# Project 001(B) Alternative Jet Fuel Supply Chain Analysis

## University of Hawaii

## Project Lead Investigator

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## University Participants

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

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

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

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

**University of Hawaii**
- PI: Scott Q. Turn, Researcher
- FAA Award Number: 13-C-AJFE-UH, Amendment 013
- Period of Performance: June 5, 2020 to August 4, 2021
- Task:
    1. 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 and 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 the University of Hawaii.

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.

## Investigation Team

**Lead**
Scott Turn, University of Hawaii, PI

**Other Lead Personnel**
Tim Rials, professor, and Burt English, Professor (University of Tennessee Co-PIs)
Manuel Garcia-Perez, Profesor (Washington State University (WSU) Co-PI)
Kristin Lewis, Principal technical advisor (Volpe National Transportation Systems Center PI)
Michael Wolcott, Professor (WSU PI)
Lara Fowler, Professor (The Pennsylvania State University, PI)

**UH Investigation Team**
Under **FAA Award Number 13-C-AJFE-UH, Amendment 005**, Task 1 and Task 2 include
Dr. Scott Turn, researcher, Hawaii Natural Energy Institute, University of Hawaii (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 include
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
Dr. Curtis Daehler, professor, Department of Botany, UH
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 include
Dr. Scott Turn, researcher, Hawaii Natural Energy Institute, UH
Dr. Trevor Morgan, assistant researcher, Hawaii Natural Energy Institute, UH
Dr. Jinxia Fu, assistant researcher, Hawaii Natural Energy Institute, UH
Dr. Quang Vu Bach, postdoctoral fellow, Hawaii Natural Energy Institute, UH
Ms. Sabrina Summers, undergraduate student, Bioengineering Department, UH
Ms. Sarah Weber, undergraduate student, Molecular Biosciences and Biotechnology, UH
Mr. Taha Elwir, undergraduate student, Chemistry Department, UH

Under **FAA Award Number 13-C-AJFE-UH, Amendment 011**, Task 1 includes
Dr. Scott Turn, researcher, Hawaii Natural Energy Institute, UH

Dr. Quang Vu Bach, postdoctoral fellow, Hawaii Natural Energy Institute, UH

Under **FAA Award Number 13-C-AJFE-UH, Amendment 013**, Task 1 includes
Dr. Scott Turn, researcher, Hawaii Natural Energy Institute, UH
Ms. Sharon Chan, 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 significant quantities of AJF 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, and
  - 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 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. Included in this objective is 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 Indonesian Directorate General of Civil Aviation (DGCA) to promote 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 improvement of existing tools and best practices.
- Support Indonesian AJF 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 AJF 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 AJF 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 sustainable aviation fuel (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 and quantify product yields and quality and contaminant concentrations.

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

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

# Task 0.1 – Informing Regional Supply Chains

University of Hawaii

## Objectives

This Task included two activities: (1) a review of the archival literature on existing tropical crops and potential new crops that could provide feedstocks for AJF production, and (2) a review of relevant pretreatment and conversion technology options and experience with feedstocks identified in (1).

## Research Approach

Activity 1: The archival literature will be reviewed to construct an updated database of relevant citations for tropical crops; new potential energy crops will be identified and added to the database. Available information on agronomic practices, crop rotations, and harvest techniques will be included. The database will be shared with and 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 will be assembled from the archival literature and from existing Project 1 team shared resources. Of particular interest are 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 provide the starting point for evaluation of tropical biorefineries that can be integrated into ASCENT Project 1 team and Volpe Center activities.

## Milestones

Task 1, Activity 1: Identify target list of databases to search for relevant literature.
Task 1, Activity 1: Interim report summarizing progress on literature search.
Task 1, Activity 2: Identify target list of databases to search for relevant literature.
Task 1, Activity 2: Interim report summarizing progress on literature search.

## Major Accomplishments

This work is completed. A report was produced for each of the two activities, and the two reports were combined to form a manuscript published in the journal *Energy & Fuels*.

## Publications

**Peer-reviewed journal publication**

Morgan, T.M., Youkhana, A., Ogoshi, R., Turn, S., & Garcia-Perez, M. (2019). Review of biomass resources and conversion technologies for alternative jet fuel production in Hawai'i and tropical regions. *Energy & Fuels*, 2699-2762.

## Outreach Efforts

On February 21, 2018, the PI participated in a ThinkTech Hawaii broadcast focused on AJFs 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
N/A

# Task 0.2 – Identification of Supply Chain Barriers in the Hawaiian Islands
University of Hawaii

## Objective
Identify the key barriers in regional supply chains that must be overcome to produce significant quantities of AJF in the Hawaiian Islands and similar tropical regions.

## Research Approach
UH developed the Hawaii Bioenergy Master Plan for the State of Hawaii (https://www.hnei.hawaii.edu/sites/www.hnei.hawaii.edu/files/Hawaii%20Bioenergy%20Master%20Plan.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 (1) land and water resources that could support biomass feedstock production, (2) potential biomass resources and their availabilities, (3) technology requirements, (4) infrastructure requirements to support logistics, (5) economic impacts, (6) environmental impacts, (7) availability of human capital, (8) permitting requirements, and (9) 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 development of regional supply chains for ASCENT will be identified by interacting 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 are excellent opportunities to receive stakeholder input, identify barriers to supply chain development, and organize data collection efforts that span supply chain participants.

## Milestones
Task 2: Introduce activities at next regularly scheduled GIFTPAC meeting after contract executed.
Task 2: Prepare interim report outlining two tropical supply chain scenarios developed in consultation with Project 1 team and with input from GIFTPAC participants.

## Major Accomplishments
This Task is completed. A stakeholder meeting was held and documented in a report submitted to the FAA. The stakeholders identified barriers to AJF production in Hawaii and ranked the barriers in order of importance as indicated below:

- Economic constraints (e.g., high costs of entry for production factors such as land) throughout the whole 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.
- AJF production technologies (emerging but have not yet demonstrated full commercial viability).
- Insufficient or inadequate infrastructure (e.g., harbors, roads, fuel distribution infrastructure, irrigation systems) to support the whole production chain.

Several of the barriers are held in common with other locations in the continental U.S. but those related to water and infrastructure are unique characteristics of an island state.

## Publications
N/A

## Outreach Efforts
This activity engaged stakeholders to identify barriers to AJF 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 about 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 outlined below.

# Task 0.3 – 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:

0.3.1 Support Volpe Center and CAAFI Farm to Fly 2.0 supply chain analysis.
0.3.2 Use GIS-based estimates of fiber crop production potential to develop preliminary technical production estimates of jet fuel in Hawaii.
0.3.3 Develop fundamental property data for tropical biomass resources.
0.3.4 Transmit data and analysis results to support improvement of existing tools (e.g., POLYSYS; https://bioenergykdf.net/content/polysys).

## Research Approach
Activity 0.3.2 has been conducted using GIS data to identify areas suitable for purpose-grown crop production of feedstocks for AJF production in Hawaii. The approach has been to use GIS layers for land capability class (LCC), slope, and zoning as preliminary screens for suitability. Lands are classified by the Natural Resources Conservation Service (NRCS) with ratings from 1 to 6. LCCs from 1 to 3 are generally suitable for agricultural production; LCC of 4 can be productive with proper management; and LCCs of 5 or 6 can support less intensive production and could 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 0.1 based on the 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. Using 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 was refined through plant breeding to adapt sugarcane varieties to a wide variety of agro-ecosystems. Analysis has purposely avoided land use conflict with food production by limiting suitability to areas capable of sustaining AFJ feedstocks under rain fed conditions. Areas suitable for AJF 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 0.3.3. 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 a number of trees growing on the island of Oahu. Fundamental measurements of chemical composition will be conducted and reported. Torrefaction of pods as a coproduct to oil production has been conducted. Investigation of pretreatment methods to improve pod feedstock properties for thermochemical conversion applications are currently underway.

## Milestones

- Identify target opportunities to augment POLYSYS, Alternative Fuel Transportation Optimization Tool (AFTOT; https://trid.trb.org/view/1376122), and conversion modules.
- Review previously developed GIS information layers for tropical fiber crops and identify updating requirements.
- Conduct preliminary estimates of AJF technical potential in Hawaii based on previously developed GIS information layers.

## Major Accomplishments

The GIS-based analysis of AJF production potential is ongoing. The assessment of potential lands meeting requirements for LCC, slope, and land-use zoning is complete. The EcoCrop model is being implemented to predict yield as a function of minimum mean monthly temperature and annual rainfall. This will allow prescription of potential AJF feedstock crops on land areas capable of supporting their production under both rain-fed and irrigated conditions. This analysis will provide information necessary in 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 historic 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 historic acreage. The difference between the EcoCrop values and those representative of Hawaii conditions can be attributed to improvements due to plant breeding and unique combinations of environmental conditions. An example of the latter is the relatively young volcanic soils present in high-rainfall areas on the island of Hawaii that allow for high drainage rates and accommodate sugar production.

Calibration of the EcoCrop model using historic sugarcane planted acreages was completed in 2018. This effort used a confusion matrix approach to validation (resulting in a kappa value >0.4) and demonstrated that 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 to include statewide working maps for each of the species summarized in a draft report currently undergoing internal review. This report will serve as the basis for a publication targeted for the upcoming, ASCENT-organized, special issue of *Frontiers in Energy Research*.

Dr. Curtis Daehler (University of Hawaii, Department of Botany) completed a report assessing the invasiveness of pongamia. Retrospective analyses show that predictive weed risk assessment systems correctly identify many major pest plants, but such predictions are not 100% accurate. The purpose of this study was to make field observations of pongamia planted around Oahu to look for direct evidence that pongamia is escaping from plantings and becoming an invasive weed. Seven field sites were visited in varying 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 canopy of mother trees. This finding suggests a lack of effective seed dispersal away from pongamia plantings. Based on 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. Seeds and seed pods are water dispersed, so future risks of pongamia escape and unwanted spread would 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 but, based on reports from elsewhere, 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 were evaluated from a number of trees growing on the island of Oahu. TerViva, a company pursuing pongamia commercialization, has 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. Chemical composition and fuel properties of the oilseed cake and the pod material have been characterized. A manuscript summarizing the results of this effort was submitted to the journal *Industrial Crops and Products*.

Coproduct evaluation of pongamia pods feedstock for thermochemical conversion has been conducted. Evaluation included both untreated pods and those pretreated by a torrefaction process to improve their properties. Torrefaction produces a material that has better grindability, reduced oxygen content, improved storage stability, and reduced 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 (HGI), 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 was submitted to the journal *Fuel*.

## Publications

**Written report**

Chan, S., Ogoshi, R. & Turn, S. Feedstocks for sustainable jet fuel production: An assessment of land suitability in Hawaii. Draft report. 82 pp.

**Peer reviewed publication**

Fu, F., Summers, S., Morgan, T.J., Turn, S.Q., & Kusch, W. 2020. Fuel properties of *Millettia pinnata* seeds and pods grown in Hawaii. *Industrial Crops and Products*. In review.

Fu, J., Summers, S., Turn, S.Q., & Kusch, W. 2020. Upgraded pongamia pod via torrefaction for the production of bioenergy. *Fuel*. In review.

## 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 their business plan.

A poster entitled "Feedstocks for Sustainable Jet Fuel Production: An Assessment of Land Suitability in Hawaii" was presented at the European Biomass Conference and Exhibition held virtually July 6–9, 2020.

"Upgraded *Milletia Pinnata* Pod via Torrefaction for the Production of Bioenergy in Hawaii" was orally presented at the 2020 Thermal & Catalytic Sciences Virtual Symposium.

Information from this Task was included in the, "Regional Supply Chain Analysis for Alternative Jet Fuel Production in the Tropics," presentation at the Hawaii Aviation and Climate Action Summit, December 3, 2019, at the Hawaii State Capitol.

## Awards

The poster entitled, "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, with primary responsibility for processing and analyzing samples of biomass materials selected for evaluation as potential AJF 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.

## Plans for Next Period

The report summarizing the analysis of the GIS analysis of SAF feedstock production potential will be completed and submitted as a manuscript for the upcoming, ASCENT-organized, special issue of *Frontiers in Energy Research*.

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 NRCS staff. Funding for planting and evaluating the more promising feedstock plants on UH experiment station land will be pursued in collaboration with stakeholders, e.g., TerViva.

The current manuscript submitted to *Industrial Crops and Products* summarizing fuel properties of pongamia seed, pod, and oilseeds will be finalized and published.

The current manuscript submitted to *Fuel* summarizing torrefaction pretreatment of pongamia pods will be finalized and published.

Analysis of coproduct development based on pongamia oilseeds and husks will be continued.

## Task 0.4 – Support of Indonesian Alternative Jet Fuel Supply Initiatives

University of Hawaii

### Objective

This Task supports the memorandum of understanding between the FAA and the Indonesian DGCA to promote 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

This Task will support the memorandum of understanding between the FAA and Indonesian DGCA to promote development and use of sustainable, alternative aviation fuels. This 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) membership includes 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. This could include data collection on Indonesian jet fuel use and resources for AJF production, airport locations, and annual and monthly jet fuel consumption patterns. Characterization of sustainable biomass resources with potential for use in producing AJF supplies could include developing preliminary GIS mapping information of their locations and distributions and preliminary estimates of their technical potentials.

### Milestones

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

### Major Accomplishments

The PI 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, followed by a general discussion. The conclusion from this introductory meeting was that the Indonesian counterparts would seek agreement on how to move forward with future cooperation.

The PI traveled to Jakarta and met with Dr. Wendy Aritenang of the International Civilian Aviation Organization Jakarta office. The same trip included meetings with renewable energy researchers at Universitas Indonesia. Following the meeting, Dr.

Aritenang suggested points of contact for future engagement: Frisda Panjaitan from the Palm Oil Research Institute and three researchers from the Bandung Institute of Technology: Tatang Soerawidjaja, Tirto Prakoso Brodjonegoro, and Imam Reksowardojo.

A source of funds external to ASCENT has been identified to hold a post-pandemic workshop on alternative jet fuel production in Indonesia. Scott Turn requested and received encouragement from FAA ASCENT program management. FAA will provide guidance on personnel, participation, and workshop content when planning begins in earnest.

### Publications
N/A

### Outreach Efforts
Outreach efforts by the PI are described in the Major Accomplishments section above.

### Awards
None

### Student Involvement
None

### Plans for Next Period
The PI will continue to develop the cooperative research agenda between UH and Indonesian universities through continued dialog with FAA, the International Civil Aviation Organization, and the Indonesian DGCA. Travel to Southeast Asia for other projects is anticipated in 2021 and meetings with the researchers at Indonesian institutions (delayed by pandemic in 2020) suggested by Dr. Aritenang will be pursued. Planning for a workshop on AJF will move forward as the situation returns to normal.

## Task 2.2 – 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
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. 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 the 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 contents; 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.

The assessment of areas in Hawaii with agricultural zoning that are suitable for rainfed 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 two to three million gallons per year based on defacto population and are directed to biodiesel production.

### Publications
N/A

### 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, with primary responsibility for processing and analyzing samples of biomass materials selected for evaluation as potential AJF 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 (MSW) stream from outer islands and mining of current stocks of waste-in-place. Waste streams and purpose-grown crops form the basis for 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 adjacent Joint Base Pearl Harbor/Hickam. Other coproduct off-takers for alternative diesel fuel include Hawaiian Electric Co. and several military bases, including Schofield Barracks (~50 MW alternative fuel-capable power plant under development) and Kaneohe Marine Corp 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 off-takes feedstock (naphtha) from refinery.


**Figure 1.** Possible locations of value chain participants for 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), 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, contaminants). [UH and WSU (Manuel Garcia-Perez)]
- 3.2.G1.2 Acquire data on feedstock size reduction, particle size of materials, 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 AJF 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 AJF conversion technologies.

Subtasks:
- 3.2.G3.1 Assess Massachusetts Institute of Technology (MIT) waste-based GHG LCA tools in context of Hawaii application. [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, leaseholder/feedstock producer, harvesting contractor, trucking, etc. [UH]
- 3.2.G4.3 Define other feedstock systems as identified. [ASCENT Project 01 Team]

**Task 3.2.G5. Develop 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 based on 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 database based on value chain location. [UH]
- 3.2.G6.2 Conduct stakeholder meeting using instruments developed in Task 3.2.G5. [UH, WSU (Season Hoard)]
- 3.2.G6.3 Analyze stakeholder response and feedback to process. [UH, WSU (Season Hoard)]

**Task 3.2.G7. Acquire transportation network and other regional data needed for 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 (Mike Wolcott)]
- 3.2.G7.2 Acquire data on interisland transport practices. [UH, Volpe (Kristin Lewis), WSU (Mike 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 (Mike Wolcott)]
- 3.2.G8.2 Evaluate transport or conveyance options from conversion location to end user and applicable regulation. [UH, Volpe (Kristin Lewis), WSU (Mike 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 C&D waste supply moving forward and mining of waste-in-place on Oahu, MSW, and mining of waste-in-place on other islands. [UH]

**Task 3.2.G10. Develop 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.

Elemental compositions of the 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 construction and demolition waste as SAF feedstock have been assembled. Preliminary discussions on GHG analysis of C&D-based SAF systems with landfill operators have been initiated.

Solid waste management plans 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

Bach, Q.V., Fu, J., & Turn, S.Q. Fuel Characterization of Construction and Demolition Wastes as Feedstock for Thermochemical Gasification, draft manuscript to be submitted to *Waste Management*.

## 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," was 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.

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 the UH and ULL. A non-disclosure agreement was subsequently signed between SENASA, ULL, UH, and the Spanish company Abengoa Energía, S.A.

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

## 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 feedstock characteristics and prediction of gasification product streams including contaminant concentrations will be submitted.

Work on the greenhouse gas analysis of construction and demolition waste use for AJF production will be extended from the landfill to a point of use (to be determined) and interfaced to 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 the data and analysis necessary to plan a project that uses C&D waste as feedstock for SAF production. Using previous years' C&D feedstock characterization data and thermochemical equilibrium analysis, the Task 4 objective is to conduct bench-scale gasification tests and quantify the product gas yield and composition and contaminant concentrations. These results will be compared with equilibrium prediction used to identify contaminants that must be addressed prior to end use and provide the basis for contaminant control system design.

## Research Approach

Using samples of construction and demolition wastes characterized in the earlier Tasks, bench-scale gasification tests will be conducted 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 needed 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 experimental bench-scale facility for testing.
Prepare and ship feedstock from Hawaii to experimental test facility.
Conduct tests, reduce data, and prepare summary report of results.

## Major Accomplishments

Preliminary listings of bench-scale facilities have been assembled and discussions for accessing them have begun.

Operational measurements to be conducted as part of bench-scale tests have been summarized to drive test plan developments and evaluate capabilities of bench-scale units.

## Publications

N/A

## Outreach Efforts

N/A

## 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 to conclude the planning phase and conduct the bench-scale gasification tests. The sequence of milestones identified above provide a roadmap of necessary subtasks.

# Task 5 – Hawaii Regional Project

University of Hawaii

## Objective

Task 5 includes two subtasks:

Subtask 5.1: Tropical oil to AJF supply chain analysis.
Subtask 5.2: Contaminants in gasification of construction and demolition wastes.

The goal of subtask 5.1 is to develop a model for tropical oil supply chains for alternative jet fuel and associated coproducts. Hawaii will be used as the initial focus, but the modeling tools will be developed for wider use in island settings.

The goal of subtask 5.2 is to develop management strategies for elements present in C&D waste that impact 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, based on suitable environmental conditions, geography, and zoning. Where unavailable, primary data were also developed for chemical and physical characteristics of these tropical oils and their coproducts (pods/shell, oil seed cake, etc.). The project will use these earlier results as the basis for developing supply chain models for alternative jet fuel 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 AJF. Potential sources of hydrogen from oil seed coproducts, other renewable resources, and fossil sources will be analyzed and included in the model. Options for points of production, AJF production technologies (ARA, SBI, or Forge, etc.), transportation strategies, and blend ratios at airports (or for specific end users, i.e., military) across Hawaii will affect model outcomes and will be evaluated. Options for coproducts such as animal feeds and higher valued materials will be evaluated and incorporated into the model decision making. Criteria used to drive the model solution might include minimizing AJF 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 alternative jet fuel production; (1) synthesis gas used in direct production of Fischer-Tropsch (FT) 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 feedstock attractiveness. Negative aspects of C&D feedstock are its physical and chemical inhomogeneity. In the latter case, inorganic elements present in the feedstock can negatively impact the gasification process (e.g., corrosion of or accumulation on reactor working surfaces, bed material agglomeration, catalyst deactivation, pollutant emissions, etc.). Using data generated from previous ACSENT Project 01 tasks, this project will assess methods for managing contaminants in C&D feedstocks. This project will be based around gasification systems proposed for production of syngas-FT liquids and green hydrogen. Technology options for contaminant removal or conversion to benign forms will be assessed at each step in the conversion process, i.e., presorting at the waste generation site, sorting/diversion at the C&D waste intake facility, removal by physical/chemical/other methods prior to gasification, in situ reactor control methods, and gas clean up. Technology options from existing process industries and from the scientific literature will be considered. Lab-scale testing of removal techniques will be conducted to provide 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 allow 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.

## Milestone

Subtask 5.1: Establish model framework for oil seed based AJF supply chain in an island setting using Hawaii scenario.

Subtask 5.2: Complete review of options to manage contaminants along the supply chain. Conduct bench scale tests to confirm the efficacy of options

## Major Accomplishments
Funding for this Task was received recently and the Task is in the planning stage.

## Publications
N/A

## Outreach Efforts
N/A

## Awards
None

## Student Involvement
None

## Plans for Next Period
Subtask 5.1: GIS data for oilseed crop production areas and petroleum jet fuel use data at Hawaii airports will be used as the starting points for building AJF model scenarios.

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.