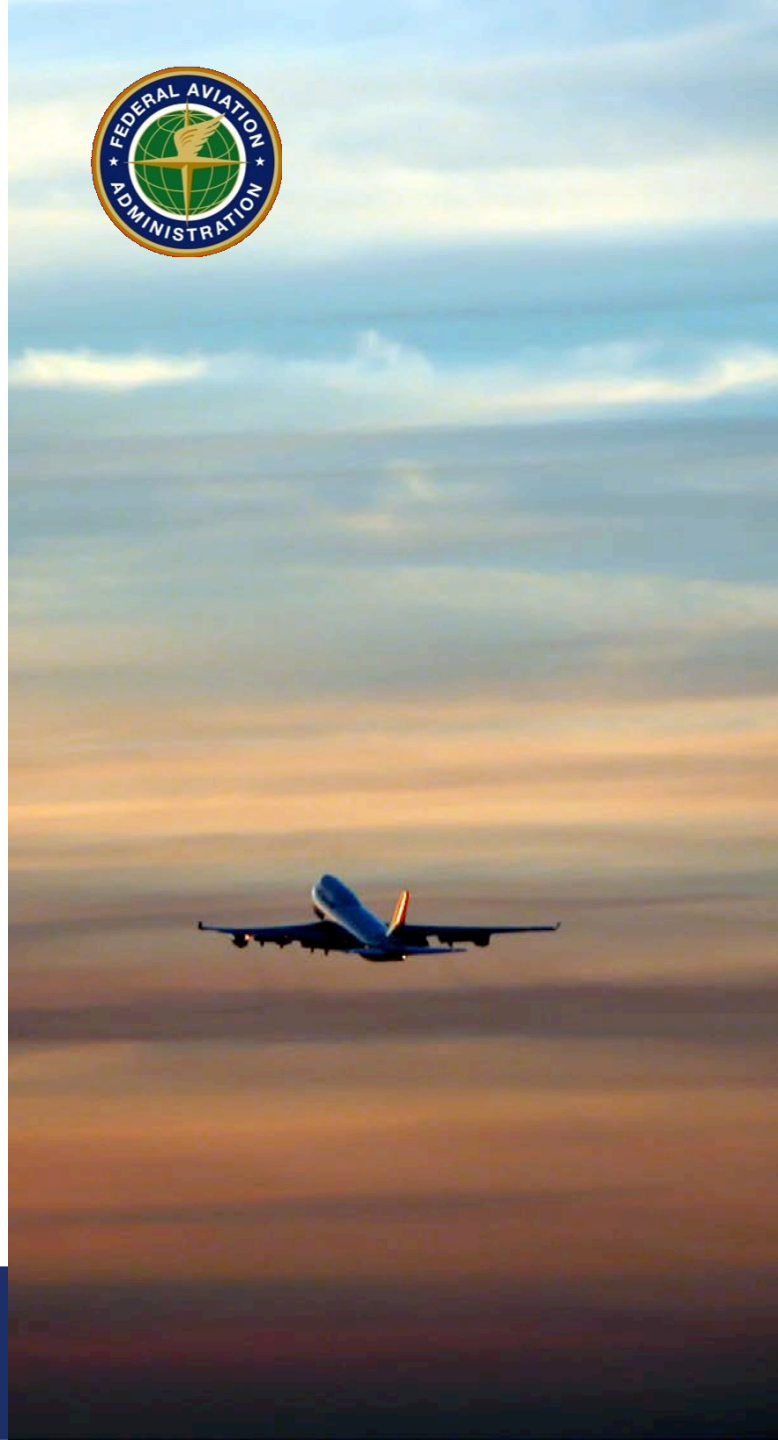
Sustainable Aviation Fuels (SAF)

Update to FAA REDAC E&E Subcommittee

To: E&E REDAC Subcommittee

By: Nate Brown & Anna Oldani

Date: March 17, 2020



FAA SAF Program Focus

Testing
accelerate SAF development

- Improve testing methods
- Conduct evaluation
- Streamline approval

Analysis
quantification of impacts

- Emissions reduction
- Supply potential
- Supply chain opportunities

Coordination
support SAF integration

- Public-private partnership – *CAAFI*
- Federal cooperation
- International cooperation – *ICAO*

Agenda

Testing

- Qualification Process
- ASTM Status

Analysis

- Supply Chain Tools

Coordination

- ICAO CAEP Fuels Task Group
- Commercialization

Agenda

Testing

- **Qualification Process**
- ASTM Status

Analysis

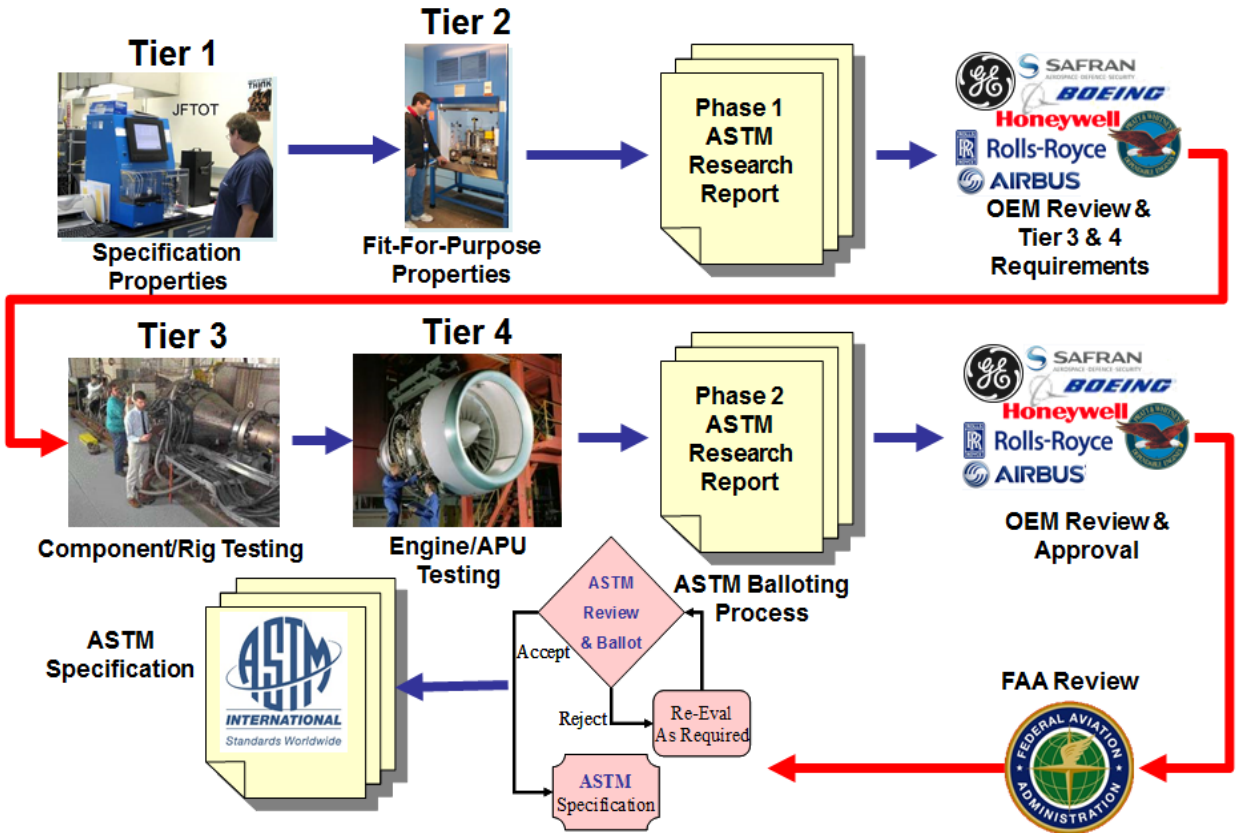
- Supply Chain Tools

Coordination

- ICAO CAEP Fuels Task Group
- Commercialization

SAF Qualification – ASTM D4054

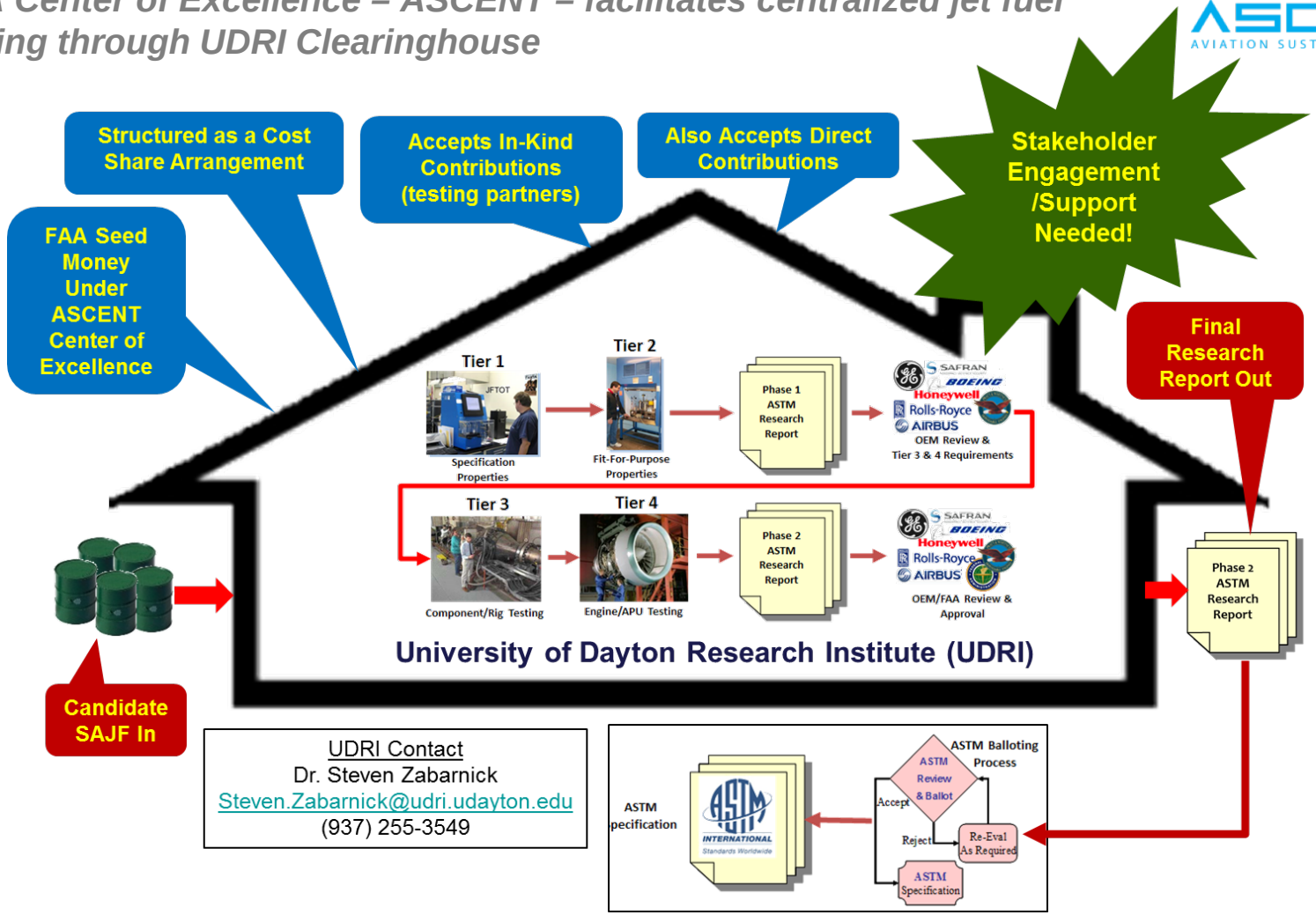
Multi-tiered qualification process involves stakeholders across industry and government



- ***ASTM International*** manages jet fuel specification
- **FAA** and **Defense** support evaluation of SAF through:
  - *Clearinghouse*: certification & qualification testing
  - Data gathering & review
  - New test method development

Clearinghouse Concept

FAA Center of Excellence – ASCENT – facilitates centralized jet fuel testing through UDRI Clearinghouse



Agenda

Testing

- Qualification Process
- **ASTM Status**

Analysis

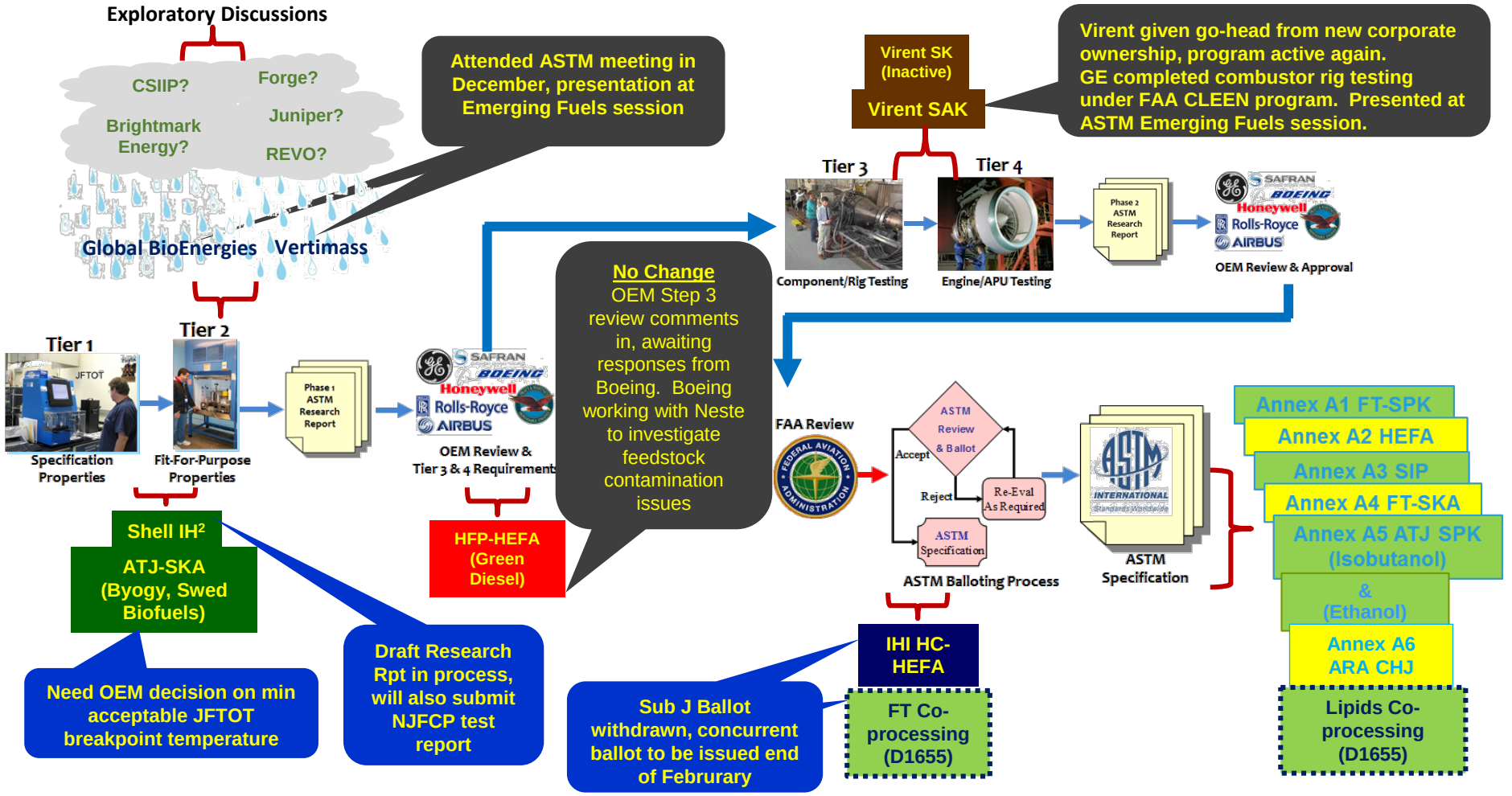
- Supply Chain Tools

Coordination

- ICAO CAEP Fuels Task Group
- Commercialization

ASTM D4054 SAF Qualification Status

Through FAA support, six SAF categories have been annexed in ASTM D7566



Reduce Fuel Approval Volumes

As a result of the investments made by FAA and others, time and fuel volume requirements for ASTM International approval have fallen over time

Fuel Type	ASTM data review	Final phase II research report	Addition to ASTM Specification (D7566)	Estimated gallons of fuel produced for testing	Estimated time from first review to approval	Composition
FT-SPK	9/2007 est.	09/2008	09/2009	710,000[1]	3 years	Largely normal/iso-paraffins
HEFA-SPK	6/2008 est.	05/2010	07/2011	626,000[2]	3 years	
SIP	6/2011	04/2013	06/2014	16,000	3 years	
Gevo ATJ-SPK (isobutanol)	12/2010	04/2015	06/2016	93,100[3]	5 $^{1}/_{2}$ years	
Lanzatech ATJ-SPK (ethanol)	09/2016	07/2017	04/2018	50[4]	1 $^{1}/_{3}$ years	
ARA CHJ	6/2012	10/2018	01/2020	79,000	7 years	Wider range of molecules

ARA Applied Research Associates

[1]USAF fuel purchases in 2007 08 for fleetwide qualification

[2]USAF & Navy fuel purchases in 2009 11 for fleetwide qualification

[3]USAF, Navy and CLEEN fuel purchases in 2012 2014

[4]Only Tier 1 2 testing due to existing knowledge base and similarity to approved fuels

D4054 Fast Track Annex

FAA Center of Excellence – ASCENT – enabled the development of the Fast Track Annex for SAF qualification

- Approved **April 2019**
  - Reduced evaluation scope for certain SAF
  - Reviewed by OEMs
- Stringent **property requirements**
  - Defined feedstock and process
  - Strict compositional criteria
- Blend ratio **limited to 10%**
  - Annexed under D7566
  - IHI Bb-Oil is first to undergo Fast Track

Additional ASTM Streamlining

FAA Center of Excellence – ASCENT – supported the NJFCP to advance knowledge of fuel property and performance relations

Prescreening

Tier α

Property Predictions & Blend Estimations

mLs

GCxGC
IR absorption
NMR

Tier β

Critical Properties & Blend Limits

¼ gal

DCN
Density
Viscosity
Distillation Curve
Surface Tension

Optional Testing

Tier 2.5

Referee Combustor Rig Testing

100 gal

- Reduce or eliminate Tier 3 and 4 testing
- Test FOM conditions to evaluate operability limits

IR – Infrared

NMR – Nuclear magnetic resonance

Next SAF Under ASTM Evaluation

- **IHI Bb-Oil (Japan)**
  - Fast Track, ASTM re-ballot in February
- **Shell IH2 catalytic conversion process**
  - Preparing Phase I research report
- **Swedish Biofuels Alcohol to Jet (ATJ)**
  - Awaiting OEM review of Phase I research report
- **Virent Synthesized Aromatic Kerosene (SAK)**
  - First phase of testing completed, second phase in process
- **High Freeze Point HEFA (HFP-HEFA)**
  - Renewable diesel stream under evaluation
- **Vertimass Catalytic Alcohol Conversion Process**
  - In preliminary discussions

Agenda

Testing

- Qualification Process
- ASTM Status

Analysis

- **Supply Chain Tools**

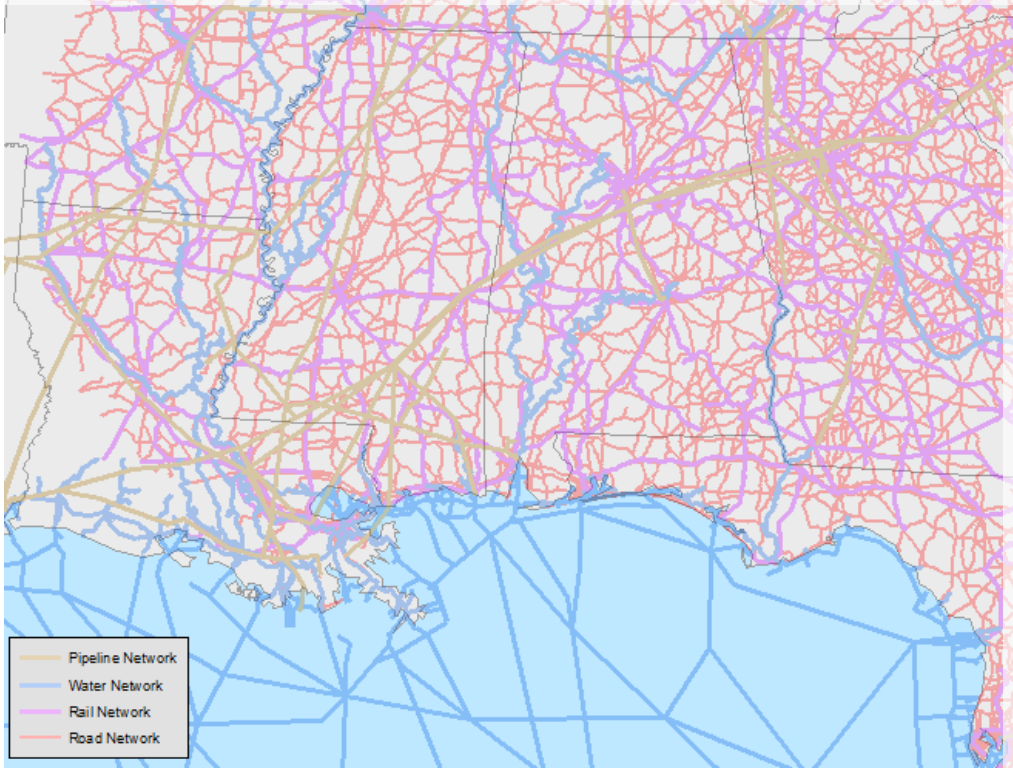
Coordination

- ICAO CAEP Fuels Task Group
- Commercialization

Freight & Fuels Transportation Optimization Tool (FTOT)

Motivation: Transportation costs, infrastructure requirements & emissions depend on mode choice & routing

Objective: Understand transportation needs & impacts of SAF production



Outcome: FTOT

- Optimize mode choice & routing of feedstocks & products
  - Assess viable options
  - Identify SAF supply patterns
- Optimize routings & material flow over multimodal GIS network
- Regional study with Southeast Partnership for Advanced Renewables from Carinata (SPARC)
- Collaboration with WSU
- **FTOT 2019.3 released 11/01/19**

Agenda

Testing

- Qualification Process
- ASTM Status

Analysis

- Supply Chain Tools

Coordination

- **ICAO CAEP Fuels Task Group**
- Commercialization

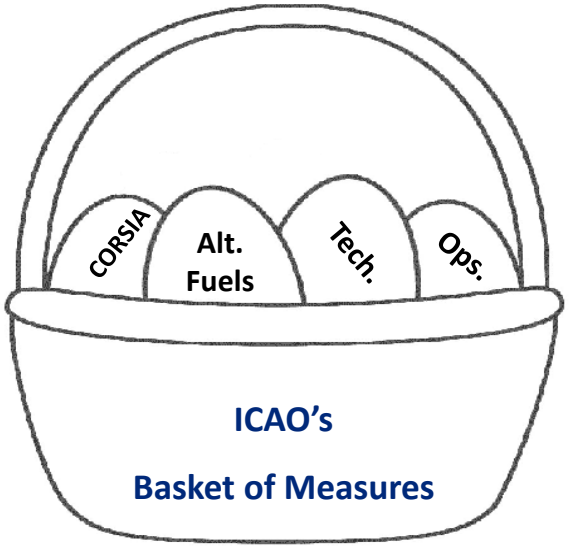
Alternative Fuels and CORSIA

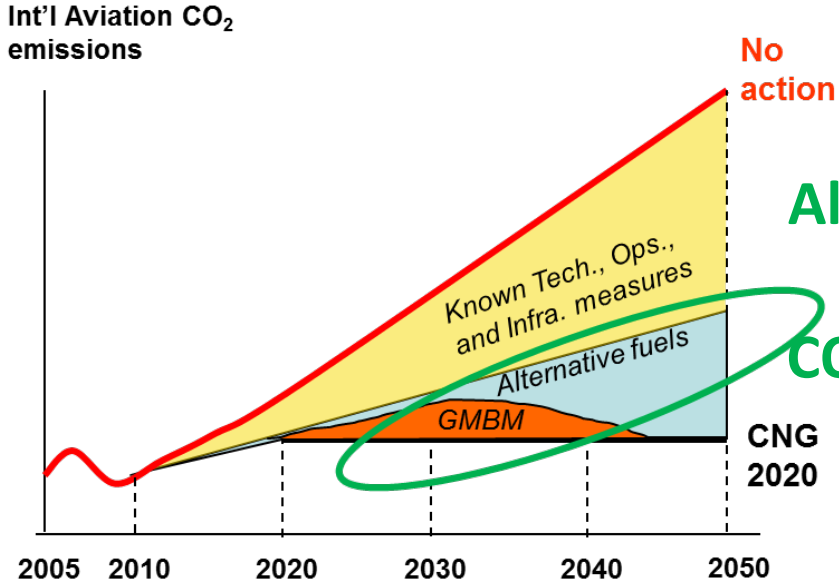
CORSIA Eligible Fuels provide a secondary means to comply with CORSIA

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

Update on the ICAO Fuels Task Group (FTG)

- FTG agreed to conduct its CAEP/12 work program tasks in five subgroups.
- held two meetings in Montreal: FTG/1 (2-3 May 2019), and FTG/2 (16 -20 Sep 2019)
- Held one meeting In Abu Dhabi: FTG/3 (9-13 Feb, 2020)

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 – just ILUC calculation
	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 – methodology for conducting LCA and default core LCA values
	S.04.01	Methodology refinements – core LCA
Emission Reductions	S.04.03	Methodology refinements – Emission Credits
	S.11	Double counting
	S.12	ILUC Permanence
All FTG	S.05	CORSIA Package Updates
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

FTG key activities

- **Core LCA default values:** carrying forward progress on Sustainable Aviation Fuels (SAF)
- **ILUC regional values:** developing an approach to generate induced land-use change (ILUC) regional values for countries beyond those currently covered.
- **Sustainability Criteria:** completed SAF criteria (presented to ICAO Council in January); ongoing investigation of application of sustainability criteria to LCAF
- **LCAF:** defining the methodology for lower carbon aviation fuels (LCAF) for both LCA and sustainability; held workshop on LCAF technologies with external specialists.

FTG key activities (continued)

- **Emissions Reductions**: assessing potential emissions reduction credits (LEC & REC) for waste pathways beyond MSW
- **Permanence:** work on the question of where negative ILUC can come from, and “permanence” of carbon capture
- **Fuel production assessment:** building on previous work and leveraging ASCENT techno economic analysis (TEA).
- **Policy Options:** continue analysis of policy options to foster CEF deployment and produce guidance material.

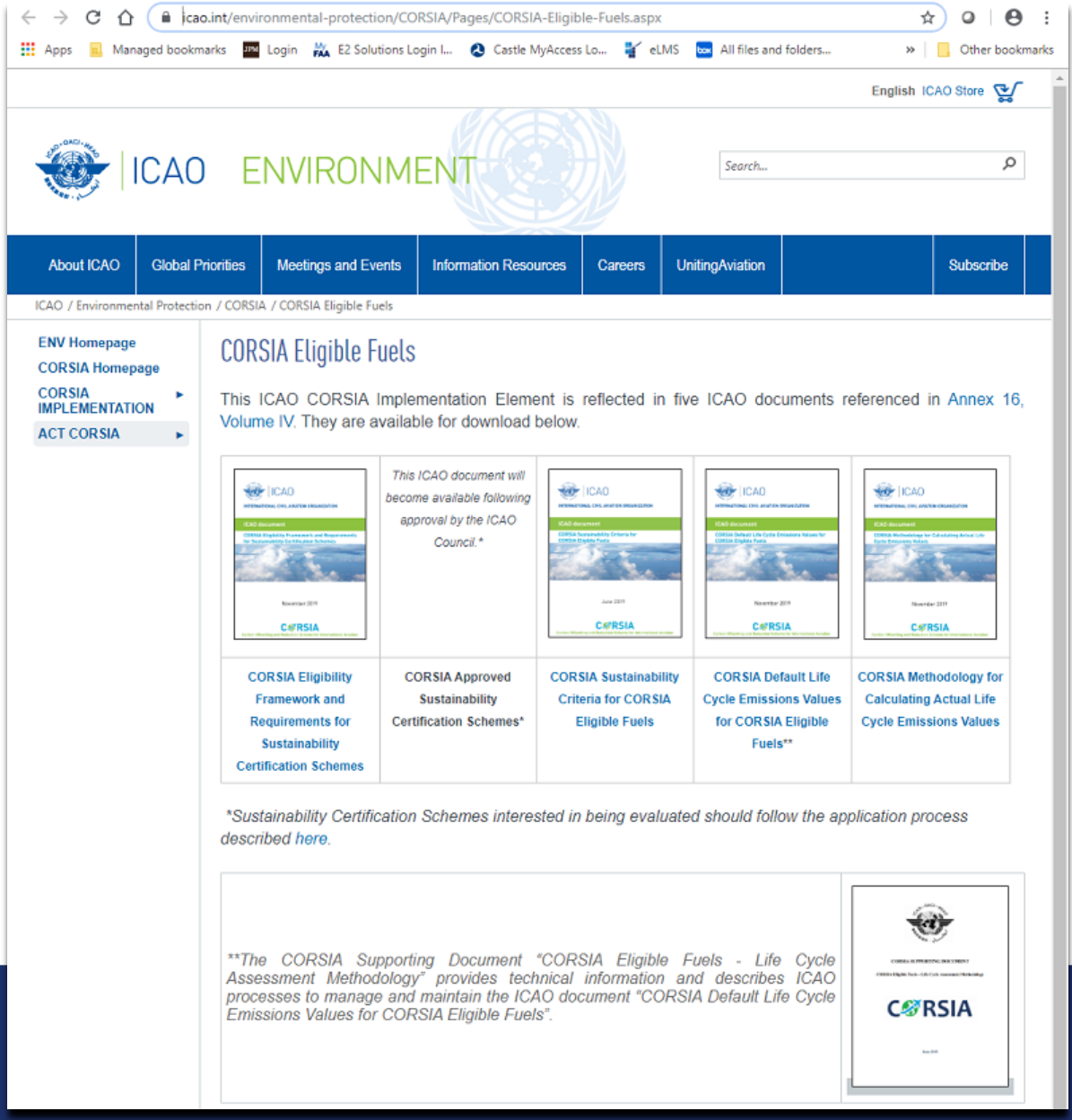
SCSEG

- The Sustainability Certification Scheme Evaluation Group
  - evaluate fuel SCS's for for participation in CORSIA
- Recommended by CAEP SG/1 in December and approved by Council in January
- Co-chairs from U.S. and Spain
- Invitation to apply posted by ICAO February 26
  - https://www.icao.int/environmental-protection/CORSIA/Pages/CORSIA-SCS-evaluation.aspx
- First round of applications due by April 30
- SCSEG meeting June 15

CORSIA Eligible Fuels Resources

https://www.icao.int/environmental-protection/CORSIA/Pages/CORSIA-Eligible-Fuels.aspx

- **CORSIA Framework and Eligibility Requirements for SCS**
- **CORSIA Sustainability Criteria**
- **CORSIA Default LCA Values**
- **CORSIA Methodology for Calculating Actual LCA Values**



Agenda

Testing

- Qualification Process
- ASTM Status

Analysis

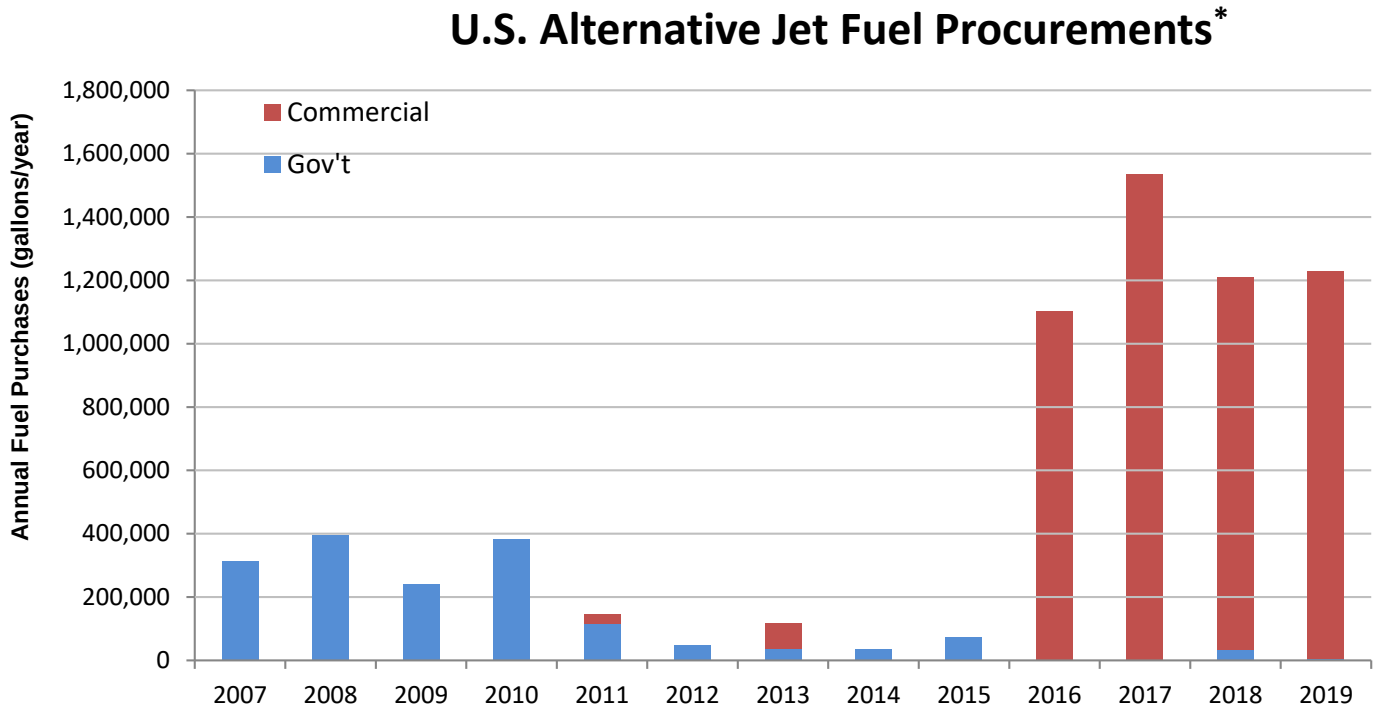
- Supply Chain Tools

Coordination

- ICAO CAEP Fuels Task Group
- **Commercialization**

What we see with SAF

- **Four years of sustained commercial use**
- **New fuels under evaluation & new facilities under construction**
- **New partnerships announced and General Aviation engaged**
- **In 2019 new incentives for jet but diesel still more profitable**
- **In 2020 new facilities will begin production**



Note: 2019 amounts preliminary

•* 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.

International RD/SAF Facilities

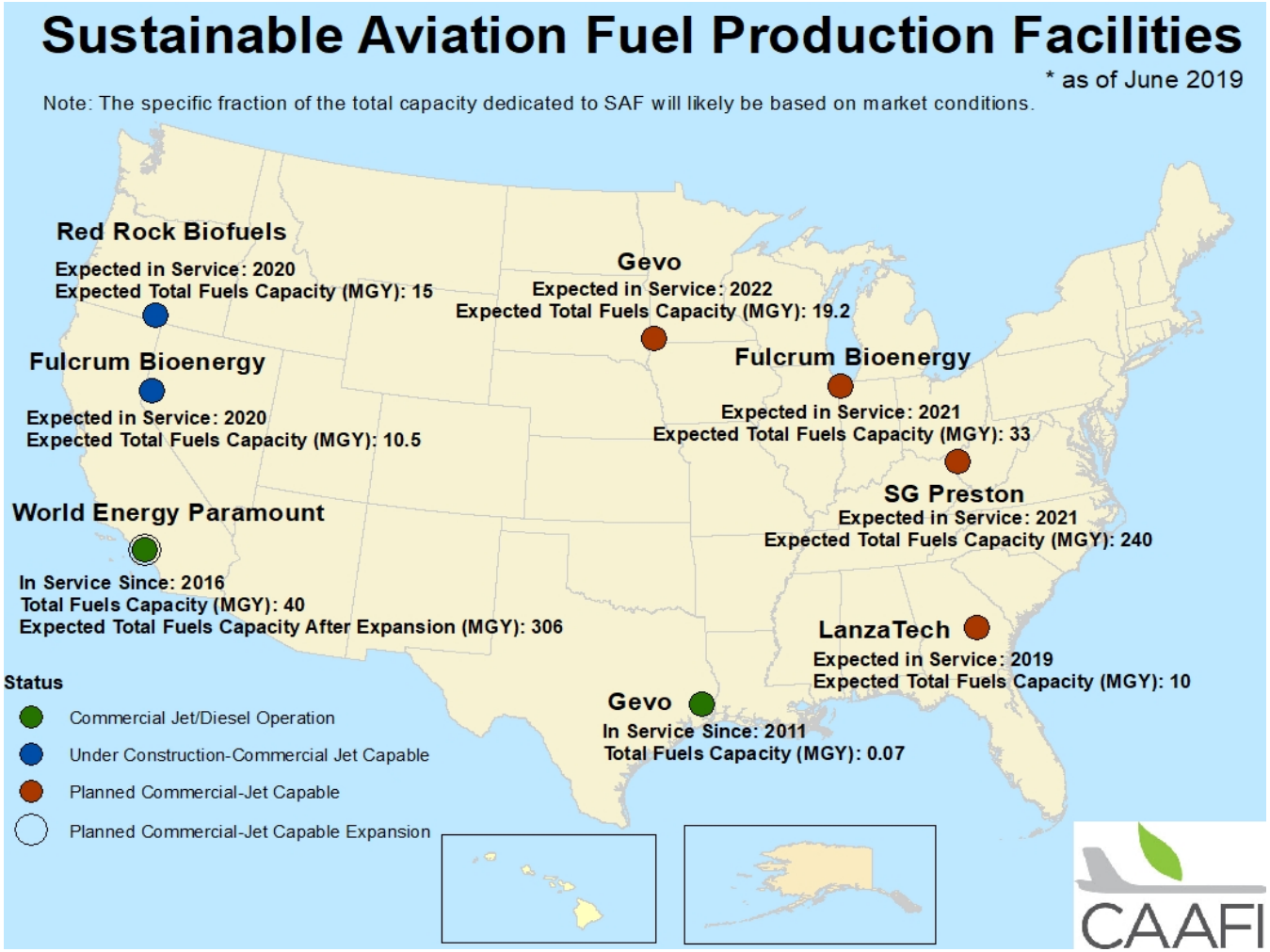
Publicly announced SAF/RD future infrastructure

Company/Location	Capacity (MMgy)	Year of Operation
Total (La Mede, France)	170	2019
Sinclair (Wyoming)	95	2019
ENI Gela (Italy)	200	2019
Fulcrum Biofuels LLC (Nevada)	10	2020
Red Rock Biofuels (Oregon)	15	2020/2021
Marathon (North Dakota)	120	2021
REG (Louisiana)	85	2021
World Energy (California)	240	2022
ECB (Paraguay)	300	2022
Neste (Singapore)	400	2022
Diamond Green (Louisiana)	400	2022
ST1 Oy (Sweden)	70	2022
HollyFrontier Corp (New Mexico)	125	2022
Gevo (Minnesota)	25	2022
Preem (Sweden)	290	2024
UPM Kotka (Finland)	170	2023/2024
TOTAL	2,715 MMgy	

Credit: ABFA and fuel producers involved with ICAO/FTG

Announced SAF Production Plans

- **Six SAF producers public**
  - Two currently in operation
  - Two currently under construction
  - Four in planning
- **Total capacity is for diesel and jet fuel**
- **Estimated 250M gallons SAF could be available in ~3 years**



Credit: CAAFI

Potential for U.S. SAF build-out with cost-advantaged feedstocks

SAF from several prevalent waste stream feedstocks

(GPY, using standard conversion efficiencies and viable SAF fractions)

3.8 B	**Wet Waste** (manures, sanitary, misc streams)
3.1 B	**MSW** (municipal solid waste: wood, paper, yard, plastics, textiles, food)
6.1 B	**Agricultural residues** (primary crop residues only, 31% removal)
0.4 B	**Woody residues** (30% of production uncommitted)
0.8 B	**F.O.G.** (Fats oils and greases: estimates vary significantly, up to 3.0B)
1.3 B	**Industrial off-gases** (steel, aluminum, petroleum)
x.x B	**Other** (C&D waste, telephone poles, rail ties, invasive tree removal, SBAR)
~15.6 B	**Current Total Potential (approx. 58% of 2019 U.S. demand)**
4.0B	**Plus, Low/zero ILUC purpose-grown oilseeds**
	Plus, …

CAAFI

Credit: CAAFI

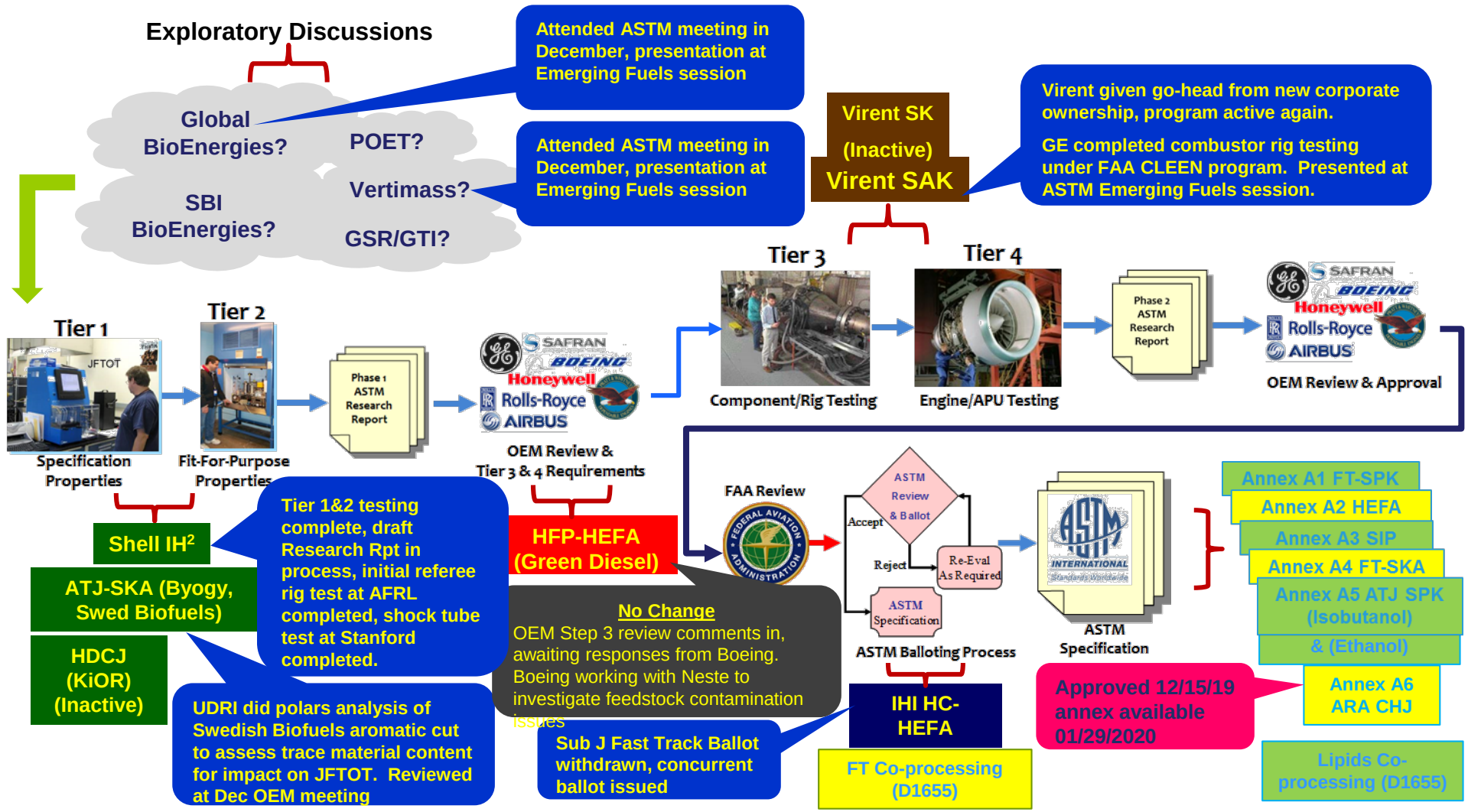
Expect to see with SAF

- **Continued high level of international interest**
- **Melding of Commercial and BizAv efforts**
  - New opportunities with BizAv build on CAAFI effort
- **Concerted efforts on policy to level/advantage SAF monetize benefits**
  - RFS, LCFS, production tax credit, CORSIA
- **More aggressive airline approaches & announcements**
- **Renewed Federal agency coordination (BRDB)**
- **Innovative purchasing approaches that enable third party involvement**
- **Buying SAF away from RD pool**
- **Engagement/Announcements from Big Oil**

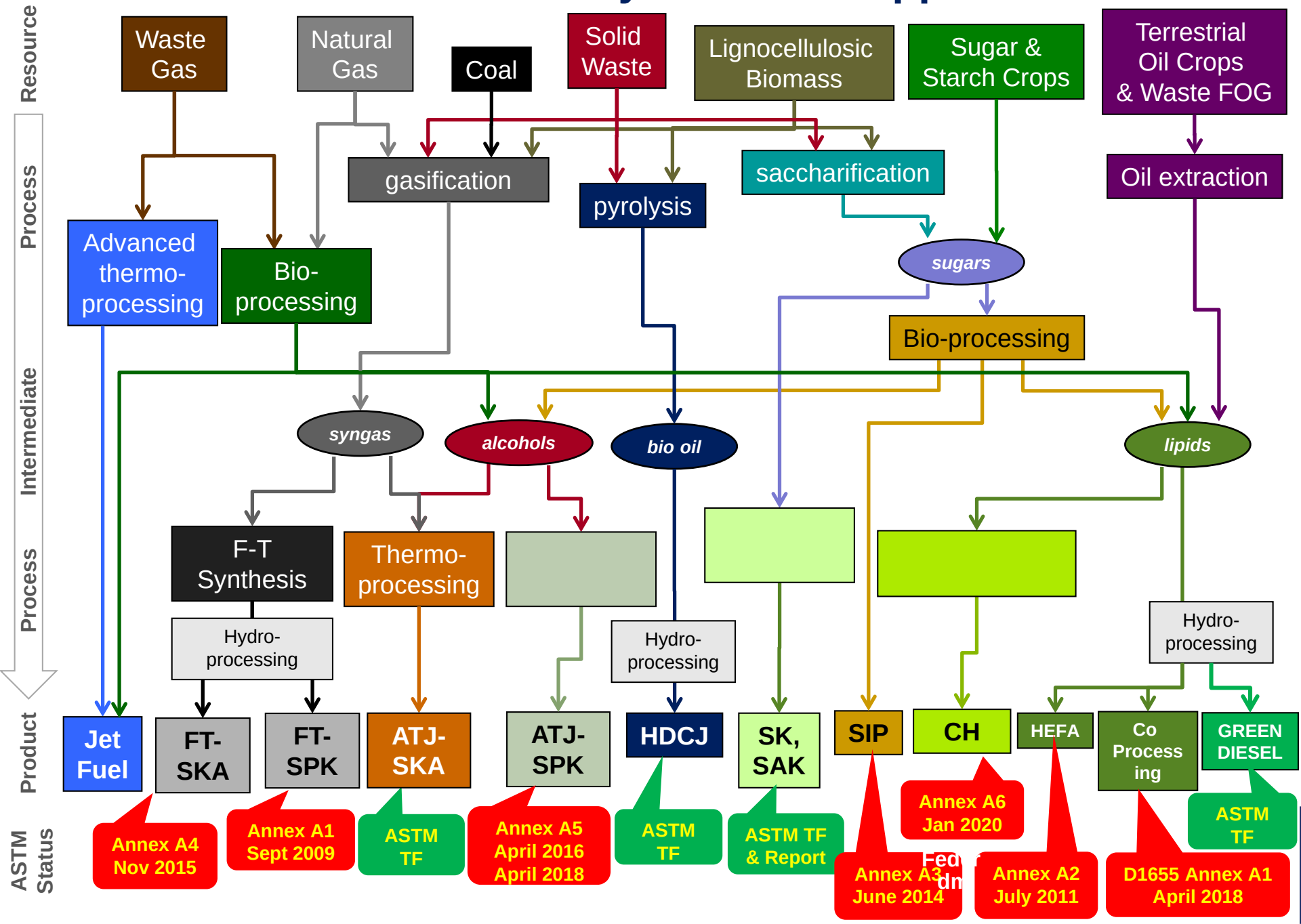
?

QUESTIONS

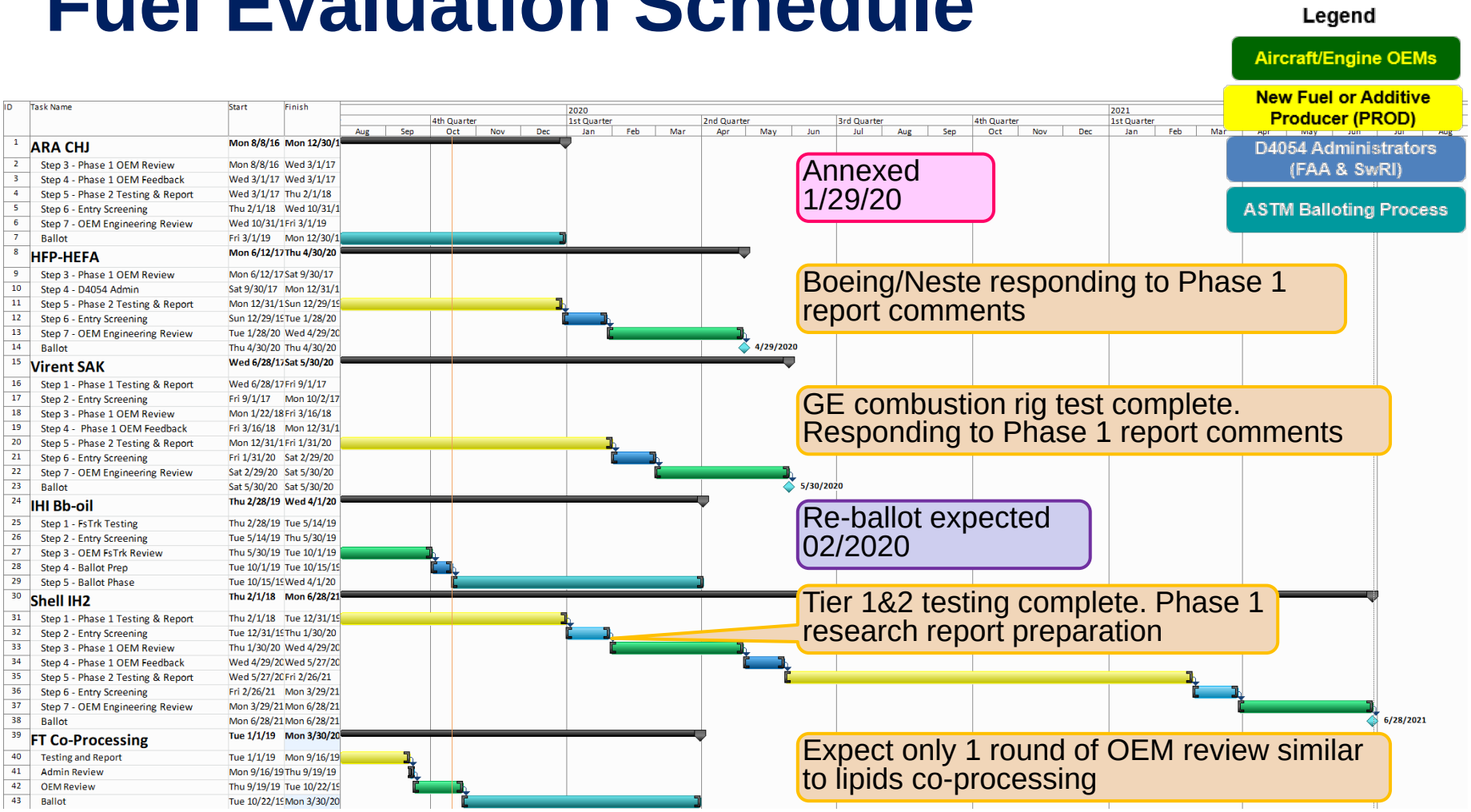
ASTM D4054 Status



Alternative Jet Fuel Pathways & D7566 Approval Status



D4054 Clearinghouse Fuel Evaluation Schedule



ID	Task Name	Start	Finish
1	**ARA CHJ**	Mon 8/8/16	Mon 12/30/1
2	Step 3 - Phase 1 OEM Review	Mon 8/8/16	Wed 3/1/17
3	Step 4 - Phase 1 OEM Feedback	Wed 3/1/17	Wed 3/1/17
4	Step 5 - Phase 2 Testing & Report	Wed 3/1/17	Thu 2/1/18
5	Step 6 - Entry Screening	Thu 2/1/18	Wed 10/31/1
6	Step 7 - OEM Engineering Review	Wed 10/31/1	Fri 3/1/19
7	Ballot	Fri 3/1/19	Mon 12/30/1
8	**HFP-HEFA**	Mon 6/12/17	Thu 4/30/20
9	Step 3 - Phase 1 OEM Review	Mon 6/12/17	Sat 9/30/17
10	Step 4 - D4054 Admin	Sat 9/30/17	Mon 12/31/1
11	Step 5 - Phase 2 Testing & Report	Mon 12/31/1	Sun 12/29/1
12	Step 6 - Entry Screening	Sun 12/29/1	Tue 1/28/20
13	Step 7 - OEM Engineering Review	Tue 1/28/20	Wed 4/29/2
14	Ballot	Thu 4/30/20	Thu 4/30/20
15	**Virent SAK**	Wed 6/28/17	Sat 5/30/20
16	Step 1 - Phase 1 Testing & Report	Wed 6/28/17	Fri 9/1/17
17	Step 2 - Entry Screening	Fri 9/1/17	Mon 10/2/17
18	Step 3 - Phase 1 OEM Review	Mon 1/22/18	Fri 3/16/18
19	Step 4 - Phase 1 OEM Feedback	Fri 3/16/18	Mon 12/31/1
20	Step 5 - Phase 2 Testing & Report	Mon 12/31/1	Fri 1/31/20
21	Step 6 - Entry Screening	Fri 1/31/20	Sat 2/29/20
22	Step 7 - OEM Engineering Review	Sat 2/29/20	Sat 5/30/20
23	Ballot	Sat 5/30/20	Sat 5/30/20
24	**IHI Bb-oil**	Thu 2/28/19	Wed 4/1/20
25	Step 1 - FsTrk Testing	Thu 2/28/19	Tue 5/14/19
26	Step 2 - Entry Screening	Tue 5/14/19	Thu 5/30/19
27	Step 3 - OEM FsTrk Review	Thu 5/30/19	Tue 10/1/19
28	Step 4 - Ballot Prep	Tue 10/1/19	Tue 10/15/19
29	Step 5 - Ballot Phase	Tue 10/15/19	Wed 4/1/20
30	**Shell IH2**	Thu 2/1/18	Mon 6/28/21
31	Step 1 - Phase 1 Testing & Report	Thu 2/1/18	Tue 12/31/19
32	Step 2 - Entry Screening	Tue 12/31/19	Thu 1/30/20
33	Step 3 - Phase 1 OEM Review	Thu 1/30/20	Wed 4/29/20
34	Step 4 - Phase 1 OEM Feedback	Wed 4/29/20	Wed 5/27/20
35	Step 5 - Phase 2 Testing & Report	Wed 5/27/20	Fri 2/26/21
36	Step 6 - Entry Screening	Fri 2/26/21	Mon 3/29/21
37	Step 7 - OEM Engineering Review	Mon 3/29/21	Mon 6/28/21
38	Ballot	Mon 6/28/21	Mon 6/28/21
39	**FT Co-Processing**	Tue 1/1/19	Mon 3/30/20
40	Testing and Report	Tue 1/1/19	Mon 9/16/19
41	Admin Review	Mon 9/16/19	Thu 9/19/19
42	OEM Review	Thu 9/19/19	Tue 10/22/19
43	Ballot	Tue 10/22/19	Mon 3/30/20

CAEP/11 AFTF accomplishments

- Greenhouse gas life cycle analysis (LCA) methodology (MIT)
- Default Core LCA values (MIT)
- Induced land use change (ILUC) methodology (Purdue)
- Default ILUC values (Purdue)
- Sustainability criteria for GHG, carbon in land (Volpe)
- Policy analysis on SAF deployment (MIT, Purdue)
- Fuel production scenarios to support 2050 trends assessment (MIT)

CAEP/12 Fuels Task Group (FTG) Work Program

- Default ILUC values & methodology refinement
- Default core LCA values & methodology refinement
- Emissions credits methodology refinement
- Sustainability - additional/strengthened criteria
- Sustainability Certification Scheme (SCS) requirements
- Forward projection of fuel availability – leverage work on CORSIA emission unit availability & costs
- Understanding emissions credits / ILUC permanence
- Analysis to support guidance on policies & approaches for deployment of SAF

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	#.#		#.#

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

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?

Upcoming Meetings

- **Business Aviation 2020 Sustainability Summit: March 24, Washington, DC**
- **Biomass R&D Board Technical Advisory Committee, March 24, Washington, DC**
- **Bioeconomy Summit: March 25, Washington, DC**
- **Advanced Biofuels Leadership Conference: March 25-27, Washington, DC**
- **Biomass R&D Board Meeting, April 7, Washington, DC**

Potential CORSIA Sustainability Criteria

Work is ongoing on additional criteria within ICAO CAEP

Sustainable = environmental +
social +
economic

greenhouse gas (1) +
carbon in the land (2) +
water quality (?) +
soil quality (?) +
air quality (?) +
conservation (?) +
waste / chemicals (?) +
human and labor rights (?) +
land use rights (?) +
water use rights (?) +
local and social development (?) +
food security (?)