Alternative Jet Fuels

Update to FAA REDAC E&E Subcommittee

To: E&E REDAC Subcommittee

By: Nate Brown & Dan Williams

Date: September 11, 2018

FAA's AJF R&D Program

Working to Achieve AJF Production

- **Coordination**
  - CAAFI
- **Testing**
  - ASTM Status
- **Analysis**
  - Supply chain analysis and tools
  - ICAO CORSIA

Commercial Aviation Alternative Fuels Initiative

A public – private coalition for commercial aviation to engage the emerging alternative fuels industry and government

- **Communicate the Value Proposition of SAJF**
- **Enhance the Fuel Qualification Approach**
- **Implement Frameworks & Share Best Practices**
- **Develop the U.S. SAJF Supply by Aligning Efforts to Enable Commercial Deployment**

CAAFI Administrative Leadership Team:

- Steve Csonka, CAAFI Executive Director
- Chris Tindal, CAAFI Assistant Director
- Kristin Lewis, Volpe
- Peter Herzig, Volpe
- Nate Brown, FAA
- Rich Altman, CAAFI Executive Director Emeritus

CAAFI Team Leads:

- C/Q: M. Rumizen, C/Q
- Sustainability: J. Hileman & N. Young,
- Business: J. Heimlich
- R&D : M. Lakeman, S Kramer, & G. Andac

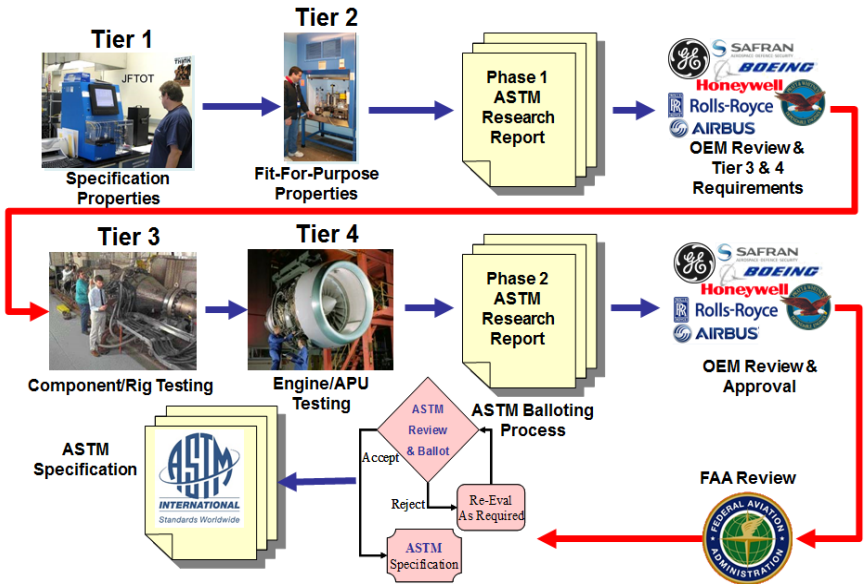
CAAFI Steering Group: AIA, ACI-NA, A4A, GE, Boeing, P&W, ASCENT, DOE, USDA

Testing: Alternative Jet Fuel Approvals

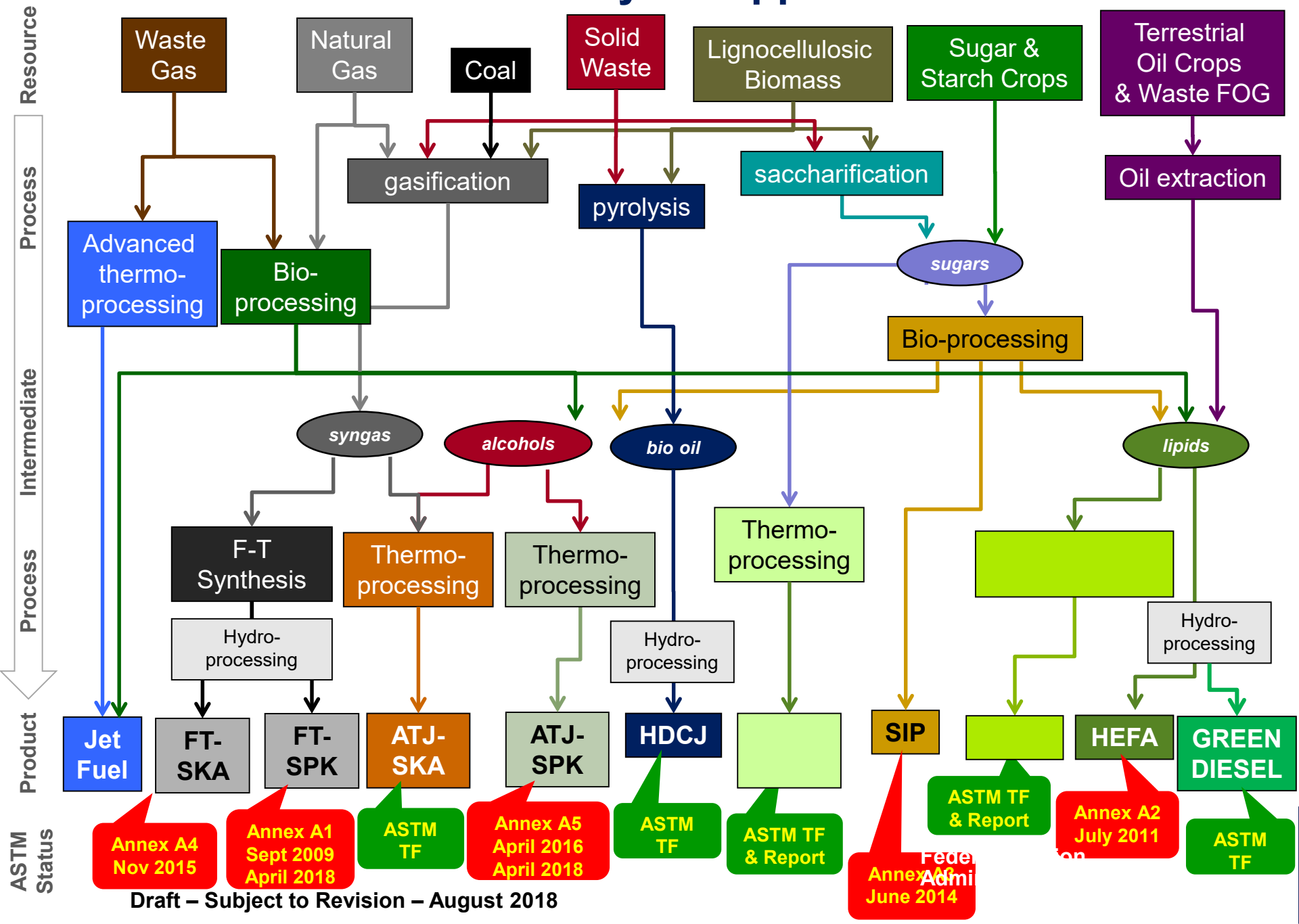
ASTM International manages jet fuel specification

FAA and Defense support evaluation of alternative jet fuels

- **Certification & qualification testing; data gathering & review; new test method development**
- **Since 2009, five fuels included in the AJF specification (ASTM D7566)**
  - **Two expansions**
- **Lipids, sugars and biomass feedstocks**
- **Six pathways under evaluation; more anticipated**



Alternative Jet Fuel Pathways & Approval Status



Draft – Subject to Revision – August 2018

Alternative Jet Fuels Evaluation Status

Exploratory Discussions

Global BioEnergies?

POET?

Vertimas?

G

Initial Batch of Fuel delivered to D4054 Clearinghouse in January for testing. Final composition will NOT include aromatics

Also developing NJFCP/D4054 Joint Test Case plan using FAA ASCENT funding

ARA working on Phase 2 Research Report. Best case scenario now is subcommittee ballot early 2019 with Annex issued June 2019

Virent SK (Inactive)

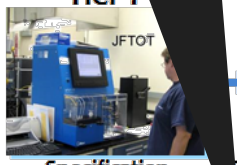
Virent SAK

ARA CHJ

NOTE: FOG Co-processing added to D1655-18a Annex A1 on April 1, 2018

OEM comments on Phase 1 rpt submitted to Virent on April 13. Virent working with UDRI to respond to comments and to initiate Tier 3 testing

Tier 1



Specification Properties

Tier 2

Fit-For-Purpose Properties

Phase 1 ASTM Research Report

SAFRAN GE BOEING Honeywell Rolls-Royce AIRBUS

OEM Review & Tier 3 & 4 Requirements

Tier 3

Component/Rig Testing

Tier 4

Engine/APU Testing

Phase 2 ASTM Research Report

SAFRAN GE BOEING Honeywell Rolls-Royce AIRBUS

OEM Review & Approval

Shell IH²

IHI Bb-Oil HEFA

ATJ-SKA (Byogy, Swed Biofuels)

HDCJ (KiOR) (Inactive)

Awaiting test fuel delivery to UDRI, hopefully by end of Oct?

HFP-HEFA (Green Diesel)

FAA Review

ASTM Review & Ballot

Accept

Reject

Re-Eval As Required

ASTM Specification

ASTM Balloting Process

ASTM Specification

Annex A1 FT-SPK

Annex A2 HEFA

Annex A3 SIP

Annex A4 FT-SKA

Annex A5 ATJ SPK (Isobutanol)

ATJ (Ethanol) added to Annex A5 April 1

OEM Step 3 review comments in, awaiting responses from Boeing. Boeing working with Neste to investigate feedstock contamination issues

Mark Rumizen
August 22, 2018

Alternative Jet Fuel Supply Chain Analysis

Understand benefits, costs and potential supply

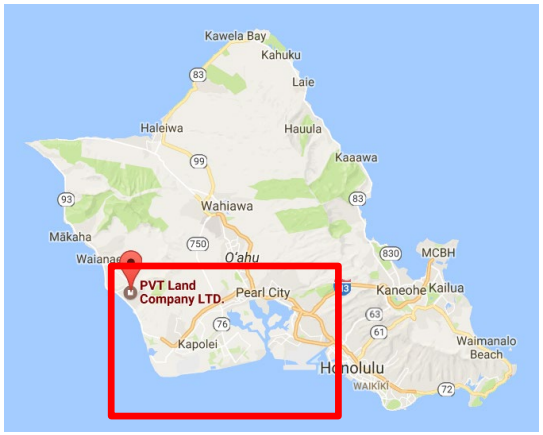
- Considering the entire supply chain via multiple aspects:
  - Feedstock production
  - Techno-economics of pathways
  - Existing infrastructure
  - Community assets
  - Transportation routes and capacity
  - Economic Impacts
- Three regional studies:
  - Inland Pacific NW
  - Hawaii
  - Southeast/Tennessee
- Developing open source tools for evaluation of supply chains
  - TEA; CAAM; FTOT

Research Team:

- ASCENT: Washington State U., MIT, Purdue, U. Tennessee, U. of Hawaii, Penn State U.
- U.S. DOT Volpe Transportation Center, DOE Argonne National Lab & National Renewable Energy Lab (NREL)

University of Hawaii Supply Chain Study

Possible Locations of Value Chain Participants



PVT Land Company

~10 miles between PVT and CIP

Map data ©2017 Google

PVT Land Company LTD.

Akupu

Reynolds Recycling Nanakuli Village...

Pearl City

Waimalu

Keaīwa Heiau State Recreation Area

Farrington Hwy

Pearlridge Center

Aiea

Don's Truck Rental

Halawa

Pearl Harbor

Joint Base Pearl Harbor-Hickam

Makakilo

Honokai Hale

Ewa Villages

Wet'n'Wild Hawaii

Kapolei Public Library

Veolia Water North America

HICKAM FIELD

Honolulu International Airport

Ewa Beach

Island Energy Refinery

Kalaeloa Airport

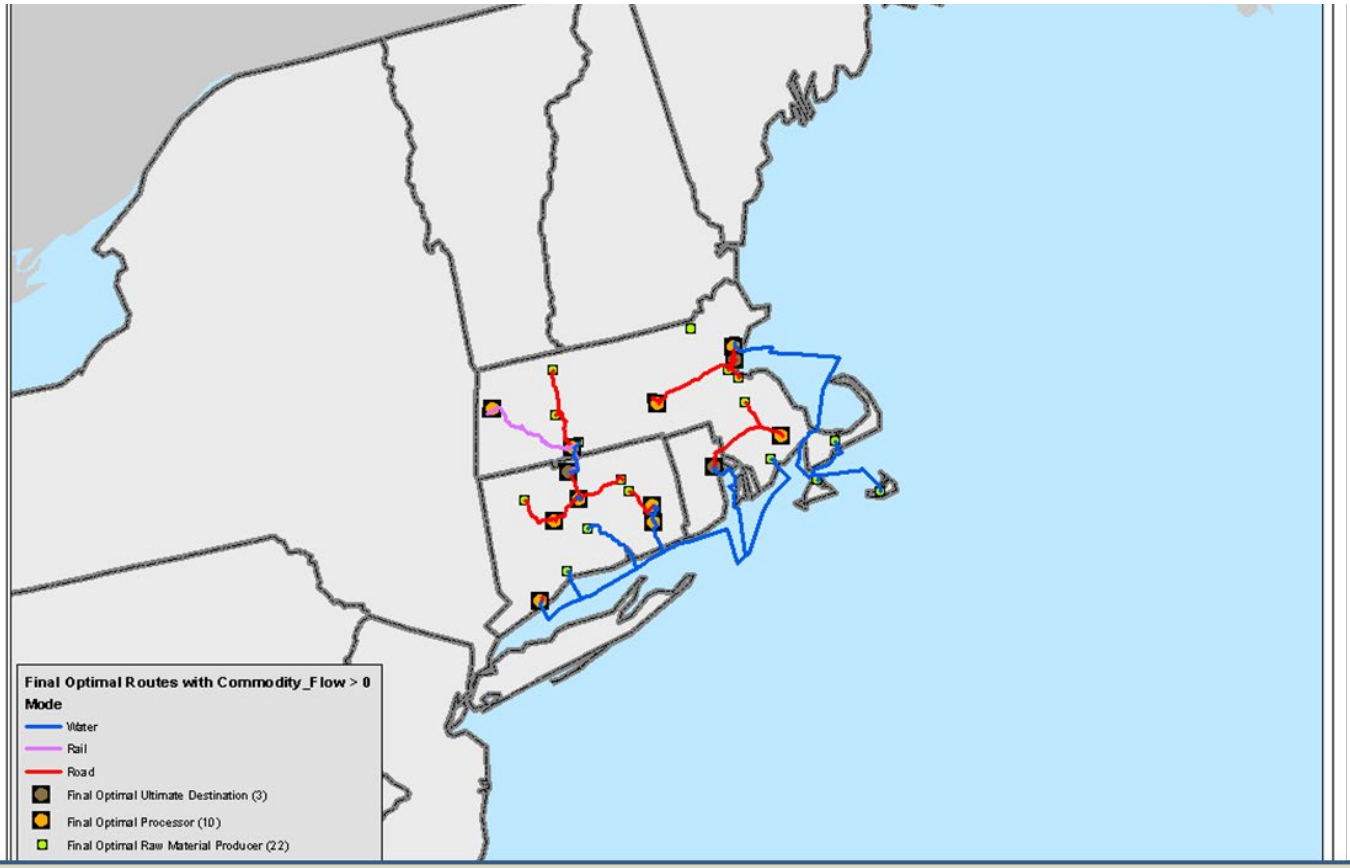
Kalaeloa Airport

Daniel K. Inouye Airport

Campbell Industrial Park

Par Hawaii Refinery

Freight and Fuels Transportation Optimization Tool (FTOT)



Origins + production

Destinations + demand

Transport cost (movement, transload)

Processing data (capex, min. facility size, efficiency, product slate)

Conversion facility location (optional)

Other weightings or penalties

FTOT

Least cost transport scenario

Fuel burned / CO2 emissions

Optimal conversion facility locations based on transport cost

Distance

VMT

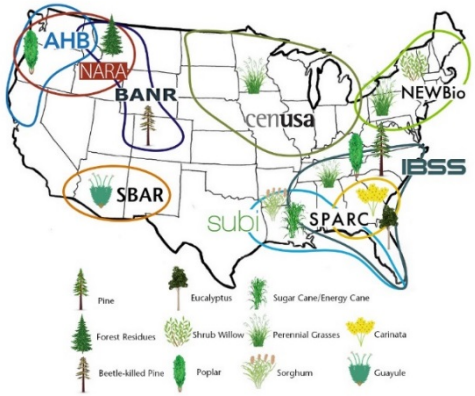
Vehicle loads (truck, rail car, etc.)

Farm to Fly 2.0 (F2F2) Agreement

- **Resolved to "enable commercially viable, sustainable bio-Jet Fuel supply chains in the U.S."**
- **Focus government & aviation industry efforts towards U.S. state and regional fuel supply opportunities**
- **Our activities are complementary and coordinated**
  - CAAFI & ASCENT (FAA)
  - NIFA AFRI CAPs (USDA)
  - DPA and IBR programs (DOE)

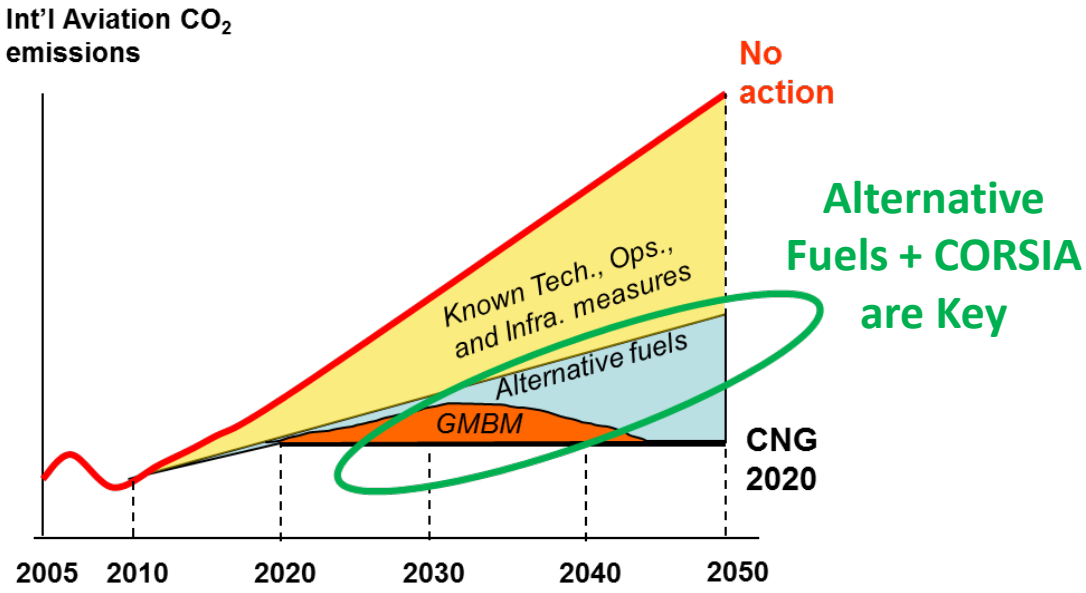
FAA funding for R&D and coordination

DOE funding for Jet fuel process development

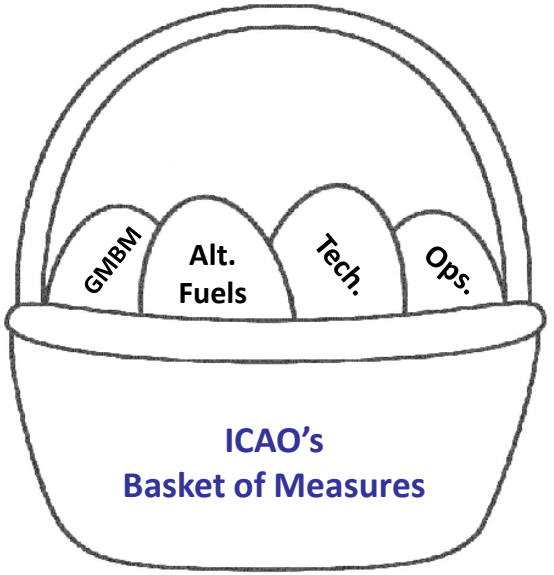


USDA NIFA AFRI Coordinated Agriculture Projects (CAPs)

CORSIA and the Basket of Measures



Alternative Fuels + CORSIA are Key



CORSIA is a complement to the other elements of ICAO's "basket of measures" to reduce the CO_2 emissions from international aviation.

Alternative Fuels and CORSIA

CORSIA Eligible Fuels provide a secondary means to comply with CORSIA

1. Offsetting
2. Claiming Emissions Reductions from CEF

$$ER_y = FCF * \left[\sum_f MS_{f,y} * \left(1 - \frac{LS_f}{LC} \right) \right]$$

Life cycle emissions value for a CORSIA eligible fuel

GMBM work added in 2014

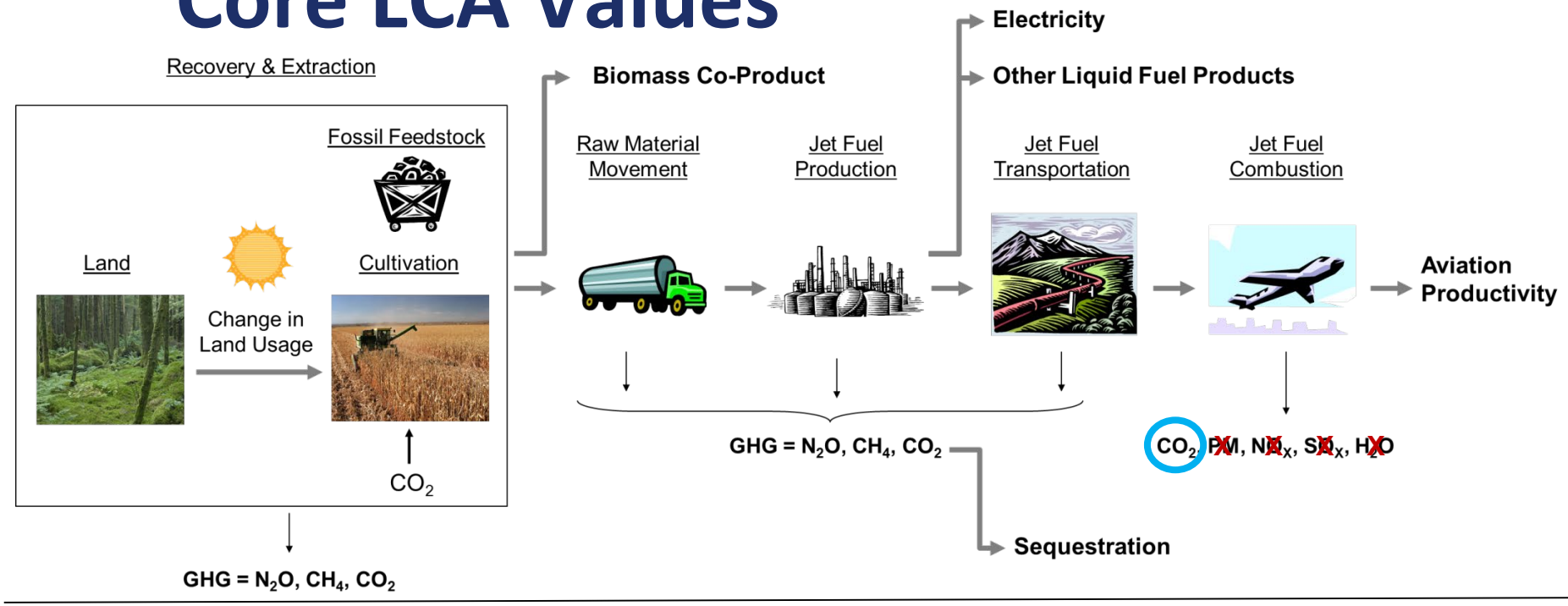
- CAEP directed AFTF to develop a methodology for assessing AJF GHG emissions so that the benefits of AJF could be incorporated into a GMBM

Current Status: Three sub-tasks to this work

- Development of Core LCA Values
- Calculation of Induced Land Use Change Values
- Defining Sustainability Criteria for AJF

Used to create "default values"

Core LCA Values



Stage #1:
Production at source (feedstock cultivation)
Stage #2:
Conditioning at source (harvest, collection, recovery)
Stage #3:
Feedstock processing and extraction
Stage #4:
Feedstock transportation to processing and fuel production facilities

Stage #5:
Feedstock-to-fuel conversion process
Stage #6:
Fuel transportation and distribution to the blend point
Stage #7:
Fuel combustion in aircraft engine

CORSIA Core LCA Calculations being done by ASCENT Project 1 (MIT) and Argonne National Labs

Induced Land Use Change Values

As part of the methodology for CORSIA Eligible Fuels, ICAO agreed to include ILUC values for fuels that are not derived from wastes, residues, or by-products

Estimate the global land use change using an economic equilibrium model

- CARD–FAPRI (FASOM, US EPA), GTAP-BIO (CARB)
- MIRAGE-BioF (EU), GLOBIOM (EU)

Calculate emissions using an emission factor/accounting model

- plant biomass carbon
- soil carbon
- forgone carbon sequestration

There are important disparities among models/estimations

- Modelling theoretical background
- Baseline assumptions, shock size, simulation approach
- Emissions calculation (amortization periods, etc.).

CORSIA ILUC calcs being done by ASCENT P1 (Purdue)

Putting It All Together

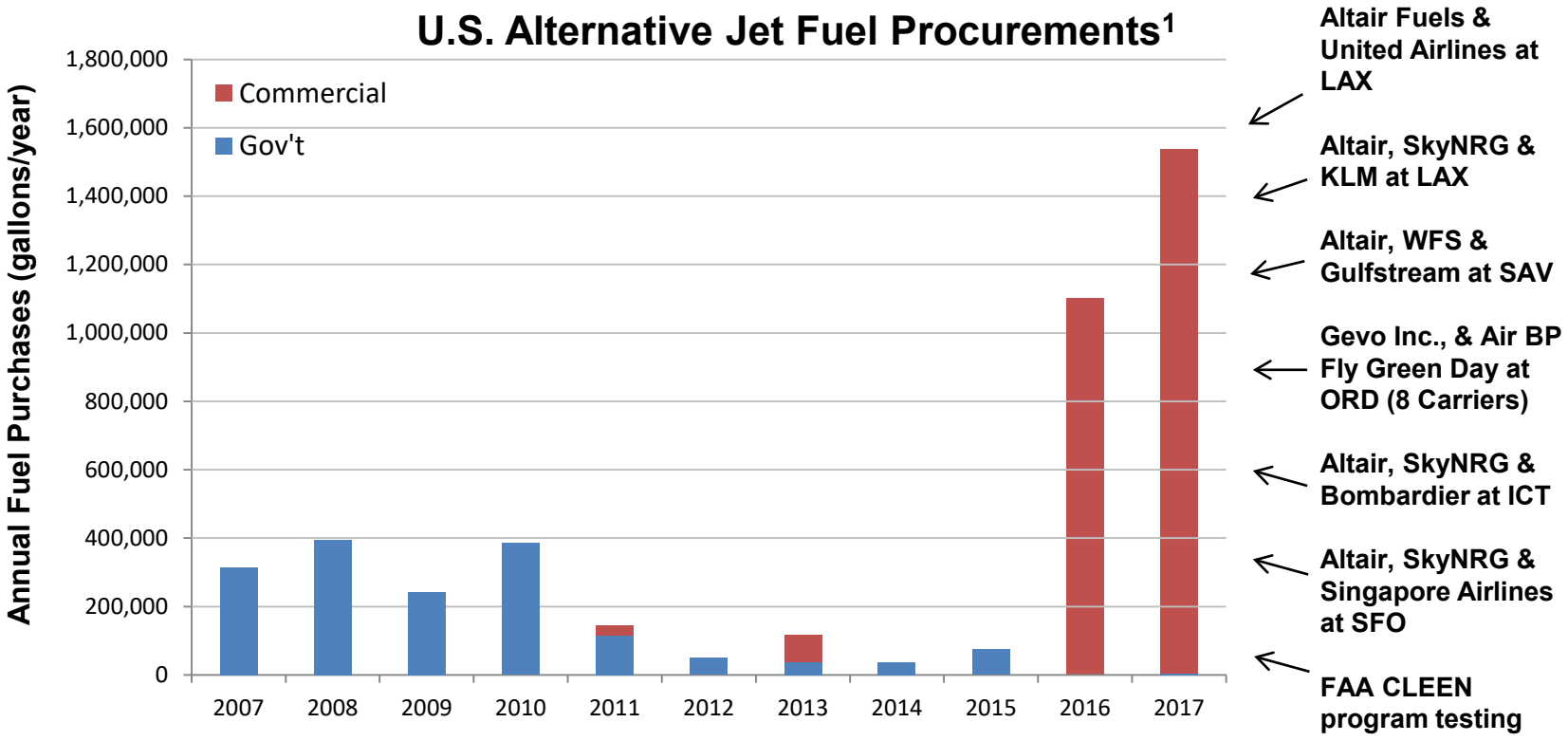
	Agricultural residues	#.#	#.#	#.#
	Forestry residues	#.#		#.#
	Municipal and solid waste (MSW), 0% non-biogenic carbon (NBC)	#.#		#.#
	Municipal solid waste (MSW) (NBC given as a percentage of the non-biogenic carbon content)	#.#		#.#
	Tallow	#.#	#.#	#.#
	Used cooking oil	#.#		#.#
	Palm fatty acid distillate	#.#		#.#
	Corn oil	#.#		#.#
	Agricultural residues	#.#	#.#	#.#
	Forestry residues	#.#		#.#

$$ER_y = FCF * \left[\sum_f MS_{f,y} * \left(1 - \frac{LS_f}{LC} \right) \right]$$

Questions

Where We Stand Today

- **Commercial flights on AJF are taking place**
- **1.5 million gallons in 2017 from two commercial producers, many commercial users**



Notes:
1. Includes procurements of fuel by U.S. government, U.S. airlines, manufacturers, and foreign carriers delivered to U.S. airports

Federal Aviation Administration

Where are we headed?

Potential for 250 million gallons/year in five years