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 July 1, 2020
- Task(s):
    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 July 1, 2020
- Task(s):
    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 July 1, 2020
- Task(s):
    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 July 1, 2020
- 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.

Investigation Team

Lead
Scott Turn, University of Hawaii, PI

Other Lead Personnel
Tim Rials, professor, and Burt English, professor (UT Co-PIs)
Manuel Garcia-Perez, profesor (WSU Co-PI)
Kristin Lewis, principal technical advisor (Volpe PI)
Michael Wolcott, professor (WSU 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, 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

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

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) data sets 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

Task 0.1 - Informing Regional Supply Chains

University of Hawaii

Objective(s)

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 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.

Milestone(s)

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 the University of Hawaii. 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.

Milestone(s)

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 United States 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

Objective(s)
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, 5 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. Model results across all of the potential feedstocks have been used to identify land-use patterns that would match plants with environmental conditions toward maximizing productivity in support of AJF production.

Pongamia (*Millettia pinnata*) will be 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 will be evaluated from a number of trees growing on the island of Oahu. Fundamental measurements of chemical composition will be conducted and reported. Development of coproducts from the pods and oilseed cake will be explored.

Milestone(s)
- 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 *Biomass & Bioenergy* or similar journal.

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. 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. Pods have been evaluated as feedstock for a torrefaction process that can produce a coal substitute. A manuscript summarizing the results of this effort has been drafted. TerViva, a company pursuing pongamia commercialization, has provided material from orchards on Oahu. Permission has been requested to include data from analysis of their pongamia samples in the manuscript. Their reply will determine whether the manuscript is submitted with the current data set or expanded to include TerViva samples.

Publications

Written report

Fu, F., Summers, S., Morgan, T.J., Turn, S.Q., & Kusch, W. Fuel properties of *Millettia pinnata* seeds and pods grown in Hawaii. Draft manuscript.

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.

Awards

None.

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 published as a manuscript in *Biomass & Bioenergy* or similar journal.

Statewide working maps for each of the feedstock species will be used as the basis for discussions with targeted stakeholder groups including landowners and NRCS staff. Funding for planting and evaluating the more promising feedstock plants on University of Hawaii experiment station land will be pursued.

The current manuscript summarizing fuel properties of pongamia seed, pod, and oilseeds 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.

Milestone(s)

- 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.

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, International Civil Aviation Organization, and the Indonesian DGCA. Travel to Southeast Asia for other projects is anticipated in 2020, and meetings with the researchers at Indonesian institutions suggested by Dr. Aritenang will be pursued.

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.

Milestone(s)
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 University of Hawaii 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.

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
Estimates of suitable oilseed crop area in Hawaii will be completed based on the recently completed GIS mapping tools. Waste oil supply estimates were not completed in the 2019 reporting period but will be assessed in 2020. Information will be provided to the lead institution (WSU).

Task 3.2 - Hawaii Regional Project
University of Hawaii

Objective(s)
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 PVT 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. [A01 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 (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. [A01 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 is the first piece of information needed to provide a basis for the ensuing analysis. The feedstock received at the landfill is an inhomogeneous mixture of C&D. PVT Land Company is

currently also mining waste-in-place from the existing landfill and processing it to produce a feedstock stream. Both sources of waste (material arriving in trucks and mined waste-in-place) produce feedstock with potentially variable fuel properties. ASTM sampling methods for refuse-derived fuels have been reviewed and adapted to the current circumstances. PVT Land Company and the University of Hawaii signed an agreement allowing UH personnel to locate equipment at the landfill, to obtain samples from the feedstock processing line, and to preprocess the samples to a particle size suitable for further work in a laboratory environment.

PVT Land Company operates a sorting line to remove recyclable and noncombustible material from the incoming C&D waste stream. The result is a product that may serve as feedstock for SAF production. Over a period of eight months, 12 samples of C&D waste were collected from the outlet of the sorting line where material drops from a conveyor into a reclaim pit. Sample sizes ranged from 35 to 50 kg. Samples were sorted to quantitatively separate noncombustible from combustible materials. The combustible fraction was size reduced and subdivided to produce ~500-g subsamples for analysis. The following sets of analyses (each replicated three times) were conducted for all samples:

- Ultimate analysis: major element, C, H, N, S, and O
- Proximate analysis (volatile matter, fixed carbon, and ash)
- Energy content as higher heating value
- Minor elements spanning the range of atomic weights from fluorine (F) to uranium (U) using X-ray fluorescence (XRF)

Ash deformation temperatures in oxidizing and reducing environments and inductively coupled plasma (ICP) analysis for metals were performed on selected samples. ICP and XRF results were compared. A summary of the data has been completed.

The element ratios calculated from these analyses were used as inputs to the software tool FactSage to predict the thermochemical equilibrium composition under steam and oxygen gasification reactor conditions. Gasification is anticipated to be the main unit operation used to convert C&D waste to synthesis gas for the Fischer–Tropsch process or to hydrogen-rich gas that can be used as a petroleum refinery input or for hydrotreating SAF intermediate products. The equilibrium analysis results provide a starting point for TEA data needs discussion by providing estimates of contaminants present in the raw product gas from the gasification process. These estimates can be used to identify contaminant removal unit operations that improve the raw gas quality to meet synthesis gas or hydrogen end-use specifications.

Preliminary discussions were held with Manuel Garcia-Perez (WSU) on using the sample analysis data and thermochemical equilibrium analysis results to inform the TEA for this regional project.

Based on GHG analysis previously conducted by ASCENT collaborators (Mark Staples), schematics for conducting inventory analysis were drafted. These will be used to drive discussions on GHG analysis of C&D-based SAF systems with landfill operators moving forward.

Publications

N/A

Outreach Efforts

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

Results of the fuel sampling, analyses, and equilibrium analyses were presented at the October 2019 *Thermochemical Biomass 2019* conference, in Chicago, Illinois.

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

During the next period, activities will focus on completing subtasks identified in the Research Approach section above. The table below includes plans for each task moving forward.

Table 1. Summary of tasks for construction and demolition waste regional project

Task Identifier	Task Title	Activity Moving Forward
3.2.G1	Analysis of feedstock-conversion pathway efficiency, product slate (including coproducts), maturation	Based on the level of effort and results from 2019 activities, further physical work on this subtask will be only be conducted as specific needs are identified. Manuscripts will be prepared based on 2019 task activities and results.
3.2.G2	Scoping of techno-economic analysis (TEA) issues	Preliminary discussions on applying the TEA tools of ASCENT collaborators (Manuel Garcia-Perez) to the construction and demolition (C&D) data set will be continued to identify additional data requirements.
3.2.G3	Screening-level greenhouse gas (GHG) life-cycle assessment (LCA)	Data requests to support the inventory analysis of the C&D production operations will be sent to the host facility. Responses will be used to advance the GHG analysis of the project.
3.2.G4	Identification of supply chain participants/partners	The anchor supply chain participants have been identified, but potential participants needed to complete the supply chain will be identified. This activity will be continued.
3.2.G5	Develop appropriate stakeholder engagement plan	Based on the supply chain participants and the stakeholders identified in Task 3.2.G6, a stakeholder engagement plan will be drafted in cooperation with Season Hoard. This activity will be continued.
3.2.G6	Identify and engage stakeholders	Stakeholder lists from previous biomass energy planning efforts in Hawaii will be reviewed and revised as needed. Stakeholder engagement will ensue as Tasks 3.2.G1 to G4 results are developed. This activity will be continued.
3.2.G7	Acquire transportation network and other regional data needed for Freight and Fuel Transportation Optimization Tool (FTOT) and other modeling efforts	In consultation with ASCENT partners Kristin Lewis and Mike Wolcott, contacts from the State of Hawaii, Department of Transportation, Harbors Division, will be engaged to initiate data collection on pipeline use and interisland barge movement of fuels. This activity will be continued.
3.2.G8	Evaluate infrastructure availability	Based on information and data developed in Task 3.2.G7, availability of existing infrastructure and options to target infrastructure expansion will be developed. This activity will be continued.
3.2.G9	Evaluate feedstock availability	Refinement and ground-truthing of purpose-grown crops will be approached by identifying existing plantings of candidate crops in botanical gardens and experiment stations and assessing them in their environment. Opportunities to establish additional plantings will be identified. After reviewing solid waste management plans, meetings will be held with the Solid Waste Divisions in each county to explore options for waste diversion opportunities. This activity 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

Task 4.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:

- 4.G1.1 Conduct bench-scale testing of feedstocks to measure product yields, identify contaminants, and investigate element partitioning between product phases (e.g., characterization, conversion efficiencies, contaminants). [UH and WSU (Manuel Garcia-Perez)]
- 4.G1.2 Evaluate potential coproducts from bench-scale test products. [A01 team]
- 4.G1.3 Evaluate coproducts at every step of the supply chain. [A01 team]

Task 4.G2. Scoping of TEA issues

This task will determine the current TEA status of targeted AJF production technologies that use fiber feedstocks as production inputs based on the results of Task 4.G1.1. [UH, WSU (Manuel Garcia-Perez)]

Task 4.G3. Screening-level GHG LCA

This task will conduct preliminary GHG LCA on the proposed target supply chains and AJF conversion technologies based on the results of Task 4.G1.1. Subtasks are outlined below.

- 4.G3.1 With appropriate modifications, apply MIT waste-based GHG LCA tools in context of Hawaii application based on the results of Task 4.G1.1. [MIT (Mark Staples)]
- 4.G3.2 Link previously completed eucalyptus energy and GHG analysis to the edge of the plantation with available GHG LCA information for conversion technology options explored in Task 4.G1.1. [MIT (Mark Staples), UH]
- 4.G3.3 Identify and fill information/data gaps.

Task 4.G4. Identification of supply chain participants/partners

This task will identify and assess technology providers that could support regional project development based on the results of 4.G1.1.

- 4.G4.1 Create evaluation rubric for technology providers. [UH, WSU (Manuel Garcia-Perez)]
- 4.G4.2 Identify and assess technology providers that could support regional project development based on the results of 4.G1.1 using the evaluation rubric. [UH, WSU (Manuel Garcia-Perez)]
- 4.G4.3 Assess technology providers' capabilities to conduct process development unit-scale testing of feedstocks.
- 4.G4.4 Identify and fill information/data gaps. [A01 Team]

Task 4.G5. Continue stakeholder engagement

Subtasks:

- 4.G5.1 Engage stakeholders to identify impacts of information developed from the results of 4.G1.1. [UH, WSU (Season Hoard)]
- 4.G5.2 Identify and update engagement strategies based on updated information generated in 4.G1.1 and 4.G5.1. [UH, WSU (Season Hoard)]

Task 4.G6. Update infrastructure requirements

Update interisland shipping options and applicable regulation based on results of 4.G1.1. [UH, Volpe (Kristin Lewis), WSU (Mike Wolcott)]

Task 4.G7. Assess preliminary supply chain economics

4.G7.1 Assemble preliminary economic model to evaluate regional project. [UH, UTK, Purdue, WSU, PSU]
4.G7.2 Assess growth in job creation and economic benefits that will result from regional project. [UH, UTK, Purdue, WSU, PSU]
4.G7.3 Initiate effort to model risk associated with the regional project. [UH, PSU].
4.G7.4 Identify and fill information/data gaps. [UH, UTK, Purdue, WSU]

Task 4.G8. Refine regional proposal

This task will use the information collected in previous years and Tasks 4.G1 through 4.G7 to update the regional project proposal.

Milestone

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

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

During the next period, activities will begin on subtasks identified in the Task 4 Research Approach section above. As this task is largely being initiated, the primary focus will be planning and then conducting the bench-scale gasification tests outlined in subtask 4.G1.1. The initial focus will be to identify and compare companies/universities/national labs that have facilities that can conduct the bench-scale testing and the capacity to make the relevant contaminant measurements. Depending on the size of the unit identified in the selection process, sufficient feedstock will be acquired and prepared to conduct all tests from a single batch. Results of these tests will be used to inform later subtasks.