# CAAFI Webinar Series:
# The State of Sustainable Aviation Fuel (SAF)

**Steve Csonka**
**Executive Director, CAAFI**

**Brought to you by the R&D Team Co-Chairs & CAAFI ALT**

CAAFI®
COMMERCIAL AVIATION
ALTERNATIVE FUELS INITIATIVE

**08Apr'20**

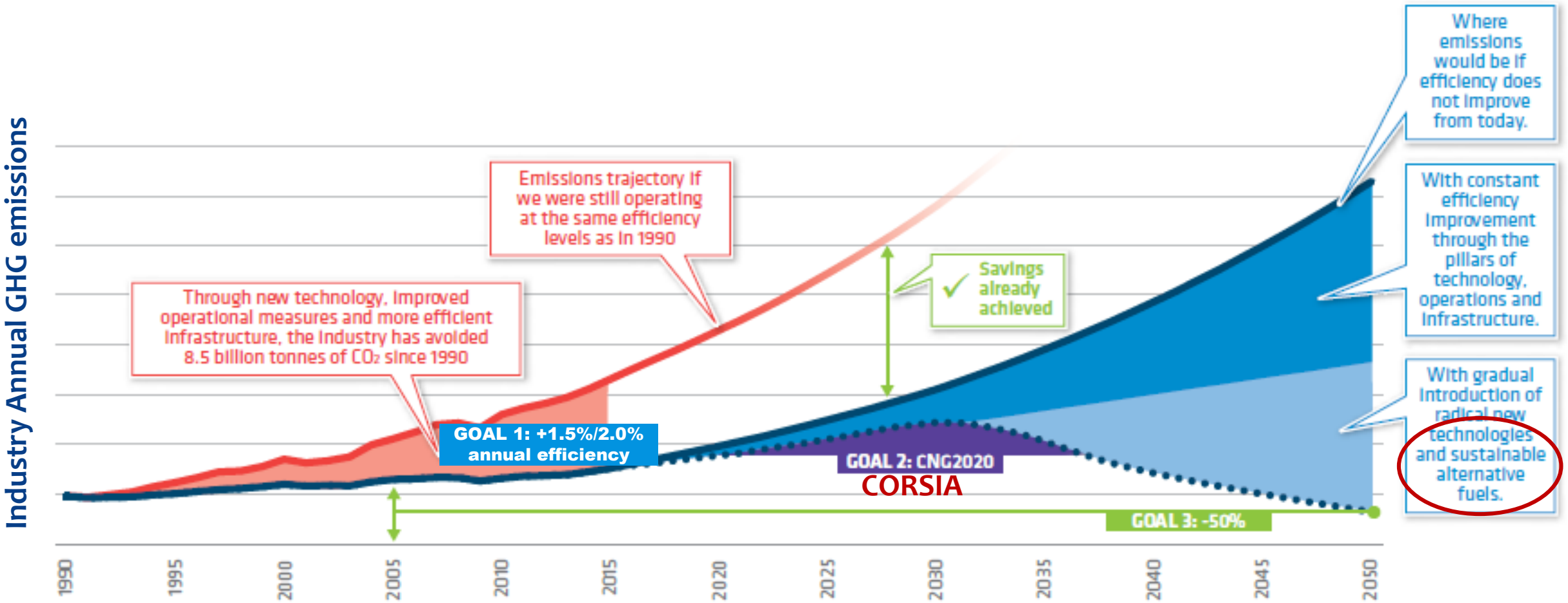
# Agenda

1) Foreword
2) State of SAF qualification
3) State of SAF market pull
4) State of SAF production
5) The future State of SAF: Commercialization challenges and recommendations



CAAFI®
COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

# 1) Foreword: Aviation commitments






Courtesy of ATAG: www.atag.org/our-publications/latest-publications.html; Beginner's Guide to Sustainable Aviation Fuel; **Business Aviation made similar commitments**

# 1) Foreword: SAF approach

- Significant effort being expended on SAF, under key guiding principles
  - Sustainability;  Availability, world-wide;  Pathway to competitive pricing
- ICAO finalizing initial implementation of CORSIA
  - Monetizes carbon, enables SAF to reduce offsetting obligations
- Airlines engaged, but progress is challenging – due chicken-egg conundrum
  - Only able to purchase initiating volumes due high SAF pricing, and SAF pricing will likely not reduce until higher volume production
- Additional policy support warranted, but has not been broadly forthcoming
  - SAF community evaluating many opportunities to close gaps, including additional policy
  - Some third parties seek acceleration - Some (EU) looking at use of mandates
  - CAAFI and Sponsors continue to focus on fundamentals: R&DDD, Tools, PPP Initiatives, …

# 2) State of SAF qualification

* Overview of the approval process
* Approved pathways
* Pathways in process
* Promising emerging technologies
* Improvements to the qualification process
* Other efforts outside D4054



CAAFI®
COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

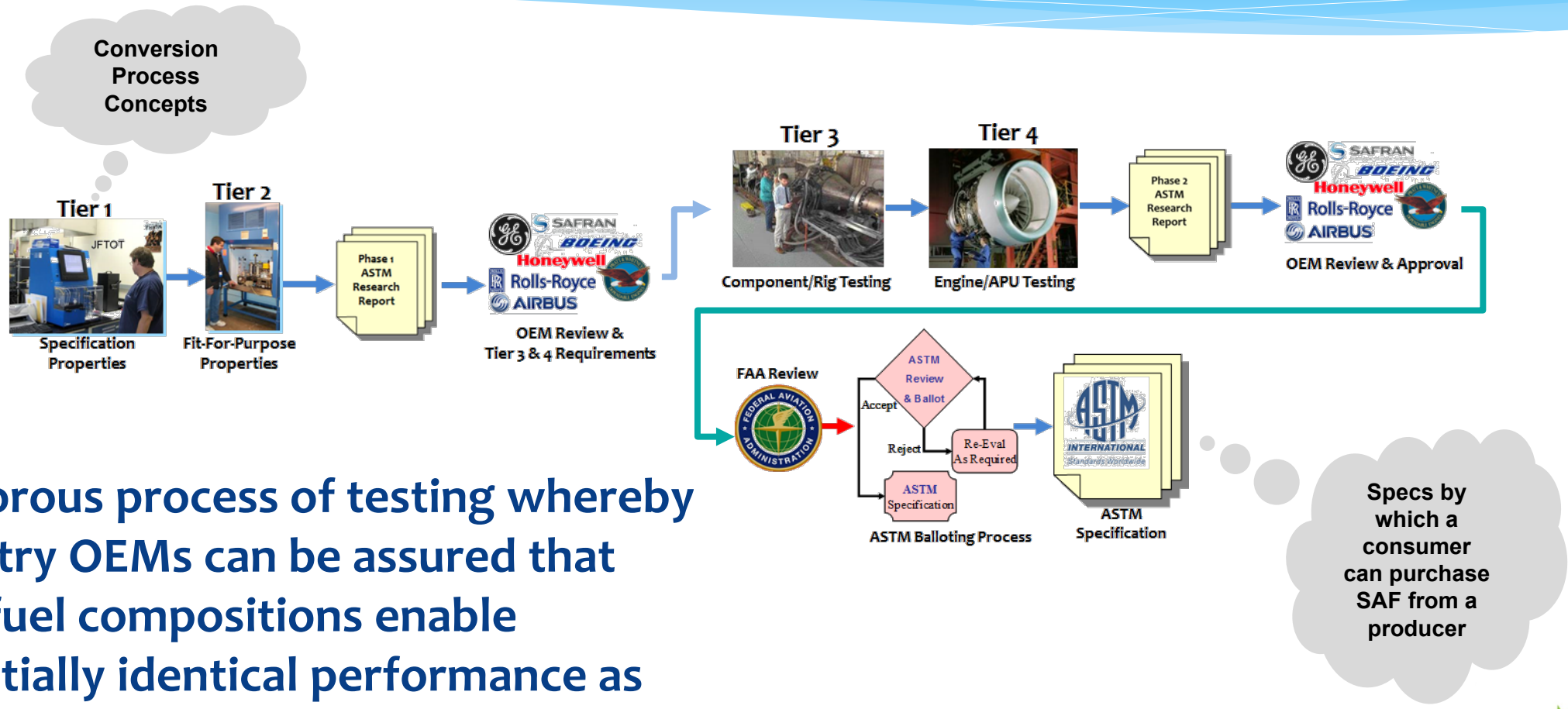
# Aviation industry path to SAF evaluation and qualification – foundation of enabling specifications

- **ASTM D1655 - Standard Specification for Aviation Turbine Fuels**
  - **A1.1.2 …** Aviation turbine fuels with synthetic components produced in accordance with Specification D7566 meet the requirements of Specification D1655.
- **ASTM D4054 - Standard Practice for Qualification and Approval of New Aviation Turbine Fuels**
  - **1.1** This practice covers and provides a framework for the qualification and approval of new fuels and new fuel additives for use in commercial and military aviation gas turbine engines…
- **ASTM D7566 - Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons**
  - **1.2 …** Aviation turbine fuel manufactured, certified and released to all the requirements of this specification, meets the requirements of Specification D1655 and shall be regarded as Specification D1655 turbine fuel.



CAAFI®
COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

# Industry approval of SAF via D4054 Process

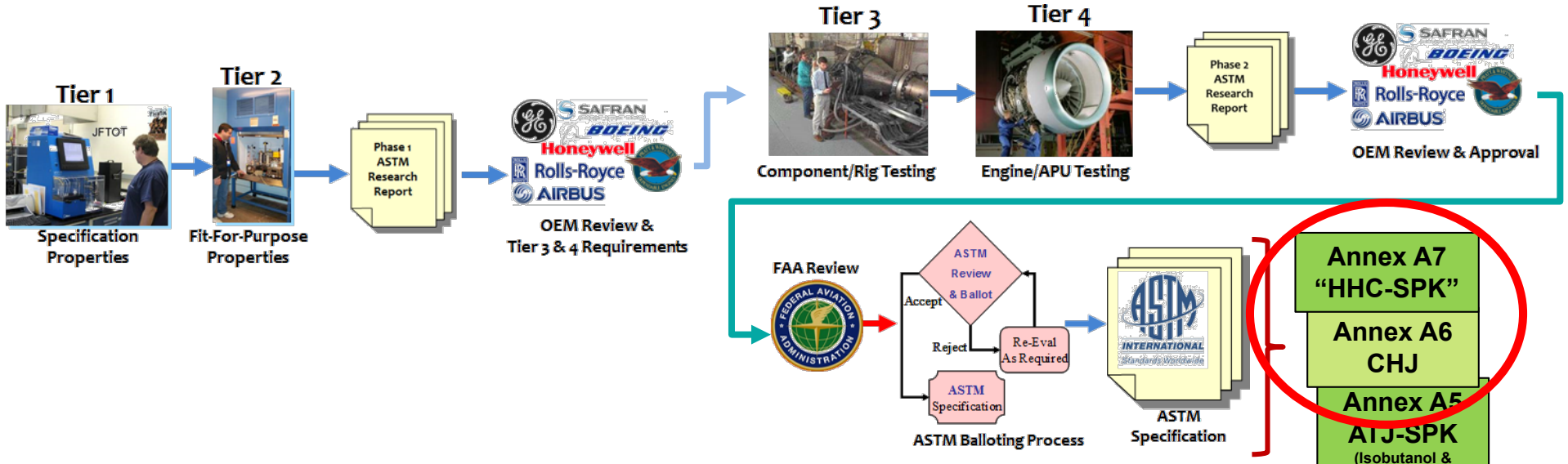



* A rigorous process of testing whereby industry OEMs can be assured that new fuel compositions enable essentially identical performance as petroleum-derived jet fuel



CAAFI®
COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

# Industry approved SAF Pathways




Annex A7 "HHC-SPK"
Annex A6 CHJ
Annex A5 ATJ-SPK (Isobutanol & ethanol)
Annex A4 FT-SKA
Annex A3 HFS-SIP
Annex A2 HEFA-SPK
Annex A1 FT-SPK

**D1655 Feedstock Expansion**

- FT Biocrude Co-processing (D1655)
- FOG Co-processing (D1655)

**Find additional details in either ASTM D7566 or keep up to date at:**
http://www.caafi.org/focus_areas/fuel_qualification.html

CAAFI® COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

# D7566 Annex A6 – CHJ

- Published 29Jan'20
- Feedstock is fatty acids and fatty acid esters (FOG)
- Process – Catalytic Hydrothermolysis
- Blending required, 50% max blend limitation
- ARA intent to commercialize with Hydrothermal Clean Up (HCU) front end, expanding availability of previously unused feedstock sources
- Work underway with producers on multiple facilities
- Euglena operating pilot facility in Japan




CAAFI®
COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

# D7566 Annex A7 – "HHC-SPK"

- Approval balloting finalized 02Apr. To be published 2Q'20.
- Tweak to HEFA production that utilizes biologically derived hydrocarbons (*Botryococcus braunii* produced triterpenes), or Bb oil, as opposed to fatty acids and fatty acid esters only
- First pathway to utilize FAA Clearinghouse as well as D4054 Fast Track Process
- Blending required, 10% max blend limitation

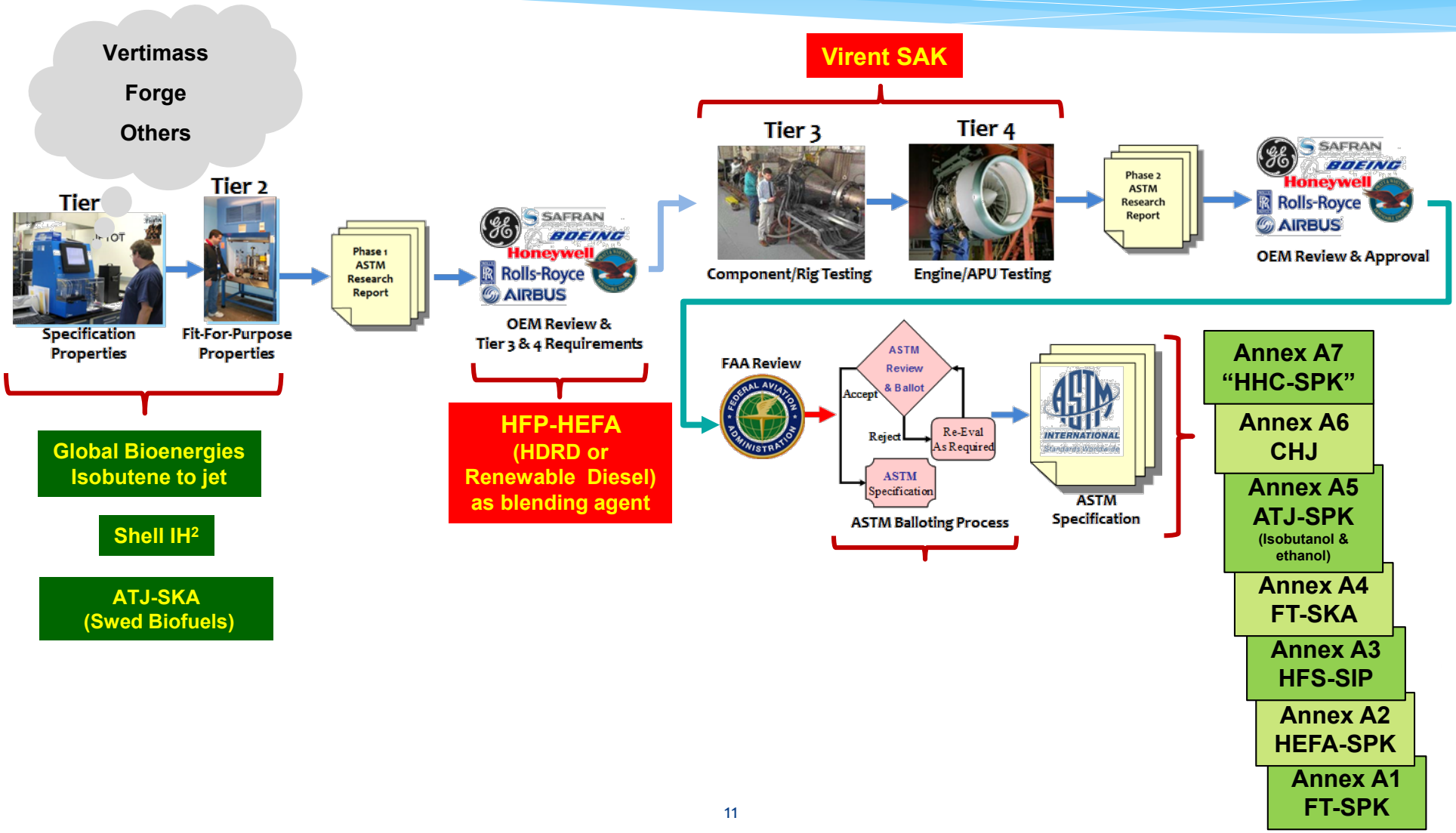
- Driven by Ishikawajima-Harima Heavy Industries (IHI), a comprehensive heavy-industry manufacturer working to create value for customers in four main areas including Aero Engines, Space and Defense. Intending to use fuel to support pending Olympic flights. (https://www.ihi.co.jp/csr/english/index.html)




CAAFI®
COMMERCIAL AVIATION
ALTERNATIVE FUELS INITIATIVE

# In process SAF Pathways, via D4054 process

## Additional technologies applicable to SAF






CAAFI® COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

# ASTM D4054 pipeline examples

| Approach | Feedstock | Companies |
|---|---|---|
| ATJ Expansion | Alcohols (via sugars) | Swedish Biofuels*, Byogy |
| HDCJ (direct or co-processing) | Lignocellulose | Ensyn/Envergent, REC |
| Microbial conversion | Isobutene (via sugars) | Global Bioenergies* |
| HTL | Lignocellulose | Steeper, Genifuel, … |
| Catalytic HTL | Lignocellulose | Licella, Muradel, QUT |
| Thermal Deoxygenation | Lipids | Forge Hydrocarbons* |
| SBI CGC PICFTR | Lipids - biodiesel | SBI Bioenergy / Shell |
| Acid Deconstruction | Lignocellulose | Mercurius |
| Bio-TCat (thermal catalytic) | Lignocellulose | Anellotech* |
| CCL | Lipids | |
| CHyP (syngas, non-FT) | Lignocellulose | |
| Hydrogenotrophic Conv. | $CO_2$ / Producer Gas | |
| Cyanobacterial Prod. | $CO_2$ | |
| STG+ GTL | C1-C4 Gas / Syngas | |
| Ionic Liquid Decon. | Lignocellulose | |
| Metal Catalytic Conversion | Lignocellulose | |
| Enzymatic Conversion | Lignin | |

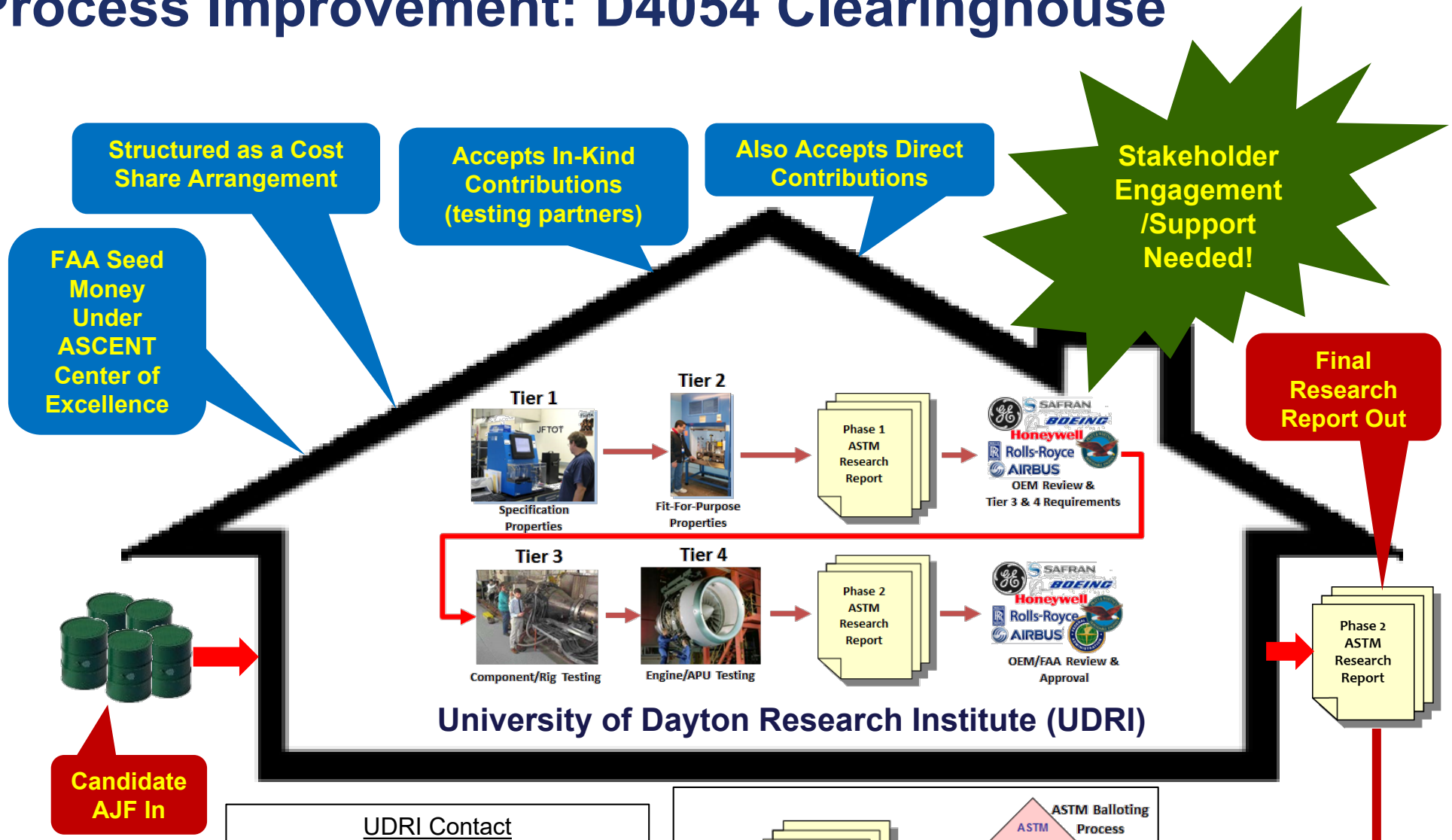
*** Recent outreach to CAAFI R&D Team, ASCENT C.H. and/or OEMs**

CAAFI®
COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

# Promising emerging technologies

- Those that lower cost or increase value
  - Lower CapEx
  - Lower OpEx – enabling use of low-cost, plentiful, 24x7 type feedstocks
  - Integrated systems
  - Finding higher value for production slip streams or byproducts
  - Capturing value from other environmental services
  - Driving to ultra low CI scores to increase value from rewarding policy
- Steady stream of low TRL examples for the above
- In some other cases, difficult to envision near-term tangible progress

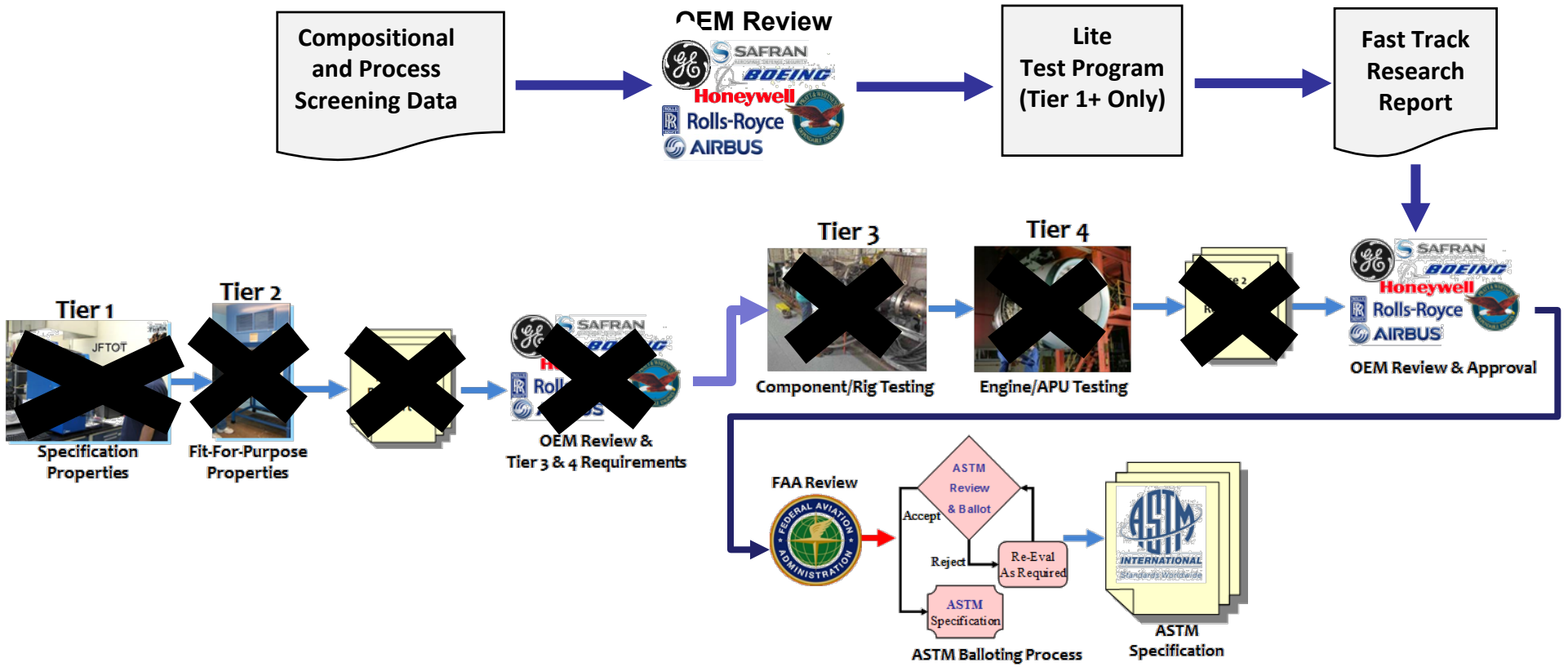
# D4054 Process Improvement: D4054 Clearinghouse





UDRI Contact
Dr. Steven Zabarnick
Steven.Zabarnick@udri.udayton.edu
(937) 255-3549

# D4054 Process Improvement: Fast Track Annex




***For AJF's with Conventional Hydrocarbon Compositions***

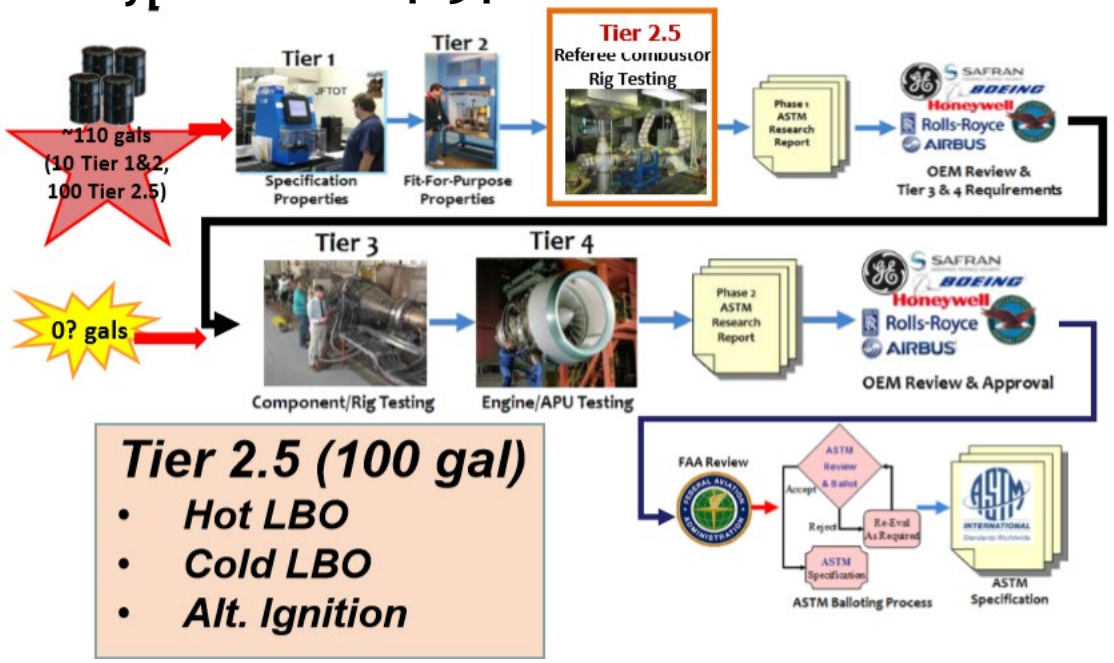
***Limited to a 10% Blend Percentage***

# Other activities facilitating fuel qualification
## Application of NJFCP

**Utilization of knowledge being gleaned from National Jet Fuel Combustion Program (NJFCP), multi-year collaborative effort initiated under FAA ASCENT**

- Assist OEMs in understanding implications of shifts in jet fuel composition by using a simpler set of physical tests and analysis …
  - Referee combustor rig, spray rig, CFD, DCN calculation
- … that can predict combustion behavior for pinch points
  - Lean blow-out, cold start, altitude relight, transient operation
- Potentially giving OEMs more confidence for limiting Tier 3 or 4 mandated testing => leading to savings in time, money and use of scarce testing resources
- Could eventually lead to changes in D4054 process
  - Back-to-back work being done with Shell IH² candidate fuel with this in mind

**Hypothetical D4054 revision:**






CAAFI®
COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

# Other activities facilitating fuel qualification
## Initiation of AJF Prescreening methods by CAAFI R&D Team

**As identified historically by OEMs, and recently validated via the work of the NJFCP, the most important fuel properties affecting airplane/engine operability are:**

- **Viscosity at -20 and -40 °C**
- **Distillation curve**
- **Mass density**
- **Flashpoint temperature**
- **Derived Cetane Number (DCN)**
- **Surface tension**

- **What is the most expeditious way to determine if candidate fuel components meet these needs?**



CAAFI®
COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

# CAAFI R&D Team fuel prescreening efforts

* Tier $\alpha$ - testing methods for chemical composition characteristics that require very low volumes of fuel have been identified to predict key performance properties
  - GCxGC (<1 mL)
  - Mid-IR absorption (<100 mL)
  - NMR (<10mL).
* Tier $\beta$ - the evaluation of fuels with the listed methods facilitates the direct comparison of AJFs to conventional fuel and previously approved AJF, minimizing future uncertainty.

*Table 1: Minimally Recommended Tier 'ZERO' properties*

| Property | ASTM Test Method | Approximate Volume Required |
|---|---|---|
| Viscosity | D445 | 20 mL |
| Distillation | D2887 | *From GC x GC/Tier α* |
| Density | D4052 | 5 mL |
| Flash Point | D56 | 50 mL |
| Surface Tension | D1331A | 10 mL |
| DCN | D6890 | 200 mL |
| Swelling | | 150 mL |

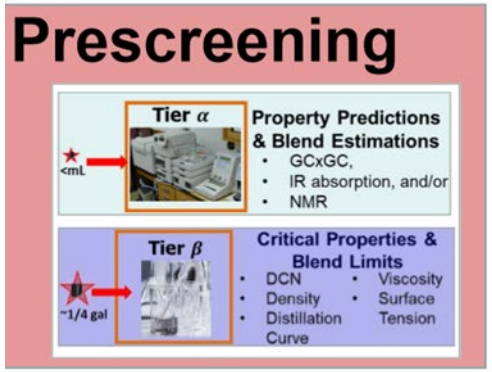
**Note that Tier α and Tier $\beta$ testing collectively requires only ~500 mL of neat fuel for limited and targeted tests that might save voluminous fuel and cost requirements.**



CAAFI®
COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

# CAAFI R&D Team fuel prescreening efforts

## 19 Fuels Currently Being Evaluated Under NJFCP Methods (P25 & 65)




| Tier | $\mathcal{O}$(gal) | # of Samples (20 March) |
|---|---|---|
| α | ~$10^{-6}$ | 18 |
| β | ~$10^{-1}$ | 7 |
| 1 & 2 | ~$10^{2}$ | |
| 2.5 | ~$10^{2}$ | 1 |
| 3 & 4 | ~$10^{3}$ | |

- 19 fuels are being evaluated via Tier α, β, and 2.5
- DOE funding for some testin
- Properties are used to predic Tier 2.5 behavior (FOM) as learned through the NJFCP.

Version 1.0, Sep. 2019

CAAFI

Research & Development Team
Technical Guidance Document[a]

**Prescreening of synthesized hydrocarbons intended for candidates as blending components for aviation turbine fuels (a.k.a. alternative jet fuels or AJF)[b]**

INTRODUCTION

The aviation industry's evaluation and qualification process for synthesized jet fuel components, as detailed in ASTM D4054[c] and elsewhere,[1] can involve four tiers of testing, two research reports, and three balloting junctions. This process can be resource-intensive but ensures that any alternative fuel specification approved by the industry outlines the production of safe, fungible Alternative Jet Fuel (AJF) that is compliant with stakeholder demands arising from their insights into the need for such physical and fit-for-use properties. However, this process can span multiple years at significant cost to all parties involved, making mid-course fuel qualification corrections painful to prospective AJF developers. The extensiveness of this process has highlighted a need for early-stage, low volume, low cost, and rapid prescreening techniques outside the formal ASTM D4054 approval and evaluation process; especially those that relate to the assessment of jet engine combustor operability, which are among the most expensive testing requirements of the evaluation process. This document identifies prescreening methods that can provide early-stage confidence to fuel developers on whether AJF formulations might encounter downstream challenges with the completion of the ASTM D4054 evaluation process.

These prescreening methods have been developed from learning acquired from the National Jet Fuels Combustion Program (NJFCP),[2] JETSCREEN,[3] prior industry approvals of AJF, and other associated AJF programs. These methods do not replace the ASTM D4054 evaluation process and its requirements. However, results from this prescreening should provide an early assessment of whether serious combustion issues could be encountered in the formal approval process. This could help AJF developers make early decisions on AJF composition or production processes that could help facilitate later approval, either for Fast-Track or Standard approvals (see ASTM D4054 Standard Practice).

[a] Prepared by members of the National Jet Fuel Combustion Program (NJFCP) and other CAAFI constituents to facilitate the early evaluation of new jet fuel component candidates in conjunction with a potential producers' engagement with the aviation community via CAAFI through their R&D Team. Special thanks to Dr. Joshua Heyne of the University of Dayton for his expertise and commitment to identify and formulate this pre-screening protocol enabling the early assessment of candidate AJF viability.
[b] After completion of the blending requirements of ASTM D7566, and meeting various sustainability criteria, these AJF may also be referred to as drop-in Sustainable Aviation Fuels (SAF), the aviation industry's current consensus naming convention.
[c] ASTM International publication, Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives.

5-Sep-19

Page 1 of 6

**Find additional guidance at:**
http://www.caafi.org/tools/docs/CAAFI_RD_Prescreening_Guidance_Document_v1.0.pdf



CAAFI
COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

# Other qualification tid-bits

* CAAFI to continue conferring producers from R&D to Qualification
* EU and UK considering European Clearinghouses
* ASTM D02.J Task Force established to evaluate considerations for blending of blending components
* Working toward consideration and approval of 100% drop-ins
  * Primary need is to demonstrate process performance, control, and management of change, suggesting the need for data from several production facilities before consideration
* With continued amassing of data and experience, will we in the long term be able move to more of a compositionally based spec?

# 3) State of SAF Market Pull

* Current market pull and influencing factors
* Offtake agreements
* Other commitments
* Other efforts

* More information about current-event impacts to airlines can be found at:

  https://www.airlines.org/dataset/impact-of-covid19-data-updates/

  https://www.iata.org/en/publications/economics/



CAAFI®
COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

# Current market pull

- Commercial and Business Aviation really are interested in acquiring supply, but with some caveats, the most important being affordability.
- Despite distractions (COVID, price of oil, survival), activities continue, including the last several weeks:
  - Several new producer explorations and outreach
    - Introductions to airlines and fuel suppliers
  - Airport instigation of broader engagement by State governments (SFO)
  - Third party explorations, including from trend-setting corporations
  - Heightened government interest in helping (both with R&DDD and policy)
- Expect interest to continue to develop based on societal influence, policy, regulation, …
- Industry working a policy approach to level the playing field with diesel, and enable petro-jet price parity for some cases.
- Difficult environment at present … We're in it for the long haul!

CAAFI®
COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

# SAF offtake agreements

## Beyond numerous demonstration programs

neat quantities

world energy Paramount *

* WEP also continues supplying fuel for multiple trial and research activities. Also moving forward with $350M expansion to enable 306M gpy total capacity & jet capacity of 150M gpy; 24Oct'18

UNITED = Up to 5 M gpy from 2016 (LAX)

World Fuel Services + Gulfstream = Multi yr agreement 30/70 blend

SkyNRG NORDIC + FINNAIR + AIRFRANCE KLM + SAS + OSLO AIRPORT + air bp + Lufthansa Group = Bioports on demand, et al.

Halmstad
Arlanda
Bromma
Goteborg
Leeuwarden

Fulcrum BIOENERGY

CATHAY PACIFIC = 37.5M gpy

UNITED = 90-180 M gpy

air bp = 50 M gpy

JAPAN AIRLINES + JOIN + Marubeni = Project Development, License, and Offtake

10 yr agreements

CAAFI® COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

# SAF offtake agreements – pg 2

## Beyond numerous demonstration programs

neat quantities

| | | | |
|---|---|---|---|
| RED ROCK BIOFUELS | Southwest | = | 3 M gpy each, 7 yrs (Bay Area, CA) |
| | FedEx | = | |
| SG Preston | jetBlue | = | 10M gpy, 10 yrs (JFK) |
| | QANTAS | = | 4M gpy, 10 yrs (LAX) |
| SkyNRG NORDIC | KLM | = | 24M gpy, 10 yrs |
| | Shell | = | SAF Supply collaboration |
| LanzaTech * capturing carbon fueling growth | ANA | = | Supply from 2021 |
| | virgin atlantic | = | UK DfT F4C Funding: ATJ Development |

* 100M gpy by 2024 from 4 facilities

CAAFI® COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

# SAF offtake agreements – pg 3

| | | effort |
|---|---|---|
| | American Airlines, DFW Dallas Fort Worth International Airport, Alaska | SAF Supply explorations |
| NESTE + | air bp, Lufthansa, jetBlue, KLM = | SAF Q4'18 restart at Porvoo, ~33M gpy rate, 330M gpy with Singapore by 2022; Supply to SFO, AMS; Supply agreement with AA |
| + | AVFUEL / AIR TOTAL = | Up to 1M gpy, 5 yrs+ / France & EU supply |
| gevo + | SAS = | No detail released |
| + | DELTA = | 10M gpy, from 2022/2023 term/blend unspecified |
| NORTHWEST ADVANCED BIOFUELS + | DELTA = | Grays Harbor, WA feasibility study, and offtake agreement, tbd |

*Combined, these offtakes/efforts represent >350 M gpy, and account for the total production slate of the first several commercialization efforts*



CAAFI® COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

# Other recent announcements

effort

| | | | | |
|---|---|---|---|---|
| Multiple Producers, TBA | + | World Fuel Services, AVFUEL | = | Full production slate offtakes |
| preem Gothenburg Refinery | + | SAS | = | Long-term supply negotiation (from 2023). Fueling all domestic flights by 2030. |
| TOTAL \| AMYRIS Others, TBA | + | Cathay Pacific, Alaska, jetBlue, Delta, ANA, China Airlines | = | New Aircraft Deliveries from Airbus and Boeing |
| TBA | + | Finnair | = | Customer funding of SAJF purchase from 2019 |
| Multiple Producers & Suppliers | + | Airports and Airline Tenants: Port of Seattle, Seattle-Tacoma International Airport, SFO | = | Exploration of Greater ambition |

CAAFI® COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

# Other recent announcements

| | | | | |
|---|---|---|---|---|
| | | | | effort |
| VELOCYS | + | BRITISH AIRWAYS | = | MSW-based FT-SPK evaluations |
| | + | In negotiation | = | BTL #1, Natchez, MS 1,400 bpd |
| AGRISOMA nuSEED | + | QANTAS | = | Carinata supply development |

# Airline commitments of greater ambition

| | |
|---|---|
| FedEx | Obtain 30% of jet fuel from alternative sources by 2030; 06Nov'17 |
| UNITED | First U.S. Airline to Pledge to Reduce Own Emissions by 50% (vs. 2005) by 2050; 13Sep'18. $40M SAF Investment Fund; 27Oct'19 |
| SpiceJet | Commits to flying 100 M passengers on SAF by 2030; 23Sep'19 |
| AIRFRANCE | Horizon 2030: offset 100% of domestic $CO_2$ from 2020; reduce 2030's $CO_2$/pax-km by 50% from 2005; R&D for French SAF industry; 01Oct'19 |
| IAG INTERNATIONAL AIRLINES GROUP | Net-zero carbon by 2050, offsetting all domestic emissions by 2020; 10Oct'19 |
| QANTAS | Net-zero carbon by 2050, CNG from 2020 on all emissions, $33M investment in SAF by 2030, matching of customer offsets; 25Nov'19 |
| SAS | SAF corresponding to the total jet consumption used in all SAS domestic flights, by the year 2030; 14Nov'19 |
| FINNAIR | Reduce its net emissions by 50% from 2019 by the end of 2025, and achieve carbon neutrality by 2045 at the latest; 09Mar'20 |

**Multiple airlines now committing to net zero carbon by 2050.**
**Pressure to look at more progress by 2035.**



CAAFI®
COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

# Commitments of Greater Ambition

## Airlines using passenger booking options to offset cost

BRAATHENS REGIONAL AIRLINES

Customer option to pay for incremental price of SAF of €29.50 on any flight

SAS

Customer option to pay for incremental price of SAF in 20-min blocks of flight time for €10 / block (up to 80% $CO_2$ reductions); fuel being allocated to future flights

Lufthansa

Compensaid – calculates specific cost of SAF for specific flights and enables customer to pay for incremental price

FINNAIR

Customer option to pay for incremental price of SAF for 3 categories of flight: intra-Finland (€10), intra-EU (€20), International (€65); fuel being allocated to future flights



CAAFI® COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

# Other commitments of greater ambition

**Norway's government introduces 0.5 % blending mandate for advanced aviation biofuels from 2020; 04Oct'18**

**Netherlands committed to transition all military aircraft to 20/80 AJF blend by 2030 and 70% by 2050; 23Jan'19**

**France, in alignment with EU Green Deal goals, announces SAF targets: 2% of SAF from 2025, 5% in 2030 and 50% in 2050; 27Jan'20**


**DG Move have now put together a comprehensive "roadmap" as a potential way forward for an integrated approach for policy intending to foster SAF commercialization in the European Union - ReFuelEU**



CAAFI®
COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

# Paradigm changing announcements
## Intent to help close price premiums

Rocky Mountain Institute + World Economic Forum — Clean Skies for Tomorrow Program

The Good Traveler — Resilient and Sustainable Aviation Fuel (RSAF) credit

SkyNRG NORDIC — Fly Green Fund → BOARD NOW coalition for sustainable flying

Microsoft, AIRFRANCE KLM, DELTA — Purchase of SAF for US-Netherlands flights (beyond offsetting employee travel)

Energy for Airlines — ***SAF Now Consortium*** launch, 15Nov'19

CAAFI® COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

# 4) State of SAF production

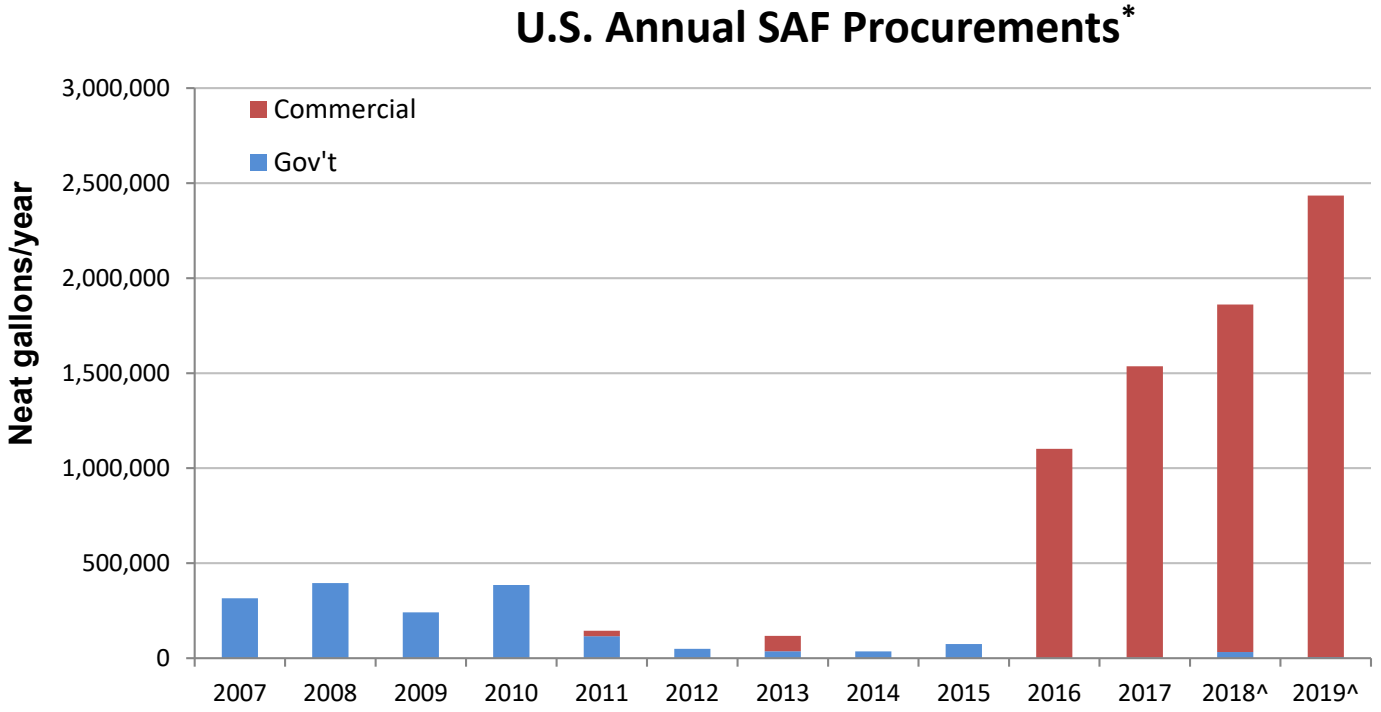
* 2016 - 2019 production and use
* Current commercial capacity & Near term projections
* Long term projections



CAAFI®
COMMERCIAL AVIATION
ALTERNATIVE FUELS INITIATIVE

# Where we stand on U.S. SAF commercialization
## Initiation under way, still early

- Four years of sustained commercial use
- Commercial & General Aviation engaged
- One+ facilities in operation
- Two facilities under construction, others in development
- Cost delta still a challenge, with renewable diesel favored policies
- We know what impact policy had on the ramp-up of ethanol and bio-diesel / renewable diesel – it can be replicated for SAF

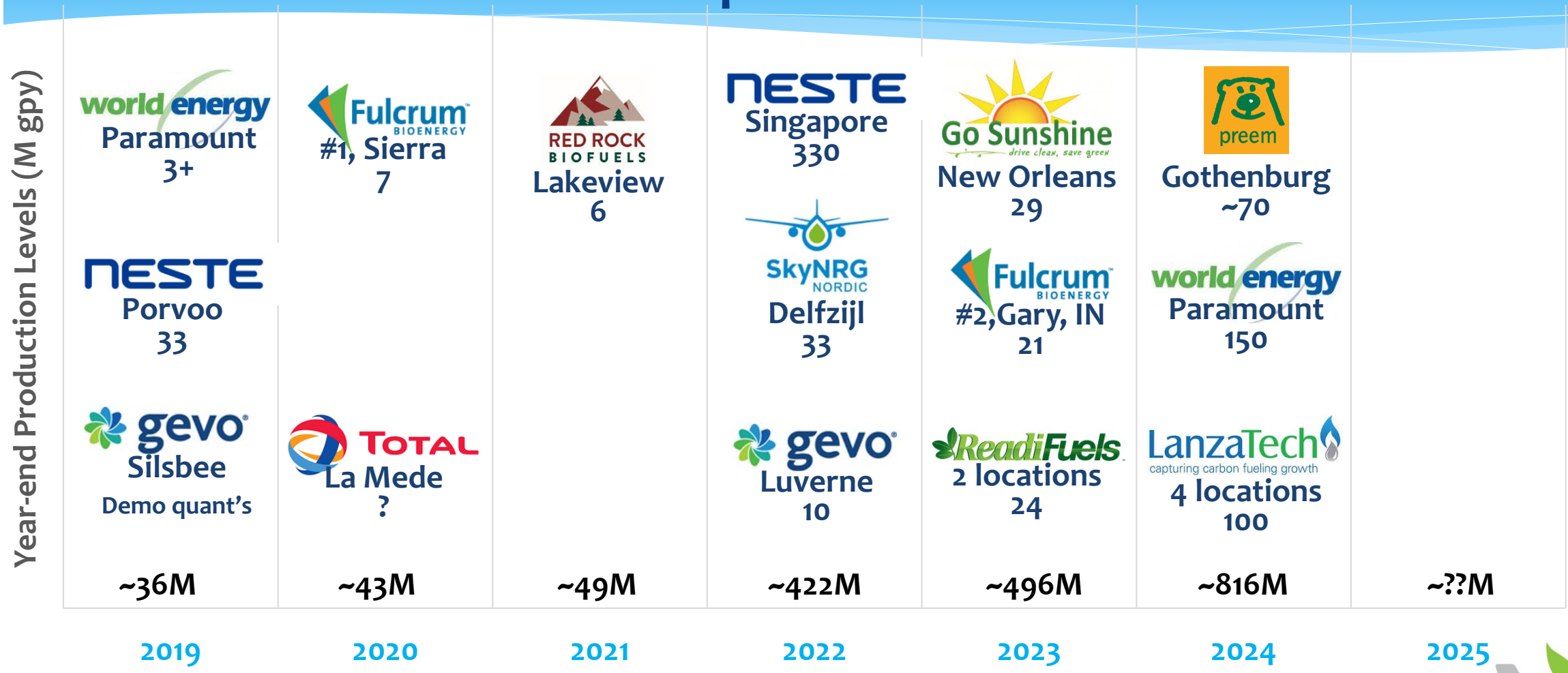



Credit: FAA

*Reflects voluntarily reported data on use by U.S. airlines, U.S. government, manufacturers, other fuel users, and foreign carriers uplifting at U.S. airports.
^2018 & 2019 calculation includes reported RFS2 RINs for jet fuel.

CAAFI®
COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

# Worldwide SAF production forecast
## Announced intentions with specific commitments to SAF




Not comprehensive; CAAFI estimates (based on technology used & public reports) where production slates are not specified

CAAFI
COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

# U.S. commercialization activity / intent
## HDRD (& SAF?) from lipids/F.O.G.

- Diamond Green: Norco, LA
- REG: Geismar, LA
- World Energy: Paramount, CA
- Diamond Green expansion (275 -> 675M)
- REG Geismar expansion (75 -> 115+M)
- World Energy Paramount (40 -> 305M)
- Andeavor Dickinson, ND conv. (180+M)
- ~~Phillips 66 / REG: Ferndale, WA~~ Looking elsewhere?
- Rhyze / Phillips 66: Reno & Las Vegas, NV (150+M)
- SG Preston: pivot announcement pending
- NEXT / Shell (575M)
- ARA licensing build-out (4+ activities)
- HollyFrontier (125 M)
- Texmark HDRD distillation
- Emerald (100M gpy)
- Tolling (Steamboat - 100M) / Co-processing

In Production: 390 M gpy Nameplate @ YE '19

In Development: Greater than 2.2B gpy capacity by 2025 !?!

Pertinent to aviation interests in 3 ways:

- HFP-HEFA
- Direct HEFA-stream distillation pivot
- Downstream fractionation

… necessitates serious engagement with purpose grown oilseed & F.O.G. development / expansion

CAAFI®
COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

# Additional forecasts – mid and far

- IATA/ATAG Waypoint 2050 activity in process
- ICAO funded research on long term possibilities of SAF penetration
  - Scenario analysis found an extremely broad range of outcomes, from 0 to 100% replacement by SAF. ICAO defined a Vision 2050 level of 50% SAF replacement.
  - Laundry list of support identified. Key criteria summarized as:
    - *…encourage States to implement the proposed developments in policy, technology and financing in order to … progress towards the ICAO Vision*
- CAAFI is often asked about SAF scale-up, and responds with observation that airlines will buy all available SAF when it is competitively priced, including consideration of policy mechanisms



CAAFI®
COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

# People then ask: When will SAF offer petro-jet equivalent pricing?

## We need answers to these questions first:

* What is the long-term price trend for petroleum?
* What will be the impact on fuel prices from demands to lower fuel sulfur content or HAPs to meet air quality mandates due health impacts?
* What will be the impact of refineries having to rebalance the production of gasoline, diesel, and jet as the former two decline due to technology shifts, while the latter climbs?
* What will be the pricing trend (based on availability of quality offsets) of a CORSIA based carbon credit over the next 25 years? How much competition for such offsets?
* Will businesses, and their related CSR obligations (either subscribed voluntarily, or driven their by their activist shareholders), drive use of SAF, as opposed to the airlines themselves?
* When will society agree on a true price of carbon? Beyond just nebulous Paris commitments.
* Will we see monetization of environmental services, and when?
* What happens with policy (regional, federal, world-wide), and how?
* How long do "low cost feedstocks" remain low cost?? How does conversion tech progress?
* What happens to other feedstock costs as a result of growing population and farming paradigms?
* Does renewable power become ubiquitous and sufficiently low cost to accelerate PtL?

# 5) Moving forward

* Challenges
* Recommendations to overcoming challenges



CAAFI®
COMMERCIAL AVIATION
ALTERNATIVE FUELS INITIATIVE

# Overall industry summary on SAF:

- SAF are key for meeting industry's commitments
  - Delivers net GHG reductions of 65-100%, other enviro services
  - Aviation enterprise aligned, representing a ~27B gpy US & ~96B gpy worldwide opt'y
  - CAAFI and growing cohort are working to foster, catalyze, enable, facilitate, …
  - Segment knows how to make it;  Activities from FRL 1 to 9
  - Pathway identified for fully synthetic (50% max blend today)
  - First 2 facilities on-line, producing SAF at various run-rates
  - Commercial agreements being pursued, fostered by policy and other unique approaches
- Making progress, but still significant challenges – only modest production: focus on enabling commercial viability for which waste streams will play significant role
- Potential for acceleration a function of engagement, first facilities' success replication, additional technologies that continue to lower production cost



CAAFI®
COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

# Potential for U.S. SAF build-out

## Targets of opportunity that do not compete for food or land use change

### SAF from various 24x7 feedstocks (GPY, using standard conversions and product slates)

"Waste" streams

| | |
|---|---|
| 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 | **Forestry residues** (30% of production uncommitted; potential of under-reporting in Billion Ton study) |
| 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) |
| ~15.6+B | **Current Total Potential (approx. 58% of total 2019 U.S. jet fuel demand)** |

**Additionally … Significant potential from sustainable, purpose-grown approaches under development (e.g. in SPARC and IPREFER)**

CAAFI®
COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

# Addressing Challenges – matrix of approaches

- A4A working general Federal policy approach – tax treatment
- Low Carbon Fuels Coalition working State Approaches – LCFS
- ABFA CARRI working shortcomings of current policy – RFS
- Multiple entities lobbying Congress for funding of Agency efforts
- CAAFI advocating for continued Agency focus and collaboration, aligning SAF development with stated priorities
  - FAA, DOE and USDA have multiple targeted efforts aligned with SAF development
- EU just announced their intention for DG MOVE to develop a comprehensive SAF development roadmap – "ReFuelEU Aviation – SAF"
- Unfortunately, many challenges are unique to specific pathways, diluting messaging that we actually need an "all of the above" approach

CAAFI®
COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

# E.g. General challenges – forestry feedstocks

- Volumes of policy-viable amounts (RFS restrictions); without policy, business case difficult
- Aggregation
  - Amounts from processing and mills are not "huge"
  - Collection of thinnings, and allowable thinning, tbd
  - NARA in-depth look at most commonly unused/wasted supply – slash piles
- Hauling (cost of moving air and water, nuisance issues)
- Although desire to use undergrowth (CA fire abatement) or dead material (BANR) is strong, have yet to see full business case pencil-out; RFS restrictions on use of feedstock from Federal Land
- Coppicing plantations
  - Establishment costs and time-to-harvest delay (AHB ongoing effort to find workable solutions)
- Energy densification technologies unproven or unintegrated – will potentially stay that way with uncertainties above, continued public deification of forests, forests used for "generating offsets," …
- Competition from pellets, mass-burn, …

# Be informed, help dispel the misconceptions

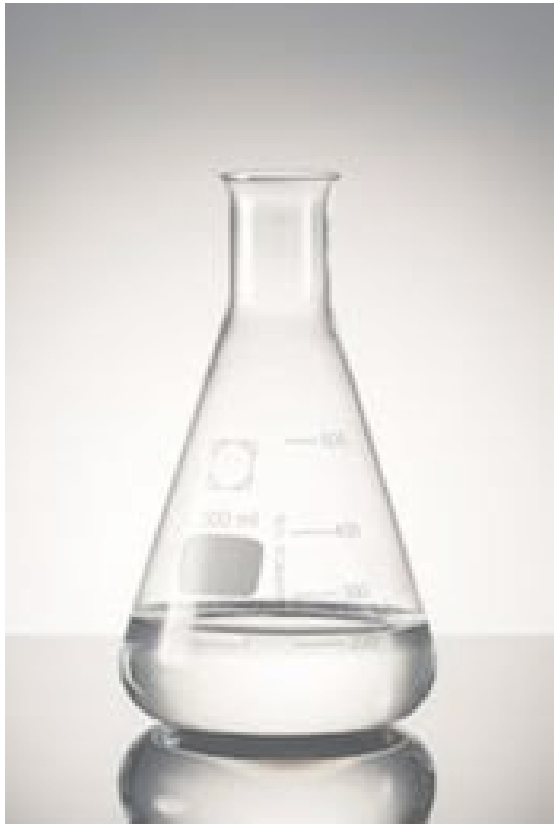
* SAF are still somehow unproven, unsafe, or inferior ✘
* SAF are a decade away from reality ✘
* SAF must be sequestered, or burden infrastructure / handling ✘
* SAF will have burdensome tracking requirements ?/✘
* The low price of oil has stopped all such efforts ✘
* All SAF is “food versus fuel” and ILUC beware ✘
* *Feedstock or conversion process xyz* will not be a major contributor ✘



CAAFI®
COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

**Steve Csonka**
**Executive Director, CAAFI**
**+1-513-800-7980**
Csonka.CAAFI.ED@gmail.com
Steve.Csonka@caafi.org
www.caafi.org
info@caafi.org

CAAFI®
COMMERCIAL AVIATION
ALTERNATIVE FUELS INITIATIVE



# Upcoming Events

**Pending CAAFI Webinars – stay tuned for announcement with dates**

- **EU supported R&D activity summary, 27May**
- **Economic Development tools review**
- **Canadian Challenge finalists update**

**ICAO has rescheduled Stocktaking Seminar: (gathering info similar to today's discussion content from worldwide participants)**

- **Online Preview held on 28Apr'20** Online Stocktaking Preview: Reducing Aviation In-Sector $CO_2$ Emissions
- **Physical meeting in Montreal on 8-10Sep'20** Seminar on aviation in-sector $CO_2$ emissions reductions

**ABLC – 08-10Jul'20 in D.C.**

**GARDN SAF Talk – being rescheduled**

**CAAFI CBGM – Summer 2021 in D.C.**

**Have an idea or interest? Let us know at info@caafi.org**



CAAFI®
COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE