



# Hawai'i Natural Energy Institute Research Highlights

## Alternative Fuels; Energy Efficiency & Transportation Sustainable Aviation Fuel Production

**OBJECTIVE AND SIGNIFICANCE:** Commercial aviation in Hawai'i currently uses nearly 700 million gallons of jet fuel per year, all of it is derived from petroleum. The University of Hawai'i (UH) is a member of the Federal Aviation Administration's (FAA) Aviation Sustainability Center (ASCENT) team of U.S. universities conducting research on production of sustainable aviation fuels (SAF). UH's specific objective is to conduct research that supports development of supply chains for alternative, renewable, sustainable, jet fuel production in Hawai'i. Results may inform similar efforts in other tropical regions.

**BACKGROUND:** This project was initiated in October 2015 and is now continuing into its 6<sup>th</sup> year. Activities undertaken in support of SAF supply chain analysis include:

- Conducting literature review of tropical biomass feedstocks and data relevant to their behavior in conversion systems for SAF production;
- Engaging stakeholders to identify and prioritize general SAF supply chain barriers (e.g. access to capital, land availability, etc.);
- Developing geographic information system (GIS) based technical production estimates of SAF in Hawai'i;
- Developing fundamental property data on biomass resources; and
- Developing and evaluating regional supply chain scenarios for SAF production in Hawai'i.

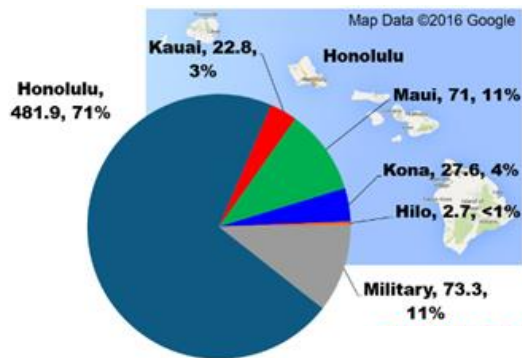


Figure 1. Commercial and military jet fuel use in 2015; Total use – 678.4M Gallons.

**PROJECT STATUS/RESULTS:** Literature reviews of both biomass feedstocks and their behavior in SAF conversion processes have been completed and published. Based on stakeholder input, barriers to SAF value chain development in Hawai'i have been

identified and reported. Technical estimates of land resources that can support agricultural and forestry-based production of SAF feedstocks have been completed using GIS analysis techniques. Samples from Honolulu's urban waste streams and candidate agricultural and forestry feedstocks have been collected and subjected to physicochemical property analyses to inform technology selection and design of SAF production facilities.

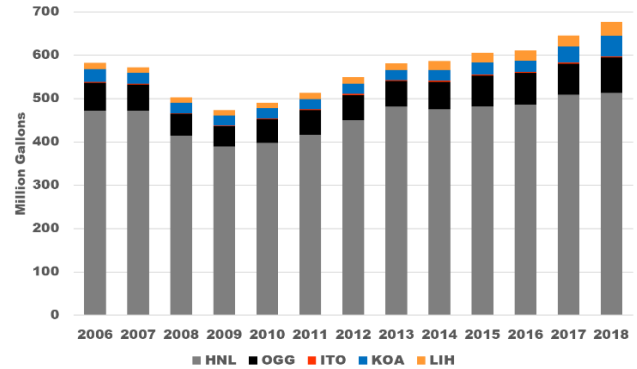


Figure 2. Commercial jet fuel consumption in Hawai'i.

### Fuel Properties of Construction and Demolition Waste Streams

A sampling and analysis campaign was undertaken to characterize fuel properties of construction and demolition waste (CDW) streams on O'ahu. As summarized in Figures 3 and 4, although the combustible fraction of the samples have elevated ash levels compared to clean biomass materials, their heating values were comparable, indicating the presence of higher energy density materials. As with most refuse derived fuels, the amount of ash in the fuel and its composition is of particular importance, since ash impacts energy facility operations, maintenance, and emissions.

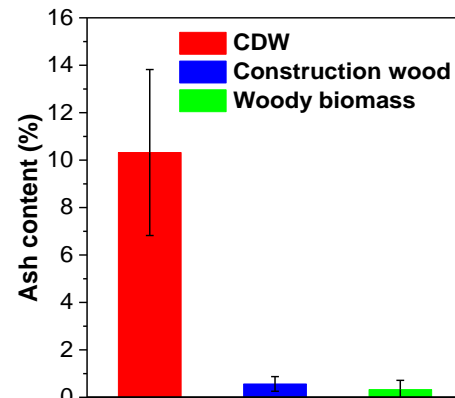


Figure 3. Ash content of the combustible fraction of CDW compared to construction wood and woody biomass.

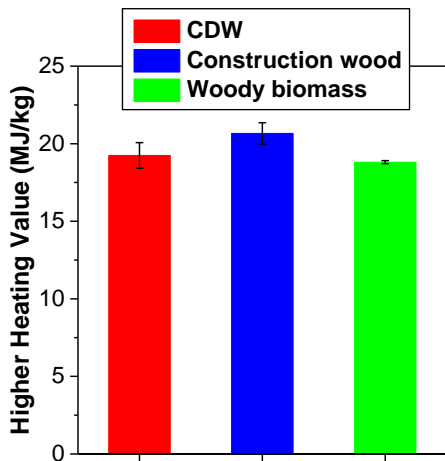


Figure 4. Heating value of the combustible fraction of CDW compared to construction wood and woody biomass.

Future work with ASCENT partners includes:

- Analysis of feedstock-conversion pathway efficiency, product slate (including co-products), maturation;
- Scoping of techno-economic analysis (TEA) issues;
- Screening level greenhouse gas (GHG) life cycle assessment (LCA);
- Identification of supply chain participants/partners;
- Continued stakeholder engagement;
- Acquiring transportation network and other regional data;
- Evaluating infrastructure availability; and
- Evaluating feedstock availability.

### Exploration of Biomass Feedstocks for Hawai‘i

Figure 5 shows the breakdown of land use of the nearly 2 million acres of agricultural lands in Hawai‘i. With the shuttering of much of the cane sugar and the pineapple industries, this total has dropped further. Bringing agricultural lands back into production can support diversification of the economy and support rural development. Biomass feedstocks for sustainable aviation fuel production are options that can contribute to this revitalization. A review of possible biomass resources and conversion technologies was performed for Hawai‘i and the tropics. This review can be found at <https://dx.doi.org/10.1021/acs.energyfuels.8b03001>.

The Eco Crop model was used to complete an assessment of plant production requirements to agro-ecological attributes of agricultural lands in the State. The analysis focused on sites capable of rain fed production to avoid using irrigated lands that could support food production. Oil seed crops, woody crops, and herbaceous crops were all considered; an example is shown for a eucalyptus species on the following page (Figure 6). Ongoing work will identify underutilized agricultural areas and supply chain components necessary to develop SAF production systems.

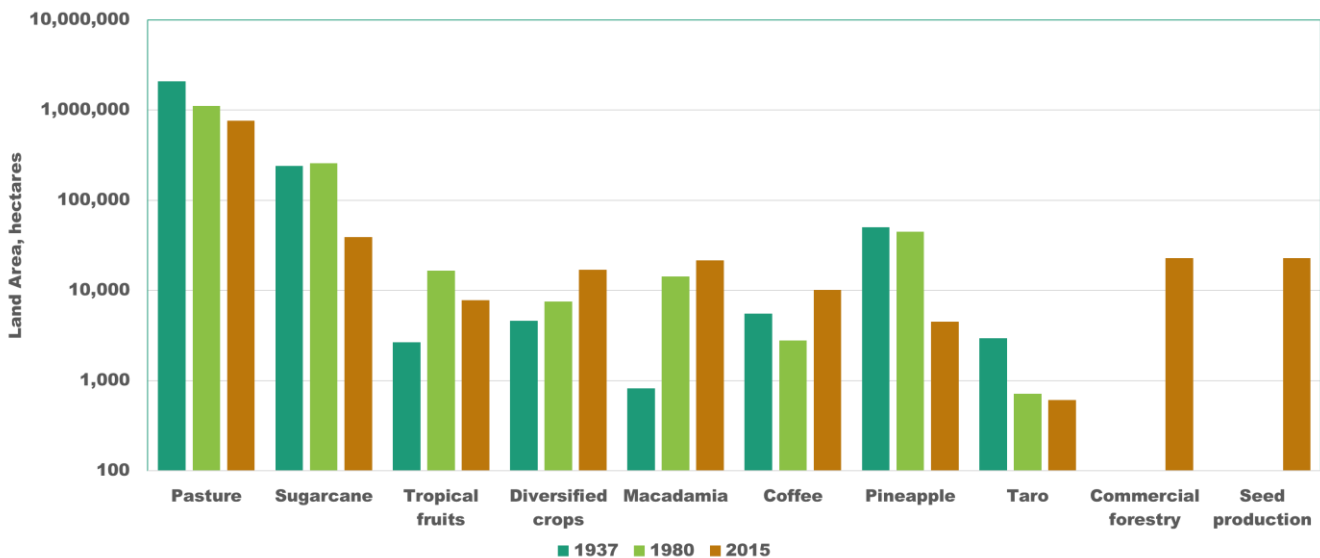


Figure 5. Breakdown of agricultural land use in Hawai‘i; in 2015, approximately 100,000 acres were harvested.

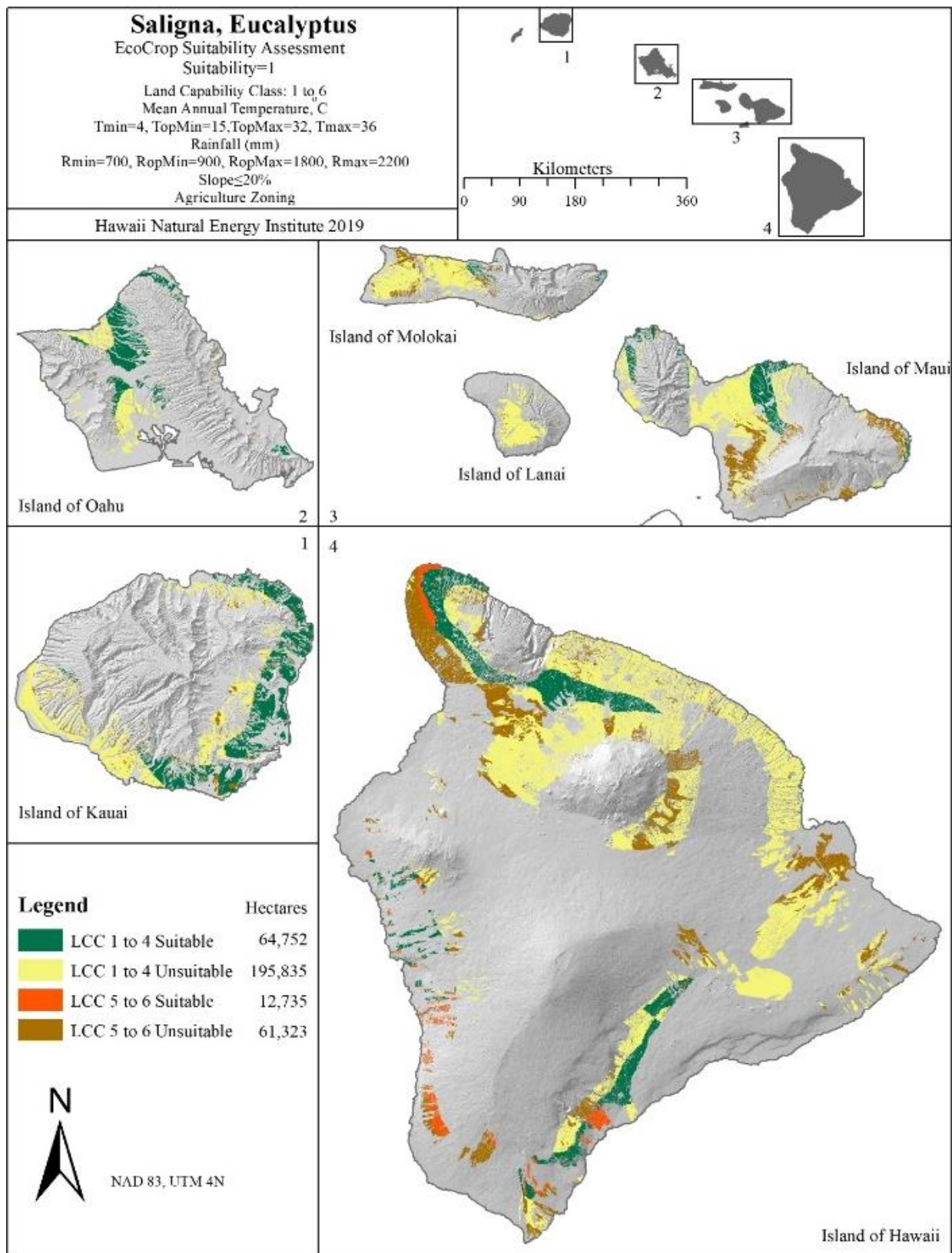


Figure 6. EcoCrop assessment of Saligna, Eucalyptus.



## Evaluation of Pongamia

Of the sustainable aviation fuels currently approved by ASTM and the FAA, those based on the use of oils derived from plants and animals have the highest SAF yield and the lowest production costs. Pongamia (*Milletia pinnata*) is a tree, native to the tropics, that bears an oil seed and has plantings established on O‘ahu.

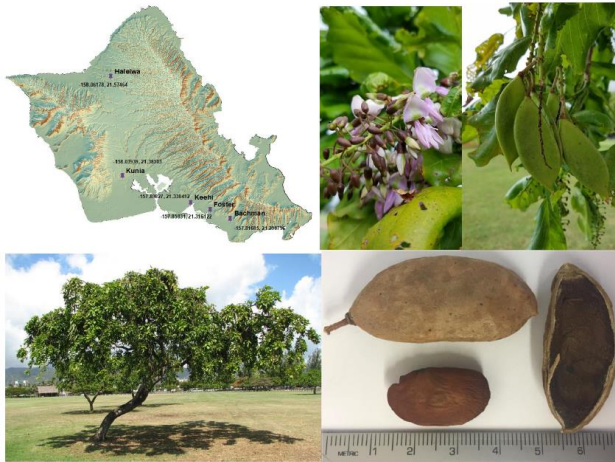


Figure 7. Locations and images of Pongamia.

### Invasiveness Assessment

Under this project, an observational field assessment of trees in seven locations on O‘ahu was conducted by Professor Curtis Daehler (UH Dept. of Botany) to look for direct evidence of pongamia escaping from plantings and becoming an invasive weed. 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 O‘ahu. Because of its limited seed dispersal and low rates of seedling establishment beyond the canopy, 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 O‘ahu,

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.

### Fuel properties

Pongamia is a potential resource for renewable fuels in general and sustainable aviation fuel in particular. This project characterized physicochemical properties of reproductive material (seeds and pods) from pongamia trees grown in different environments at five locations on O‘ahu. Proximate and ultimate analyses, heating value, and elemental composition of the seeds, pods, and de-oiled seed cake were determined. The oil content of the seeds and the properties of the oil were determined using American Society for Testing and Materials (ASTM) and American Oil Chemist’s Society (AOCS) methods. The seed oil content ranged from 19 to 33 % wt. across the trees and locations. Oleic (C18:1) was the fatty acid present in greatest abundance (47 to 60 % wt) and unsaturated fatty acids accounted for 77 to 83 % wt of the oil. Pongamia oil was found to have similar characteristics as other plant seed oils (canola and jatropha) and would be expected to be well suited for hydro-processed production of sustainable aviation fuel.

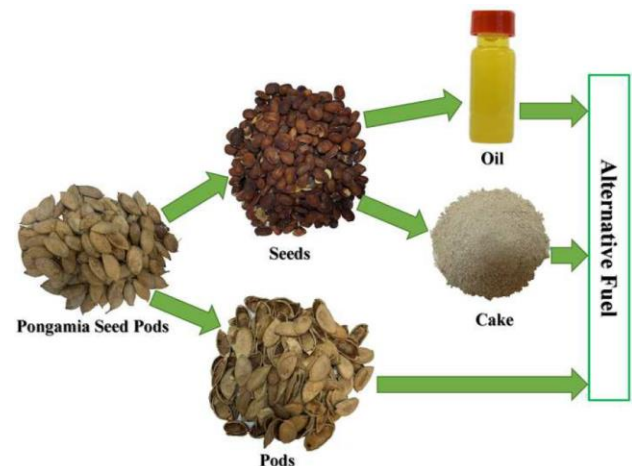


Figure 8. Pathways from Pongamia seed pods to fuel.

### Coproduct Development

Additional study was devoted to developing coproducts from pongamia pods. Torrefaction is a thermochemical treatment method conducted at

200-300°C and atmospheric pressure in the absence of oxygen. The main objective is to reduce the oxygen content of the torrefied product compared to the parent biomass. In general, torrefaction of woody biomass materials results in mass and energy yields of 70 % and 90 %, respectively. Consequently, energy densification (mass basis) improvement by a factor of 1.3 is typical. The mass fraction of the parent biomass volatilized during torrefaction (~30%) is of low energy content, only ~10% of the total energy. Torrefied materials generally possess higher energy density, better grindability, better hydrophobicity and biological stability, which can all contribute to reducing the overall conversion cost. In addition, the torrefied biomass should have lower H/C and O/C ratio compared to the raw biomass.

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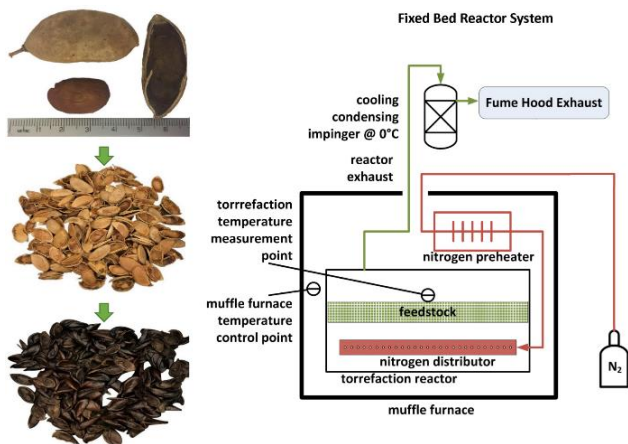


Figure 9. Laboratory scale torrefaction test bed.

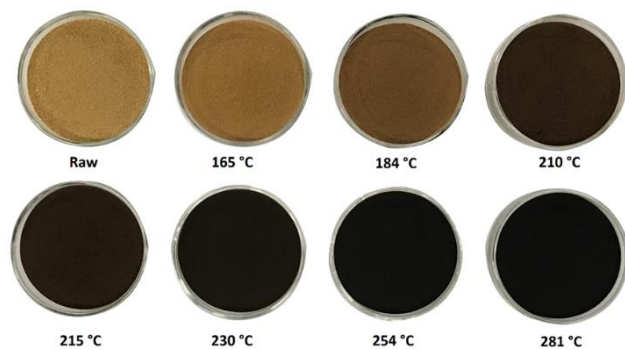


Figure 10. Torrefied pongamia pods prepared at varied treatment temperatures.