Alternative Jet Fuel Development

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Opinions, findings, conclusions and recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of ASCENT sponsor organizations.
Overview

• International Civilian Aviation Organization’s (ICAO) Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)
• U.S. Federal Alternative Jet Fuels Research and Development Strategy
• Federal Aviation Administration’s Aviation Sustainability Center (ASCENT)
• University of Hawaii activities under ASCENT
Overview

- **International Civilian Aviation Organization’s (ICAO) Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)**
- U.S. Federal Alternative Jet Fuels Research and Development Strategy
- Federal Aviation Administration’s Aviation Sustainability Center (ASCENT)
- University of Hawaii activities under ASCENT
International Civilian Aviation Organization

• UN specialized agency to manage the administration and governance of the Convention on International Civil Aviation (1944)

• Reach consensus on international civil aviation Standards and Recommended Practices (SARPs)

• Ensure that local civil aviation operations and regulations conform to global norms

• Currently 100,000 flights per day around the globe
Aircraft CO₂ Emissions from International Aviation, 2005 to 2050

Airports supplied with AJF

• Los Angeles International (LAX)
• Stockholm Arlanda Airport (ARN)
• Oslo Gardermoen (OSL)
• Bergen Flesland (BRO)
• ICAO Alternative Jet Fueled Planes
Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)

- Global market based management scheme developed by the International Civilian Aviation Organization (ICAO) to address any annual increase in total CO₂ emissions from international civil aviation above 2020 levels
- Voluntary participation from 2021 through 2026 (pilot and first phases)
- Mandatory participation by member States beginning in 2027
- Exemptions for SIDS, LDCs, and LLDCs
- Exemptions for States with a share of international aviation below 0.5 percent in 2018 and lower 10% ranking among States (based on revenue tonne kilometer (RTK), weight of sold capacity of passengers and cargo multiplied by distance flown)

https://www.icao.int/environmental-protection/Pages/A39_CORSIA_FAQ2.aspx
## 2016 International Scheduled RTK\(^{(1)}\)

<table>
<thead>
<tr>
<th>State</th>
<th>International Scheduled RTK (million) (2016)</th>
<th>Ranking by State</th>
<th>Share by State (%)</th>
<th>Cumulative Share (%)</th>
<th>SIDS(^{(3)})</th>
<th>LDC(^{(4)})</th>
<th>LLDC(^{(5)})</th>
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</table>

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\(^{(1)}\) Source: ICAO Sustainability Pages

\(^{(2)}\) Note: CHINA (2)

\(^{(3)}\) SIDS: Small Island Developing States

\(^{(4)}\) LDC: Least Developed Countries

\(^{(5)}\) LLDC: Least Landlocked Developing Countries

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[Link to ICAO Sustainability Page](https://www.icao.int/sustainability/Pages/RTK_ranking.aspx)
<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>Share by State (%)</th>
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<tr>
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<td>6</td>
<td>R of Korea</td>
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<td>8</td>
<td>Singapore*</td>
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<td>11</td>
<td>Japan</td>
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<td>1.6</td>
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<td>18</td>
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<tr>
<td>34</td>
<td>Indonesia</td>
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</table>

*Indicates APEC states.
Overview

- International Civilian Aviation Organization’s (ICAO) Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)

- **U.S. Federal Alternative Jet Fuels Research and Development Strategy**

- Federal Aviation Administration’s Aviation Sustainability Center (ASCENT)

- University of Hawaii activities under ASCENT
Coordinated U.S. Approach to Alternative Jet Fuel

Federal Alternative Jet Fuels Research and Development Strategy

Product of the Aeronautics Science and Technology Subcommittee Committee on Technology of the National Science and Technology Council

June 2016


• Enhance energy security
• Expand domestic energy sources
• Facilitate a diverse, secure, and reliable fuel supply
• Contribute to price and supply stability
• Reduce emissions that affect air quality and global climate
• Generate economic and rural development
• Promote social welfare
Feedstock Development, Production and Logistics

- Increase crop yields and water and nutrient use efficiency
- Improve disease and pest resistance
- Improve feedstock conversion characteristics
- Develop sustainable and resilient feedstock production systems
- Improve harvesting, collection, storage, densification, pretreatment and transport of physical biomass to the conversion facility
- Improve collection, storage, densification, pretreatment and transport of MSW to the conversion facility

*Federal alternative jet fuels research and development strategy, 2016. Alternative Jet Fuel Interagency Working Group, National Science and Technology Council*  
Fuel Conversion and Scale-Up

• Enable discovery, development, enhancement and scale-up of conversion processes with improved yield and efficiency and reduced energy requirements leading to cost-competitive AJF production

• Develop conversion technologies that can produce AJF from multiple feedstocks and in a distributed manner

*Federal alternative jet fuels research and development strategy, 2016. Alternative Jet Fuel Interagency Working Group, National Science and Technology Council*  
Fuel Testing and Evaluation

• Facilitate civil and military approval of additional AJF pathways by advancing certification and qualification processes

• Improve scientific understanding of how AJF composition impacts gas turbine combustion emissions and operability

Federal alternative jet fuels research and development strategy, 2016. Alternative Jet Fuel Interagency Working Group, National Science and Technology Council
Integrated Challenges

• Advance understanding of and improve environmental sustainability of AJF production and use

• Develop and validate comprehensive systems model to support AJF deployment

• Promote communication and scientific and technical R&D best practices for the national enterprise

*Federal alternative jet fuels research and development strategy, 2016. Alternative Jet Fuel Interagency Working Group, National Science and Technology Council*  
Non-Technical Challenges

- Petroleum price volatility
- Limitations in production infrastructure
- Regulatory, legislative, and policy barriers
- Access to financing
- Investment risk and uncertainty
- Workforce development

*Federal alternative jet fuels research and development strategy, 2016. Alternative Jet Fuel Interagency Working Group, National Science and Technology Council*
*www.caafi.org/files/Federal_Alternative_Jet_Fuels_Research_and_Development_Strategy.pdf*
# US Agency Specific Contributions

<table>
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*Note: X indicates involvement in the respective category.*
The Federal Aviation Administration is a modal organization within the Department of Transportation
Overview

- International Civilian Aviation Organization’s (ICAO) Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)
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- University of Hawaii activities under ASCENT
Federal Aviation Administration  
Office of Environment and Energy

• Vision: Environmental protection that allows sustained aviation growth.

• Environmental and energy goals
  – Noise: Reduce the number of people exposed to significant noise around U.S. airports
  – Air Quality: Reduce significant air quality impacts attributable to aviation
  – Climate: Achieve carbon neutral growth by 2020 relative to a 2005 baseline
  – Energy: Improve National Airspace System energy efficiency by at least two percent per year, and develop and deploy alternative jet fuels for commercial aviation
Five Pillar Approach

• Alternative Fuels: Sustainable Alternative Aviation Fuels
  – Reduce environmental impacts, enhance energy security, and provide economic benefits
  – Collaborate with stakeholders through the Commercial Aviation Alternative Fuels Initiative (CAAFI)
  – Test alternative jet fuels to ensure they are safe for use through ASCENT and CLEEN (Continuous Lower Energy, Emissions and Noise program)
  – Analyze their potential for reducing the environmental impacts of aviation

• Science and Tools: improved scientific knowledge and integrated modeling

• Technology: new aircraft technologies

• Operations: air traffic management modernization and operational improvement

• Policy: policies, environmental standards, and market based measures
ASCENT Focus Areas

Alternative Jet Fuels

Feedstock Development, Processing and Conversion
Regional Supply and Refining Infrastructure
Environmental Benefits Analysis
Aircraft Component Deterioration and Wear
Fuel Performance Testing
ASCENT Team

**Lead Universities:**
Washington State University (WSU)
Massachusetts Institute of Technology (MIT)

**Core Universities:**
Boston University (BU)
Georgia Institute of Technology (Ga Tech)
Missouri University of Science and Technology (MS&T)
Oregon State University (OSU)
Pennsylvania State University (PSU)
Purdue University (PU)
Stanford University (SU)
University of Dayton (UD)
University of Hawaii (UH)
University of Illinois at Urbana-Champaign (UIUC)
University of North Carolina at Chapel Hill (UNC)
University of Pennsylvania (UPenn)
University of Tennessee (UT)
University of Washington (UW)

Denotes Alternative Jet Fuel Participants

**Advisory Committee - 58 organizations:**
5 airports
4 airlines
7 NGO/advocacy
9 aviation manufacturers
11 feedstock/fuel manufacturers
22 R&D, service to aviation sector
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Alternative Jet Fuel Supply Chain, Tropical Region Analysis -- Motivation

- The tropics account for 36% of the world’s land mass
- Tropics are home to unique biomass materials, production practices/systems, and temporal availabilities

Adapted from https://commons.wikimedia.org/wiki/File:World_map_indicating_tropics_and_subtropics.png
https://creativecommons.org/licenses/by-sa/3.0/deed.en
Jet Fuel Use in Hawaii, 2015
Commercial Airports and Military (million gallons)

<table>
<thead>
<tr>
<th>Airport</th>
<th>Use (M Gallons)</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Honolulu</td>
<td>481.9</td>
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<tr>
<td>Kauai</td>
<td>22.8</td>
<td>3%</td>
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<tr>
<td>Maui</td>
<td>71</td>
<td>11%</td>
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<tr>
<td>Kona</td>
<td>27.6</td>
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<tr>
<td>Hilo</td>
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<tr>
<td>Military</td>
<td>73.3</td>
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</table>

Total Use in 2015: 678.4 M Gallons
University of Hawaii Objectives

- Conduct literature review of tropical biomass feedstocks and data relevant to their behavior in conversion systems for AJF production
- Engage stakeholders to identify and prioritize general AJF supply chain barriers (e.g. access to capital, land availability, etc.)
- Develop geographic information system (GIS) based technical production estimates of AJF in Hawaii
- Develop fundamental property data on biomass resources
- Develop and evaluate regional supply chain scenarios for AFJ production in Hawaii
Barriers to AJF Production

• Stakeholder meeting – barriers to AJF production
  – Facilitated stakeholder meeting with representatives from agricultural landowners, biofuel companies, utilities, military, state government, refiners, fuel distributors, etc.

• Barriers identified and prioritized
  – Economic constraints (e.g. high costs of entry for production factors)
  – Issues associated with access to capital (high initial risk and uncertain ROI)
  – Insufficient government support (financial & policy incentives)
  – Cost, availability, and competition for water *
  – AJF production technologies are emerging, need commercially demonstrated technologies
  – Insufficient or inaccessibility of infrastructure (harbors, roads, fuel distribution, irrigation) to support production chain *
Approach – Estimates of AJF production potential in Hawaii

• GIS based approach
  – Land Capability Classification system developed by USDA/NRCS in 1972 focused on soil type and climatic classification
    • Strengths – extensive soil data, GIS ready
    • Limitations – developed with mindset of agriculture at the time and indexed to sugarcane and pineapple production
  – Water availability – rainfall and irrigation
  – Slope
  – Land use zoning
  – Contiguous area
  – Distance from industrial zoning

• Crop information from literature review
  – Soil
  – Water
  – Climate
  – Mechanization limitations (slope, soil moisture, etc.)
  – Contiguous cultivation area (scale requirements)
  – Invasiveness
Kauai
552 sq mi ≈ 24mi x 24 mi
5,243 ft peak elevation
Slope

Legend

Slope (%)
- 15.01 - 20.00
- 10.01 - 15.00
- 7.51 - 10.00
- 5.01 - 7.50
- 4.01 - 5.00
- 3.01 - 4.00
- 2.01 - 3.00
- 1.01 - 2.00
- 0.01 - 1.00

Major Roads

Alternative Jet Fuel Production Siting

Slope

<= 20%

Hawaii Natural Energy Institute 2017

NAD 83, UTM Zone 4N
Rainfed Areas
~32,000 acres
Rainfed and Irrigation
~52,000 acres
Develop fundamental property data for tropical biomass resources

- Identified from stakeholder meetings and CAAFI/programmatic interest

- Pongamia (*Millettia pinnata*) – initial focus
  - Oil seed tree with current productivity estimated ~5 Mg/ha/year
  - Production potential in Hawaii and Florida
  - *Terviva* – start up company focused on providing pongamia germplasm for agricultural producers
  - 100 ha planted on Oahu and 100 ha scheduled for Maui
  - Property data to focus on characterization of pongamia oil, oil seed press cake, seed pod material
  - Revisit invasiveness based on plants already established in Hawaii
  - Longer term goal -- energy input/output analysis of pongamia production system
Value Chain for AJF Production

**Feedstock Production**

**Feedstock Logistics**

**Conversion**

**Distribution**

**End Use**

Agriculture ---- Industry ---- Investors ---- Government ---- Community
PVT Feedstock Processing Facility
Possible Locations of Value Chain Participants

PVT Land Company

~10 miles between PVT and CIP

Island Energy Refinery

Campbell Industrial Park

Kalaeloa Airport

Par Hawaii Refinery

Joint Base Pearl Harbor-Hickam

Daniel K. Inouye Airport
PVT Feedstock Characterization

• Characterization of feedstock properties needed to inform conversion process design
  – Ultimate analysis for major elements: C, H, O, N, S
  – Proximate analysis: volatile matter, fixed carbon and ash
  – Major ash species: K, Cl, Na, P, Mg, Si, Fe, Ti, Al, and Ca
  – Minor ash species: Mn, Fe, Cu, Zn, Rb, and Sr
  – Moisture content
  – Energy content or heating value

• Characterization of feedstock properties needed for logistics: particle size of materials, bulk densities, etc.

• Time series data to assess variability in supply
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Questions?