Sustainable Aviation Fuels (SAF)

Update to FAA REDAC E&E Subcommittee

To: E&E REDAC Subcommittee

By: Nate Brown & Dan Williams

Date: March 19, 2019

Agenda

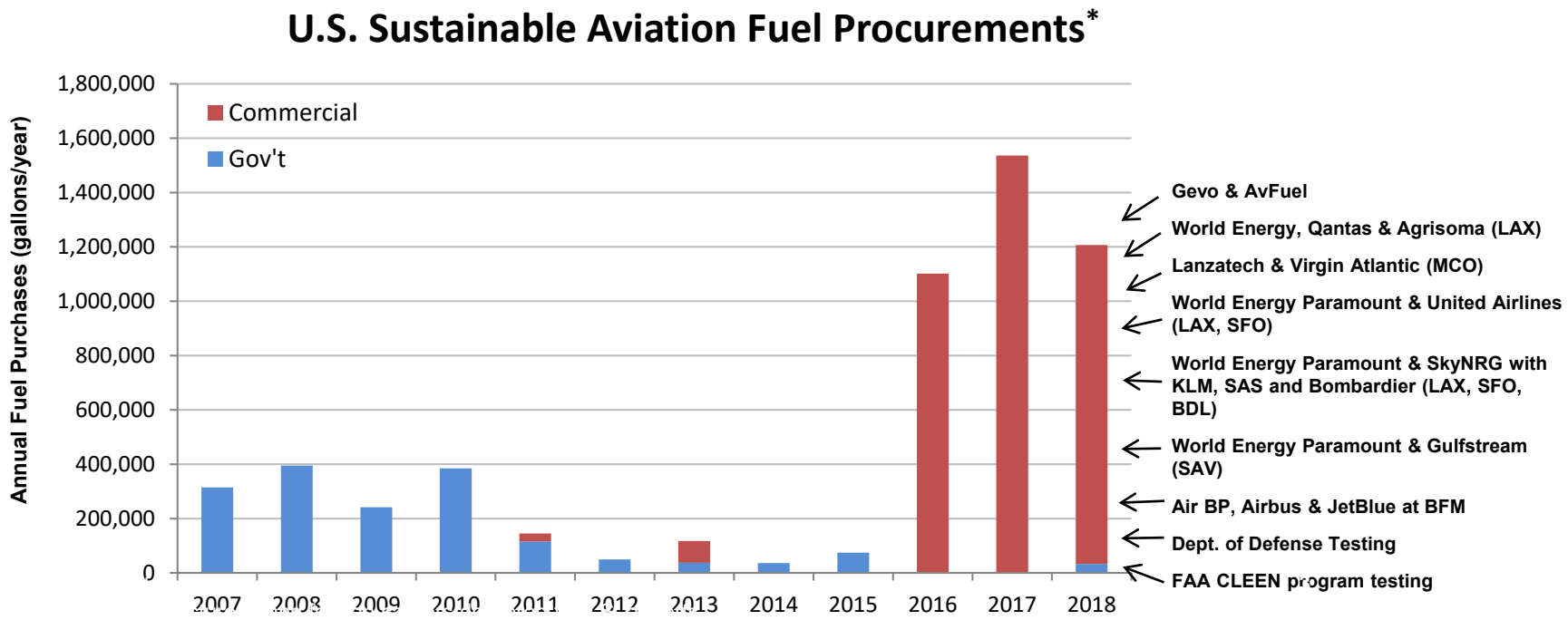
Current State of SAF Deployment (Nate)

- Current Production
- Production Facilities
- ASTM Status
- Supply chain analysis and tools

Alternative Fuels and CORSIA (Dan)

Sustainable Aviation Fuel Production

- **Three years of sustained commercial production and airline use**
- **>1.2 million gallons in 2018 from additional producers, users, and airports**
- **New fuels under evaluation & construction of new facilities under way**
- ***Potential for 250+ million gallons/year in <five years***



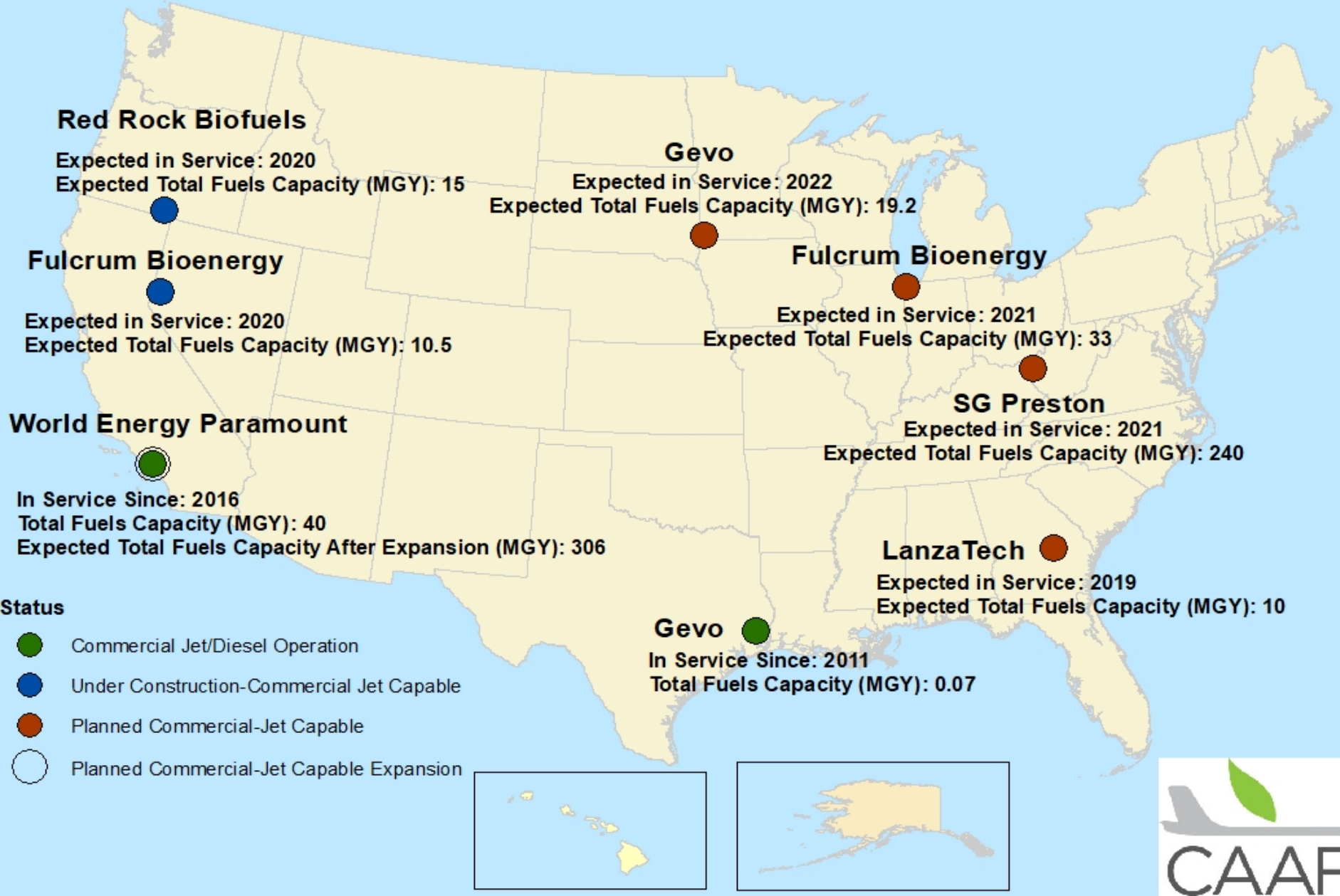
* Reflects voluntarily reported use by U.S. airlines, U.S. government, manufacturers, other fuel users, and foreign carriers uplifting at U.S. airports. Credit: FAA.

Federal Aviation Administration

Sustainable Aviation Fuel Production Facilities

* as of June 2019

Note: The specific fraction of the total capacity dedicated to SAF will likely be based on market conditions.

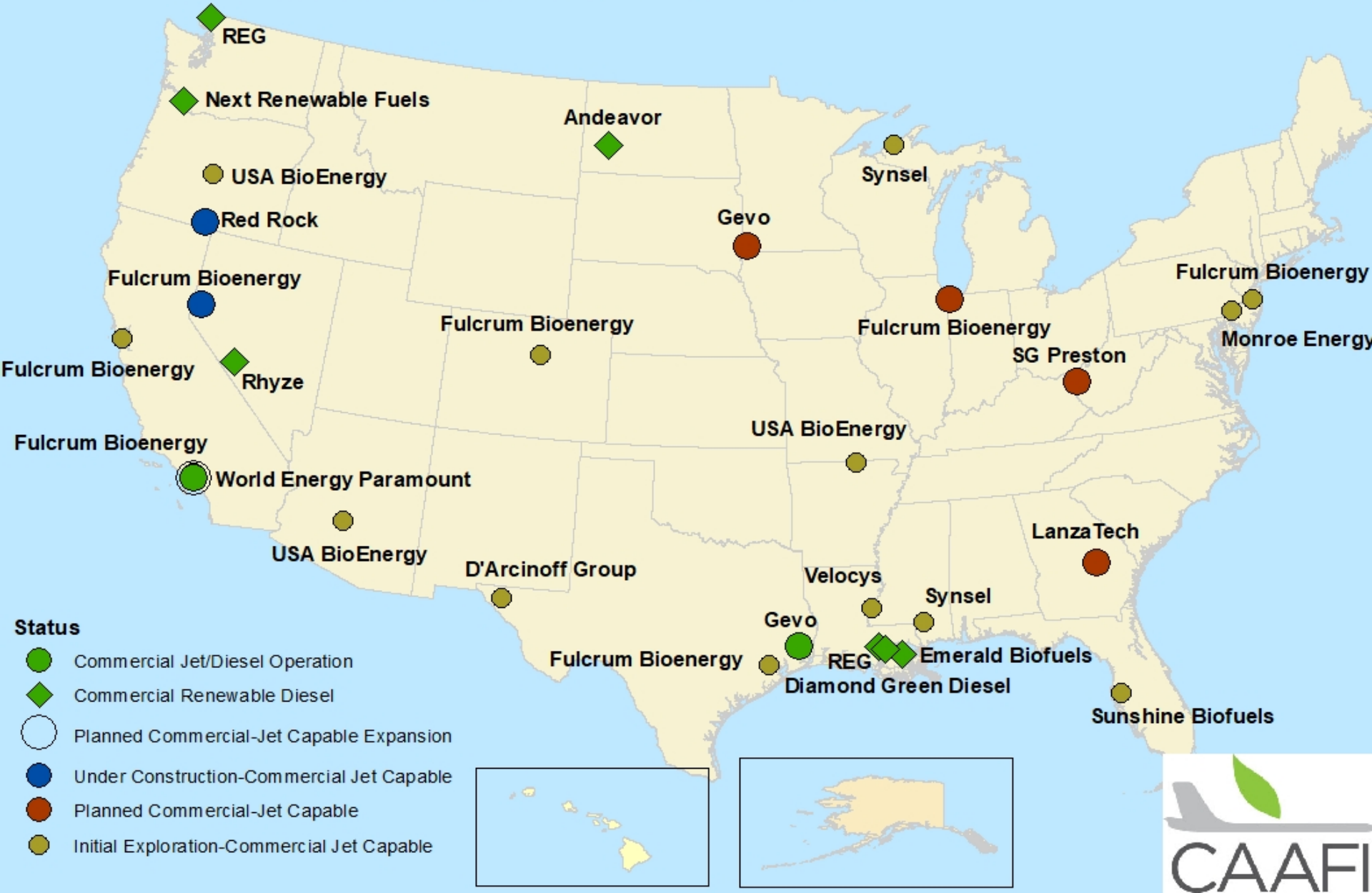


CAAFI

SAF and Renewable Diesel Production Facilities

Note: Some fraction of renewable diesel could be converted to SAF production and/or the aviation industry is evaluating the use of renewable diesel as a blending component for jet fuel.

* as of June 2019



CAAFI

International SAF Production Facilities

- **Neste - Porvoo, Finland; Rotterdam, the Netherlands; Singapore**
  - Continuous production from 4Q'18; expansion in 2022
- **Total - La Mede, France**
  - Online in Jun'19
- **LanzaTech - ATJ Demo Facility in China**
- **Euglena - Demo Plant in Yokohama, Japan**
  - Using ARA's CHJ Process
- **SkyNRG - Delfzijl, the Netherlands**
  - First SAF-dedicated plant in Europe

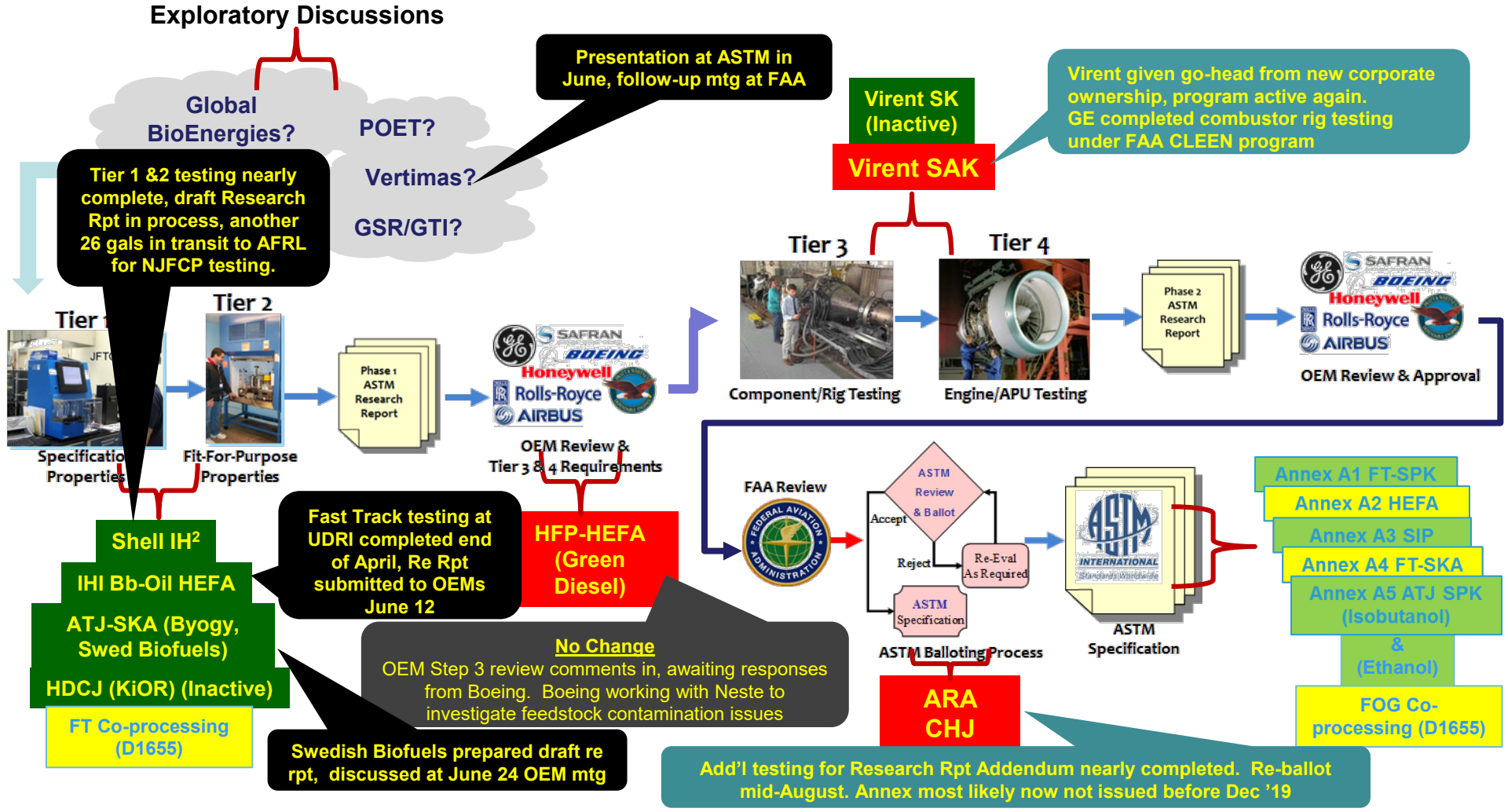
SAF Approval Process Status

Alternative Jet Fuels Under ASTM Evaluation

1. **Applied Research Associates (ARA)**
   - Catalytic Hydrothermolysis Jet (CHJ)
   - Testing completed, ASTM ballot in process
2. **Virent Synthesized Aromatic Kerosene (SAK)**
   - First phase of testing completed, second phase in process
3. **High Freeze Point HEFA (HFP-HEFA)**
   - A high freeze point renewable diesel stream
   - Under evaluation
4. **IHI Corporation (Japan)**
   - Improved feedstock (Bb-Oil) with HEFA conversion process
   - Testing completed, ASTM ballot in process
5. **Shell IH^2 catalytic conversion process**
   - First phase of testing nearly completed
6. **Swedish Biofuels Alcohol to Jet (ATJ)**
   - Under preliminary review
7. **Vertimass Catalytic Alcohol Conversion Process**
   - Initial discussions conducted

SAF Approval Process Status

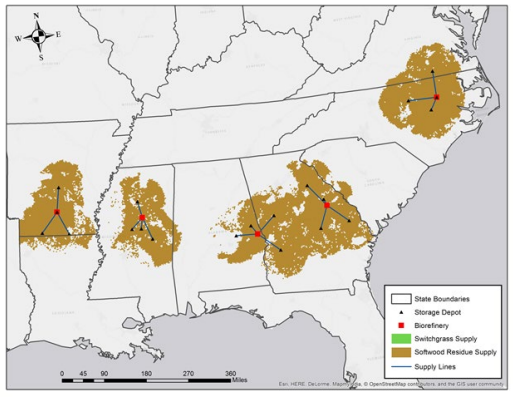
Alternative Jet Fuels Under ASTM Evaluation



Alternative Jet Fuel Supply Chain Analysis & Tools

Understand benefits, costs and potential supply

- Considering 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 Northwest
  - Hawaii
  - Southeast/Tennessee
- Developing open source tools for evaluation of supply chains
  - Economics; Community assets; Supply chain Risk Sharing; Logistics



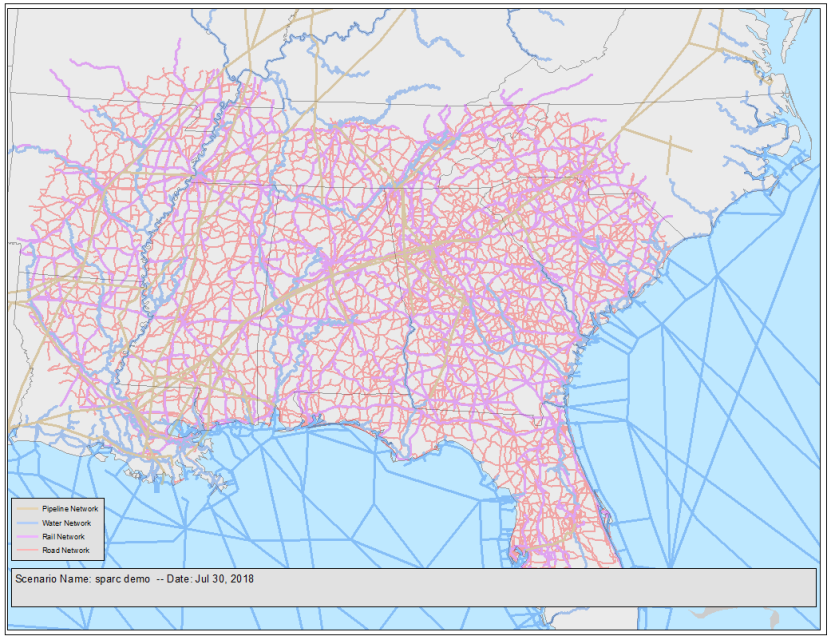
Images: University of Tennessee & University of Hawaii

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)

Freight and Fuels Transportation Optimization Tool (FTOT)

- **Problem: Understand transportation needs and impacts of SAF production**
  - Transportation costs, infrastructure requirements, and emissions depend on mode choice and routing.
  - optimizing mode choice and routing of feedstocks and products can help assess viable options and identify likely geographic patterns of AJF supply
- **Solution: FTOT**
  - Optimizes routings and flow of materials over multimodal GIS network for national or regional analyses.
  - Regional study in collaboration with Southeast Partnership for Advanced Renewables from Carinata (SPARC)
  - Beta version in testing this summer
  - Public version and user documentation to be released this fall



Agenda

- Alternative Fuels and CORSIA
- Where We Left Off
- What's New
- How's the Work Going
- Why We Care

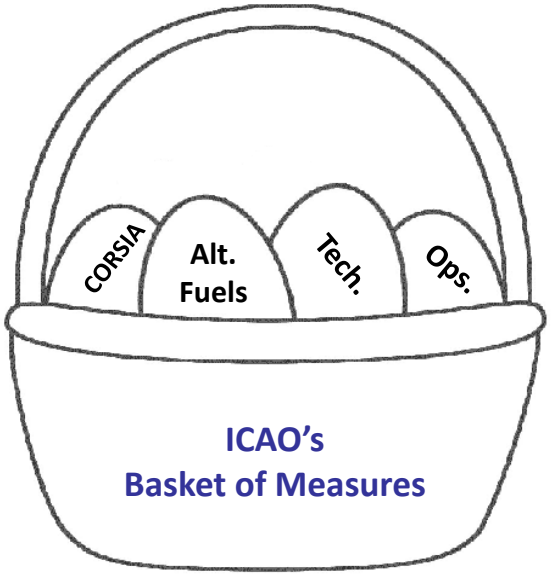
Alternative Fuels and CORSIA

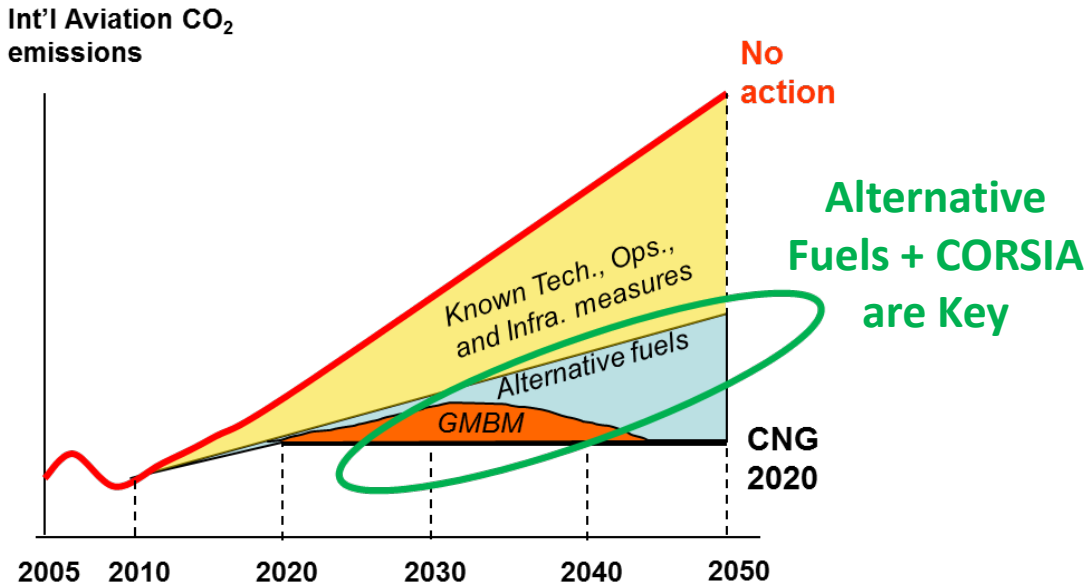
CORSIA Eligible Fuels provide a secondary means to comply with CORSIA

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





Alternative Fuels + CORSIA are Key

Where We Left Off

Fuel Conversion Process	Fuel Feedstock	Core LCA Value	ILUC LCA Value	LSf (gCO_2e/MJ)
Fischer-Tropsch (FT)	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)	#.#		#.#
Hydroprocessed esters and fatty acids (HEFA)	Tallow	#.#	#.#	#.#
	Used cooking oil	#.#		#.#
	Palm fatty acid distillate	#.#		#.#
	Corn oil	#.#		#.#
Alcohol (isobutanol) to jet (ATJ)	Agricultural residues	#.#	#.#	#.#
	Forestry residues	#.#		#.#

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

What's New

Subgroup	Task Number	Task Title
ILUC	S.01.01	Computation of induced land use change emissions for SAF for use in CORSIA
	S.01.02	Low ILUC risk practices
	S.03	Co-processing of esters and fatty acids in petroleum refineries
	S.04.02	Methodology refinements – ILUC
Core LCA	S.01.03	Feedstocks classification
	S.02	Computation of default core LCA emission values for SAF for use in CORSIA
	S.03	Co-processing of esters and fatty acids in petroleum refineries
	S.04.01	Methodology refinements – core LCA
Emission Reductions and Accounting	S.04.03	Methodology refinements – Emission Credits
	S.11	Double counting
	S.12	ILUC Permanence
Sustainability	S.06	Sustainability criteria
	S.07	SCS Requirements
Technology and Production	S.08	Technology evaluation
	S.09	Fuel Production Evaluation
	S.10	Guidance on Potential Policies and Coordinated Approaches for the Deployment of SAF

How's the Work Going

Emissions Credits

Issue: Some viable fuel pathways have emissions reductions that aren't captured in the methodology

Process:

- Compare Emission Unit Criteria to methodology to assess "quality"
- Examine whether reductions could be captured or taken elsewhere
- Develop general criteria for these kind of reductions
- Assess implications and appropriateness of these credits

Sustainability Criteria

Issue: What are the criteria to be used to determine that CEF is sustainable?

Process:

- Draft a report to ICAO Council examining the criteria developed during CAEP/11
- For each criterion, assess:
  - Why is it required?
  - Which criteria are a "must have" vs a "desirable"
  - How does ICAO assess and apply each criterion?
  - Benefits of each criterion?
  - Dis-benefits of any/all criterion?
  - Current SAF best practices?
  - Does each criterion have universal applicability?

Fuel Production

Issue: What's technically and economically viable in terms of SAF availability for CORSIA (through 2035)?

Process:

- Review near-term projections and databases
- Extract pathways with near-term potential
- Harmonize TEA models for consistency in comparisons
- Compare SAF prices to offset prices
- Consider how to include policy incentives

Why We Care

Emissions Credits

Some facilities scheduled to begin production in 2020 and 2021 will use a MSW pathway.

Absent a way to credit certain reductions from these fuels, their benefits significantly decrease.

Sustainability Criteria

A harmonized set of criteria will provide necessary certainty to fuel producers going forward.

It will also provide assurance to operators that SAF purchased outside of the U.S. will meet the same sustainability standards as a domestically produced fuel would.

Fuel Production

If CORSIA is designed as a "gap filler," can it stimulate demand for SAF?

How much fuel can we actually expect to see used during the CORSIA timeframe?

Questions