017**, Task 1:
Dr. Scott Turn, Researcher, Hawaii Natural Energy Institute, UH

Project Overview

Under **FAA Award Number 13-C-AJFE-UH, Amendment 005**, the research effort has two objectives. The first objective is to develop information on regional supply chains for use in creating scenarios of future alternative 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 the 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 **FAA Award Number 13-C-AJFE-UH, Amendment 005** project goals are to

- Review and summarize:
  - 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 systems (GIS) datasets available for assessment of AJF production systems in the tropics
- Identify AJF supply chain barriers in the Hawaiian Islands

Under **FAA Award Number 13-C-AJFE-UH, Amendment 007**, the research effort 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 (DGCA) to promote the development and use of sustainable alternative aviation fuels.

The **FAA Award Number 13-C-AJFE-UH, Amendment 007** project goals are to

- 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 Hawaii
- Develop fundamental property data for tropical biomass resources
- Transmit data and analysis results to other ASCENT Project 1 researchers to support the improvement of existing tools and best practices
- Support Indonesian SAF supply initiatives

Under **FAA Award Number 13-C-AJFE-UH, Amendment 008**, the research effort 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 Hawaii regional project.
The **FAA Award Number 13-C-AJFE-UH, Amendment 008** project goals are to

- 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 Hawaii to a location in the principal industrial park on the island of Oahu

Under **FAA Award Number 13-C-AJFE-UH, Amendment 011**, the main objective of the research effort is to conduct bench-scale testing of tropical feedstocks for use in targeted supply chain analysis for a SAF production facility based on the Hawaii regional project initiated under Amendment 008.

The **FAA Award Number 13-C-AJFE-UH, Amendment 011** project goals are to

- 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 quantify product yields and contaminant concentrations
- Conduct bench-scale feedstock tests; quantify product yields, quality, and contaminant concentrations

The **FAA Award Number 13-C-AJFE-UH, Amendment 013** project goals are to

- Conduct tropical oil to SAF supply chain analysis
- Develop management strategies for elements present in construction and demolition waste that affect use in thermochemical-conversion-based SAF production pathways

The **FAA Award Number 13-C-AJFE-UH, Amendment 017** project goals are to

- Explore the impacts of HB2386 on waste management in Hawaii and potential for waste-based SAF production systems

Task 1.1 - Informing Regional Supply Chains

University of Hawaii

Objectives

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

Research Approach

Activity 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 1 team and Volpe Center analyses of regional supply chains.

Activity 2

A database of relevant pretreatment and conversion technology options, and experience with potential tropical feedstock materials, was assembled from the archival literature and from existing Project 1 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 the underlying analysis. Pairings of pretreatment and conversion technology options provided the starting point for the evaluation of tropical biorefineries that can be integrated into ASCENT Project 1 team and Volpe Center activities.

Milestones

Activity 1

- Identified a target list of databases to search for relevant literature

- Provided an interim report summarizing progress in the literature search

Activity 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*.

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 Hawaii 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 - Identification of Supply Chain Barriers in the Hawaiian Islands

University of Hawaii

Objective

The objective of this task was to identify the 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

UH developed the Hawaii Bioenergy Master Plan for the State of Hawaii (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 Hawaii 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 could 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 Hawaii Bioenergy Master Plan, barriers to the development of regional supply chains for ASCENT were identified through interaction with key stakeholder groups. Green Initiative for Fuels Transition Pacific (GIFTPAC) meetings are held quarterly and attended by biofuel development interests in Hawaii, including representatives of large landowners, producers of first-generation biofuels, petroleum refiners, electric utilities, the State Energy Office, U.S. Pacific Command, biofuel entrepreneurs, county government officials, and UH. Additional stakeholders are invited as necessary to fill information and value chain gaps. 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 1 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 Hawaii and ranked the barriers in order of importance as follows:

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

Several of the barriers are also faced by other 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 Hawaii. 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

hnei.hawaii.edu

Task 2.1 - Informing Regional Supply Chains

University of Hawaii

Objectives

Building on FY16 activities, additional supporting analysis will be conducted for proposed supply chains in Hawaii, including the following:

3.1
Support Volpe Center and CAAFI Farm to Fly 2.0 supply chain analysis.

3.2
Use GIS-based estimates of fiber crop production potential to develop preliminary technical production estimates of jet fuel in Hawaii.

3.3
Develop fundamental property data for tropical biomass resources.

3.4
Transmit data and analysis results to support the improvement of existing tools (e.g., POLYSYS; https://bioenergykdf.net/content/polysys).

Research Approach

Activity 3.2 has been conducted by using GIS data to identify areas suitable for purpose-grown crop production of feedstocks for SAF production in Hawaii. 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 from 1 to 3 are generally suitable for agricultural production; an LCC of 4 can be productive with proper management; and LCCs of 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 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 the differences between parameters developed from global sugar production and a century of production experience in Hawaii 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 Activity 3.3. *Pongamia* is an oilseed-bearing, leguminous tree that has production potential in Hawaii and Florida. The tree produces pods containing oil-bearing seeds. Pods, oilseed cake, and oil were evaluated from trees growing on the island of Oahu. Fundamental measurements of chemical composition were conducted and reported. Torrefaction of pods as a coproduct in oil production has been conducted. 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 (AFTOT; https://trid.trb.org/view/1376122), and conversion modules
- Reviewed previously developed GIS information layers for tropical fiber crops, and identify updating requirements
- Conducted preliminary estimates of SAF technical potential in Hawaii, 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 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 transport costs 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. 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 Hawaii 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 Hawaii that enable high drainage rates and accommodate sugar production.

Calibration of the EcoCrop model by using historical sugarcane planted acreages was completed in 2018. This effort used a confusion matrix approach for validation (resulting in a kappa value >.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. 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 Oahu to identify direct evidence of *Pongamia* escaping from plantings and becoming an invasive weed. Seven field sites were visited in various environments across Oahu. 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 Oahu. 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 water dispersed, future risks of *Pongamia* escape and unwanted spread could be minimized by avoiding planting at sites near flowing water, near areas exposed to tides, or on or near steep slopes. Vegetative spread by root suckers was not observed around plantings on Oahu; however, 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 Oahu. TerViva, a company pursuing *Pongamia* commercialization, provided material from orchards on Oahu. Fundamental measurements of chemical composition were made for seeds, pods, extracted oil, and post-extraction seed material. Measured values included C, H, N, and S 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*.

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 and storage stability, and 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*.

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 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*.

Aleurites moluccanus, commonly known as kukui and candlenut, is an oil-nut-bearing tree frequently found in the tropics. It is also the state tree of Hawaii. Nuts from a number of trees growing on the island of Oahu were collected, and the nut shell, oilseed cake, and oil components were fractionated and analyzed for common properties necessary for designing SAF production systems. A manuscript has been submitted to the journal *Biomass & Bioenergy*. Revisions are in process.

Publications

Peer-reviewed journal publications

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

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

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,* 9222–9233. doi:10.1021/acsomega.1c00635

Written report

Chan, S., Ogoshi, R. & Turn, S. 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]. European Biomass Conference and Exhibition. Virtual.

Fu, J., Summers, S. & Turn, S. "Upgraded *Millettia Pinnata* Pod via Torrefaction for the Production of Bioenergy in Hawaii" was presented orally at the 2020 Thermal & Catalytic Sciences Virtual Symposium.

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

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]. 2021 Fall National Meeting of the American Chemical Society, Atlanta, GA, United States.

Fu, J., Summers, S. & Turn, S. "Upgraded *Millettia Pinnata* Pod via Torrefaction for the Production of Bioenergy in Hawaii" was presented virtually and orally at the 2021 Spring National Meeting of the American Chemical Society, April 5–16, 2021.

Fu, J., Weber, S. & Turn, S. "Comprehensive Characterization of Kukui Nuts for Bioenergy Production in Hawaii" was presented orally at the 2022 Fall American Chemical Society National Meeting & Exposition, Chicago, IL, August 21–25, 2022

Awards

The poster titled "Feedstocks for Sustainable Jet Fuel Production: An Assessment of Land Suitability in Hawaii," presented at the European Biomass Conference and Exhibition held virtually July 6–9, 2020, 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 fall 2019 American Chemical Society 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.

Plans for Next Period

The report summarizing the analysis of the GIS analysis of SAF feedstock production potential and a companion manuscript will be completed.

Statewide working maps for each of the feedstock species will be used as the basis for ongoing discussions with targeted stakeholder groups, including landowners and Natural Resources Conservation Service staff. Funding for planting and evaluating the more promising feedstock plants on UH experimental station land will be pursued in collaboration with stakeholders (e.g., TerViva).

Task 2.2 - Support of Indonesian Alternative Jet Fuel Supply Initiatives

University of Hawaii

Objectives

This task supports the memorandum of understanding between the FAA and the Indonesian DGCA 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

The process will begin with working with the FAA to establish points of contact to coordinate efforts with Indonesian counterparts. The Indonesian Aviation Biofuels and Renewable Energy Task Force (ABRETF) members 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 could include developing preliminary GIS mapping information of their locations and distributions, and preliminary estimates of their technical potential.

Milestones

- Identify points of contact at Indonesian universities participating in ABRETF
- Identify research needs and develop a project plan
- Develop data for potential projects

Major Accomplishments

The P.I. traveled to Jakarta 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 & 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. The conclusion from this introductory meeting was that the Indonesian counterparts would seek agreement on how to move forward with future cooperation.

The P.I. traveled to Jakarta 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 of 2022, the P.I. traveled to Jakarta and met with Dr. Wendy Aritenang in Jakarta. The following day, the P.I. and Dr. Aritenang traveled to Bandung to visit the Bandung Institute of Technology (ITB) and meet with faculty members Professor Adiwan Aritenang (Head Department of Regional Planning) and Professors Tatang Soerawidjaja, Tirto Prakoso Brodjonegoro, and Iman Reksowardojo from the Faculty of Industrial Technology. Ongoing UH ASCENT activities were presented, and the ITB 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, and gave a presentation entitled "US Initiatives on Sustainable Aviation Fuel."

Awards
None.

Student Involvement
None.

Plans for Next Period
The P.I. will continue to develop the cooperative research agenda between UH and Indonesian universities through continued dialog with the FAA, the International Civil Aviation Organization, and the Indonesian DGCA. Travel to Southeast Asia for other projects is anticipated in 2023, and meetings and relationship building with researchers at Indonesian institutions will be continued. ITB faculty members have expressed interest in pursuing collaborative work. Planning for a regional workshop on SAF is in progress.

Task 3.1 - National Lipid Supply Availability Analysis
University of Hawaii

Objective
Activities under this task 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, 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* tree 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 Oahu's 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 Oahu. Fundamental measurements of chemical composition were made for seeds, pods, extracted oil, and post-extraction seed material. Measured values included C, H, N, and S 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. Development of coproducts from the pods and oilseed cake will be explored.

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

Waste oil resources in Hawaii 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
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
Characteristics and suitable production areas for additional oilseed crops in Hawaii will be assessed as needed. Information will be provided to the lead institution (WSU).

Task 3.2 - Hawaii Regional Project
University of Hawaii

Objectives
A supply chain based on fiber feedstocks transported to a conversion facility located at Campbell Industrial Park (CIP) on Oahu will be evaluated (Figure 1). CIP is the current site of two oil refineries. Construction and demolition (C&D) wood waste from the PVT Land Company's landfill could be the primary source of feedstock. Other sources will be evaluated from elsewhere on Oahu and from outer islands, including municipal solid waste streams from outer islands and mining of current stocks of waste-in-place. Waste streams and purpose-grown crops form the basis of a hub-and-spoke supply system, with the hub located on Oahu. 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-MW alternative fuel-capable power plant under development) and Kaneohe Marine Corps Base. Hawaii 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. Hawaii 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 located at Campbell Industrial Park, Oahu.

Research Approach

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

Building on activities from previous years, additional supporting analysis will be conducted for proposed supply chains in Hawaii, as follows:

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

Task 3.2.G2. Scoping 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. Screening-level greenhouse gas (GHG) life-cycle assessment (LCA)
This task will conduct screening-level GHG LCA on the proposed target supply chains and SAF conversion technologies.

Subtasks:
- 3.2.G3.1 Assess Massachusetts Institute of Technology (MIT) waste-based GHG LCA tools in the context of application to Hawaii [MIT (Mark Staples)]
- 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]
- 3.2.G3.3 Identify and fill information/data gaps

Task 3.2.G4. Identification of supply chain participants/partners
Subtasks:
- 3.2.G4.1 Define C&D landfill case
- 3.2.G4.2 Identify eucalyptus in existing plantations, landowners, leaseholders/feedstock producers, harvesting contractors, truckers, etc. [UH]
- 3.2.G4.3 Define other feedstock systems as identified [ASCENT Project 01 Team]

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

Task 3.2.G6. Identify and engage stakeholders
Subtasks:
- 3.2.G6.1 Identify stakeholders along the value chain, and create a database based on value chain location [UH]
- 3.2.G6.2 Conduct a stakeholder meeting by using the instruments developed in Task 3.2.G5 [UH, WSU (Season Hoard)]
- 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 (FTOT) and other modeling efforts
Subtasks:
- 3.2.G7.1 Acquire necessary data to evaluate harbor capacities and current usage [UH, Volpe (Kristin Lewis), WSU (Michael Wolcott)]
- 3.2.G7.2 Acquire data on interisland transport practices [UH, Volpe (Kristin Lewis), WSU (Michael Wolcott)]

Task 3.2.G8. Evaluate infrastructure availability
Subtasks:
- 3.2.G8.1 Evaluate interisland shipping options and applicable regulation [UH, Volpe (Kristin Lewis), WSU (Michael Wolcott)]
- 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:
- 3.2.G9.1 Refine/ground truth prior evaluations of options for purpose-grown feedstock supply [UH]
- 3.2.G9.2 Conduct projections of future C&D waste supply and mining of waste-in-place on Oahu, 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 through 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

Characteristics of the feedstock generated at the landfill have been determined and summarized in a draft publication.

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.

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.

Plans for solid waste management from all counties in Hawaii have been used to provide a broader picture of the waste stream composition, diversion, and 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. 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 2019 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 Hawaii Aviation and Climate Action Summit, December 3, 2019, at the Hawaii State Capitol.

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.

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

Discussion with Dr. Kristin Lewis and Volpe Center staff on the addition of Hawaii transportation infrastructure to the FTOT 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.

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. This manuscript awaits comparative data from the bench-scale gasification test underway at ThermoChem Recovery International facilities.

Work on the GHG analysis of C&D waste use for SAF production will be extended from the landfill to a point of use (to be determined) and interfaced with the system TEAs described by WSU.

Outreach to interested industries will be continued.

Task 4 - Hawaii Regional Project

University of Hawaii

Objective

This task builds upon the results from the previous years' work under the Hawaii regional project. The focus is 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 previous years' C&D feedstock characterization data and thermochemical equilibrium analysis 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.

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

- Identify and evaluate capabilities of experimental bench-scale facilities to gasifier tests
- Specify system performance parameters to be measured
- Specify techniques to sample and analyze contaminants
- Select and engage an experimental bench-scale facility for testing
- Prepare and ship feedstock from Hawaii to the experimental test facility
- Conduct 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 Hawaii and the tropics.

A synthetic construction and demolition 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 with 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 aid in decreasing test-to-test variability.

In November and December of 2021, tests were conducted in the bench-scale facility at the ThermoChem Recovery International facility in Durham, NC. After shakedown testing was completed, two subsequent tests were conducted: the first used *Leucaena leucocephela* stemwood, and the second used synthetic construction and demolition waste. ThermoChem Recovery International has provided a draft summary report for the *Leucaena* test, and revisions are in process.

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
None.

Awards
None.

Student Involvement
None.

Plans for Next Period
During the next period, activities identified in the Research Approach section above will continue. The primary focus will be on conducting the bench-scale gasification tests, collecting and analyzing samples from the tests, and preparing reports and publications summarizing the results. The sequence of milestones identified above provides a roadmap of necessary subtasks.

Task 5 - Hawaii Regional Project
University of Hawaii

Objective
Subtask 5.1: Tropical oil to SAF supply chain analysis
The goal of subtask 5.1 is to develop a model for tropical oil supply chains for AJF and associated coproducts. Hawaii will be the initial focus, but the modeling tools will be developed for wider use in island settings.

Subtask 5.2: Contaminants in the gasification of C&D wastes
The goal of subtask 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
Subtask 5.1:
Prior ASCENT EcoCrop GIS modeling activities identified growing locations for *Pongamia*, kamani, croton, and *Jatropha*, according to suitable environmental conditions, geography, and zoning. If unavailable, 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. Model results will identify feedstock production areas, and 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., ARA, SBI, or Forge), transportation strategies, and blend ratios at airports (or for specific end users, e.g., the military) across Hawaii 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. Criteria used to drive the model solution might include minimizing SAF production costs while meeting a minimum total production benchmark or 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.

Subtask 5.2:
Thermochemical gasification of biorenewable resources is the initial conversion process for two entry points to AJF production: (a) synthesis gas (syngas) used in direct production of Fischer–Tropsch liquids, and/or (b) 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. Negative aspects of C&D feedstock are its physical and chemical inhomogeneity. In the latter case, 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 01 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 syngas/Fischer–Tropsch liquids and green hydrogen. Technology options for contaminant removal or conversion to benign forms will be assessed at each step in the conversion process; that is, 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. Technology options from existing process industries and from 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. Integrated gasification process options and contaminant control options will be evaluated as complete systems to guide system design and enable system comparisons. Risks associated with the technology options will also be assessed to guide implementation and risk mitigation of the system as a whole. Impacts of processing scale (e.g., Mg waste/day) on selection of technology options will also be assessed.

Milestones
Subtask 5.1: Established a model framework for an oilseed-based SAF supply chain in an island setting, using the scenario of Hawaii

Subtask 5.2: Completed a review of options to manage contaminants along the supply chain; conduct 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 all locations with (a) industrial zoning and (b) lands with slope of less than 5%, a contiguous area of 50 acres, and agricultural zoning. A total transportation cost index was calculated for each candidate processing site, according to the *Pongamia* production estimates and the road distance from each production site to candidate processing sites.

Publications
None.

Outreach Efforts
None.

Awards
None.

Student Involvement
None.

Plans for Next Period
Subtask 5.1: Costs for *Pongamia* delivered to the processing site gate will be used with TEA spreadsheets (oilseed crushing, hydroprocessed esters and fatty acids, etc.) developed by WSU collaborators to provide estimates of SAF production costs according to supply chain scenario assumptions.

Subtask 5.2: A review of options to manage contaminants along the supply chain will be conducted. Results of the review and contaminant measurements from the bench-scale gasification tests in Task 4 will be used to target bench-scale contaminant control tests.

Task 6 - Hawaii Regional Project
University of Hawaii

Objective
Task activities in Year 6 will explore the impacts of Hawaii 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 Hawaii. HB2386 was disruptive to disposal practices for C&D waste on the island of Oahu, and its impacts are currently not fully understood. Task 6 seeks to collect updated waste generation data, understand how HAVE BEen2386 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. Preliminary assessment of restricted and unrestricted sites for waste and disposal facilities will be reviewed and refined as necessary. Preliminary impacts on GHGs and SAF technology choices will be explored.

Milestone
Impacts of removing or diminishing the role of an active C&D landfill as a supply chain participant will also be evaluated.

Major Accomplishments
None.

Publications
None.

Outreach Efforts
None.

Awards
None.

Student Involvement
None.

Plans for Next Period
A postdoctoral fellow will be recruited to work on this task, and analysis will begin.