# Efforts of the FAA to Address the Aviation Climate Change Challenge


Prepared for: IWACC 2021

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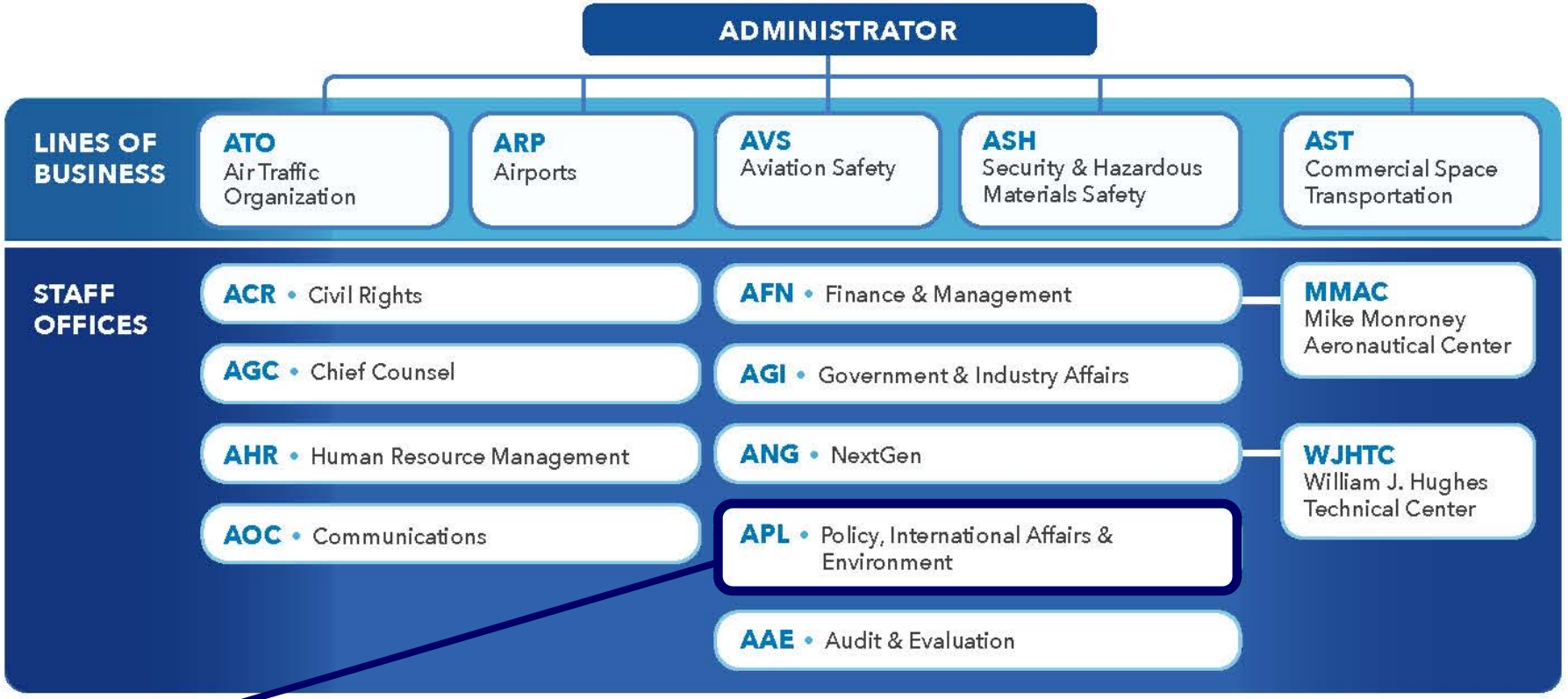
# FAA Organizational Structure




**Office of Environment and Energy (AEE)**

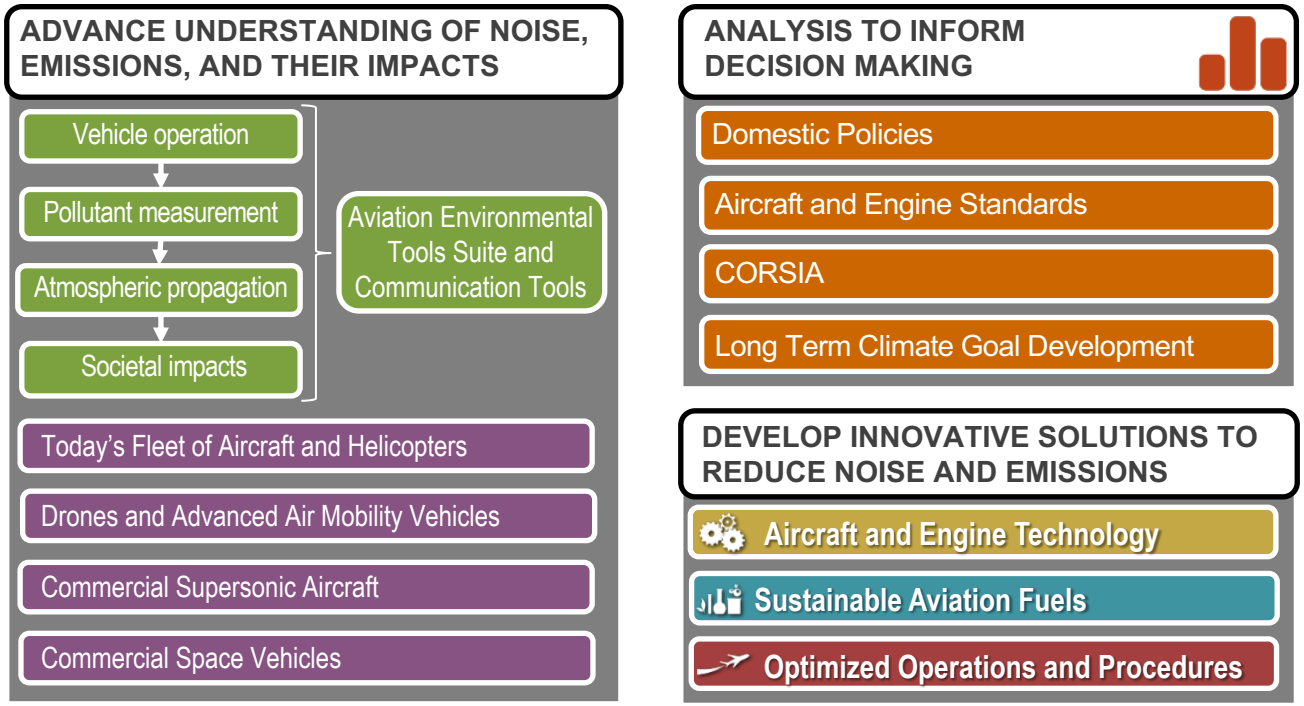
- Office within APL, responsible for broad range of environmental policies
- Roughly 45 staff members
- Responsible for roughly one-fourth of FAA RE&D Budget

# Environmental & Energy (E&E) Strategy

**E&E Mission:** *To understand, manage, and reduce the environmental impacts of global aviation through research, technological innovation, policy, and outreach to benefit the public*

**E&E Vision:** *Remove environmental constraints on aviation growth by achieving quiet, clean, and efficient air transportation*

## E&E R&D Portfolio Activities & Programs




ASCENT Aviation Sustainability Center
www.ascent.aero/

CLEEN Continuous Lower Energy, Emissions & Noise — Federal Aviation Administration
www.faa.gov/go/cleen/

CAAFI®
www.caafi.org/

the VOLPE center

# Environmental Impacts of Aviation

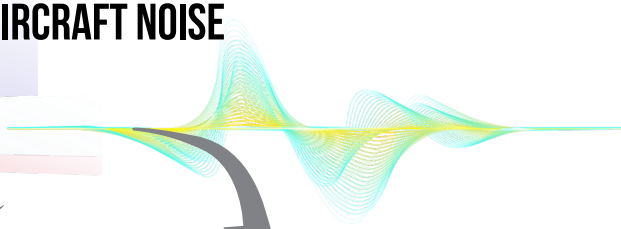
## COMBUSTION EMISSIONS

$CO_2$: 71%

Water: 28%

CO, HC, $NO_x$, $SO_x$, Primary $PM_{2.5}$: <1%

## AIRCRAFT NOISE



## ATMOSPHERIC CHEMISTRY & PHYSICS

Primary $PM_{2.5}$

$SO_x$

$NO_x$

UHC

CO

Secondary $PM_{2.5}$

Ozone

Primary $PM_{2.5}$

$SO_x$

$NO_x$

Ozone

$CH_4$

$CO_2$

$H_2O$

Contrails & Cirrus Clouds

## POPULATION EXPOSURE AND HEALTH IMPACTS

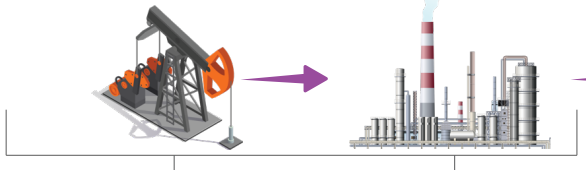
## GLOBAL CLIMATE CHANGE

Cooling Effects

Warming Effects

## OZONE LAYER

## EMISSIONS FROM FUEL PRODUCTION



$CH_4$, $N_2O$, $CO_2$

## SUSTAINABILITY IMPACTS

Slide created in collaboration with NASA ARMD

# Noise R&D Update

## Federal Register Notice

Provides comprehensive overview of FAA R&D efforts on noise

- Effects of Aircraft Noise on Individuals and Communities
- Noise Modeling, Noise Metrics and Environmental Data Visualization
- Reduction, Abatement and Mitigation of Aviation Noise

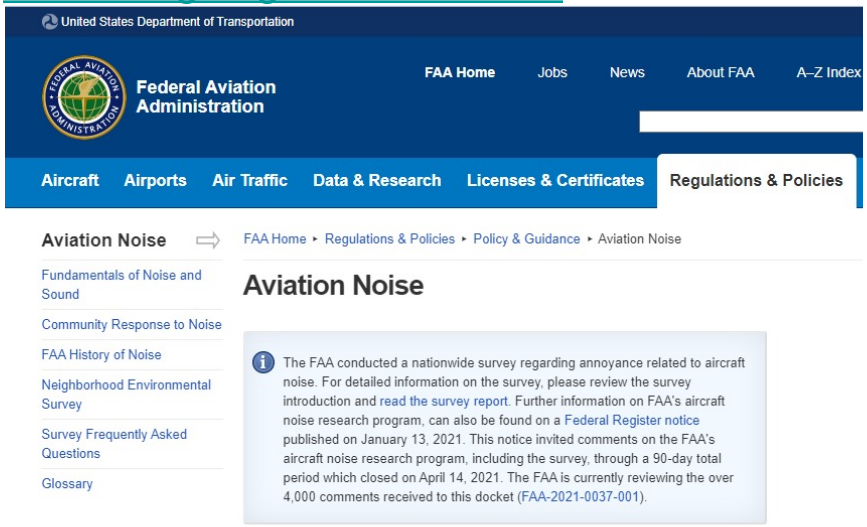
Includes neighborhood environmental survey results with a link to the full study

Expanded the aviation noise website to include details on the noise survey
https://www.faa.gov/regulations_policies/policy_guidance/noise/survey/

Have had extensive outreach on FRN including a public webinar on the Neighborhood Environmental Survey and Noise Research Portfolio on February 22, 2021.

Webinar link https://www.youtube.com/watch?v=Mku13gL0xGc

www.faa.gov/go/aviationnoise




# Biden Administration Commitment on Climate Change


- **Day One:** Took action to re-join the Paris Agreement
- **Executive Order 14008 on Tackling the Climate Crisis**
  - *"put the United States on a path to achieve net-zero emissions, economy-wide, by no later than 2050"*
- **Leaders Summit on Climate – April 23, 2021:**
  *"**Reducing emissions from international aviation.** The United States is committed to working with other countries on a vision toward reducing the aviation sector's emissions in a manner consistent with the goal of net-zero emissions for our economy by 2050, as well as on robust standards that integrate climate protection and safety. The United States intends to advance the development and deployment of high integrity sustainable aviation fuels and other clean technologies that meet rigorous international standards, building on existing partnerships, such as through ASCENT– the Aviation Sustainability Center – and pursue policies to increase the supply and demand of sustainable aviation fuels. In the International Civil Aviation Organization, we will engage in processes to advance a new long-term aspirational goal in line with our vision for reducing greenhouse gas emissions in the aviation sector, and continue to participate in the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)."*

Fact sheet from President Biden's Leaders Summit on Climate: https://www.whitehouse.gov/briefing-room/statements-releases/2021/04/23/fact-sheet-president-bidens-leaders-summit-on-climate/

# Climate Change - Direction of the R&D Portfolio

## Background on Aviation and Climate Change

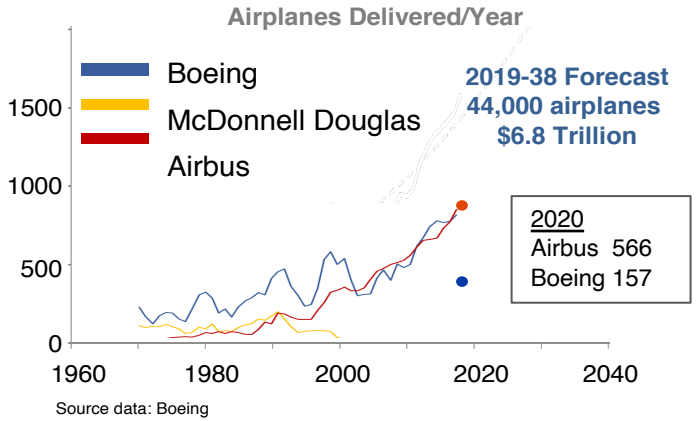
- Aviation has three primary contributors to climate change: $CO_2$ emissions, $NO_X$ emissions, and aviation-induced cloudiness
- Need to take a holistic approach to de-carbonizing aviation (SAF, technology, operations, policy) and ensure international leadership from the U.S. on aviation climate issues

## Climate Research Portfolio Direction

- Technology Development: required for both climate challenge and noise challenge
- Sustainable Aviation Fuels: most promising near to medium-term means to reduce aviation $CO_2$ emissions, will also be needed in long term
- Operational Procedures: seeking opportunities to reduce fuel use and laying ground work on decision support tools to address aviation induced cloudiness
- International leadership: R&D program provides the scientific data and analyses that are required for the U.S. to lead direction of international aviation climate negotiations
- Advancing Understanding: conducting research to better understand the impacts of non-$CO_2$ combustion emissions from all flight vehicles
- Analytical Tools: providing the models that are used across the globe to quantify aviation fuel burn and emissions
- Emerging Technologies and Energy Sources: need to give appropriate consideration to emerging technologies and concepts, but avoid looking for a “silver bullet”

# Global Competition and Environmental Pressure Increasing

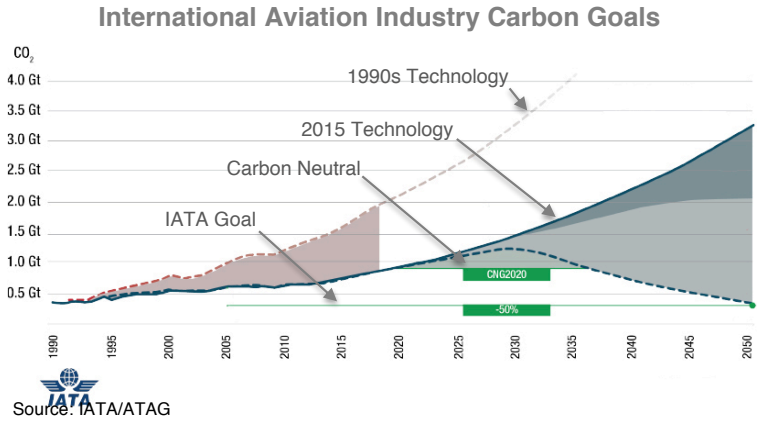
## Economic Perspective




Source data: Boeing

- Airline industry particularly hard hit by COVID-19*
  - U.S. passenger airline traffic fell 60.1% in 2020 (lowest since 1984)
  - The nine biggest US carriers lost $46 billion before taxes in 2020
- Global competition among manufacturers is growing
- Limited industry funding for needed R&D investments

## Environmental Context




Source: IATA/ATAG

- Societal pressure growing on climate globally
- Primary contributors to climate change: $CO_2$ emissions and aviation-induced cloudiness
- Broad community concerns in U.S. about aircraft noise
- Air quality continues to be a challenge in select areas
- Need to address environmental justice concerns

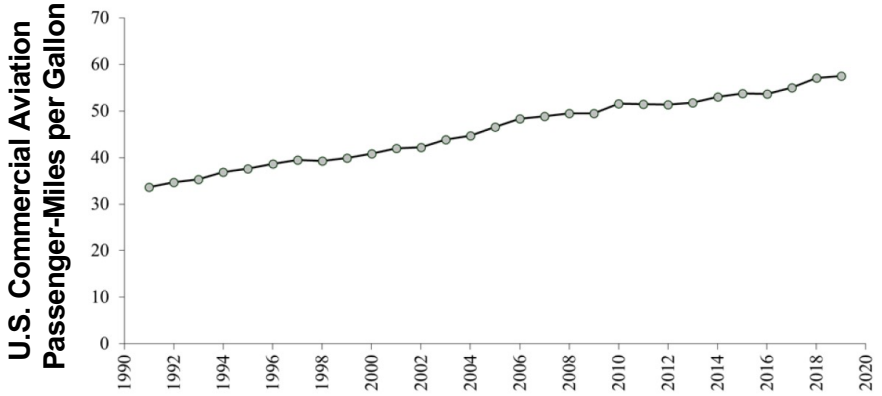
**Environmental challenges must be addressed to remain competitive in the global marketplace**

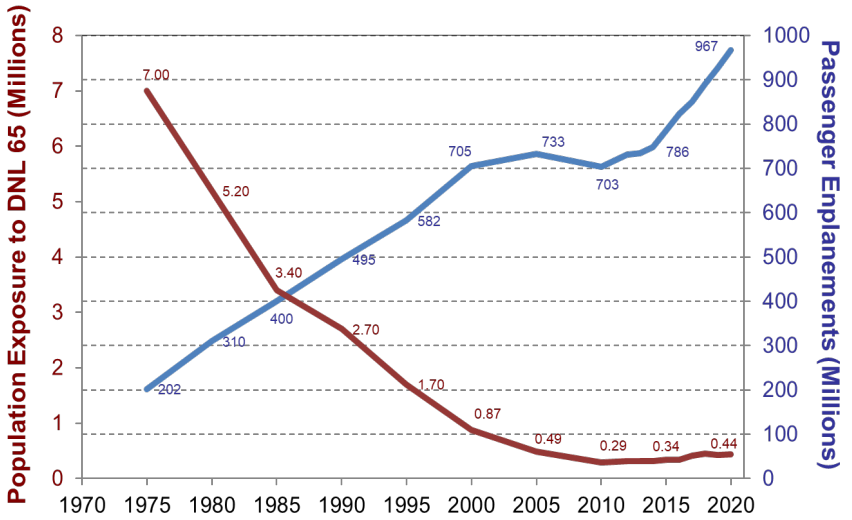
- **Environmental performance provides competitive edge**
- **National economy-wide carbon neutral goals: 2045 in Germany and Sweden; 2050 in Canada, Denmark, France, Hungary, Japan, New Zealand, South Korea, UK, and United States; 2060 in China**
- **$CO_2$ goals publicly stated by: Alaska Airlines, American Airlines, Delta Airlines, FedEx, JetBlue, United Airlines**

* https://www.reuters.com/article/us-health-coronavirus-usa-airlines/us-airline-passenger-traffic-fell-601-in-2020-dot-id

# Rationale for Investing in Aircraft Technology

- Historically, advances in aircraft technology have been the main factor in reducing aviation's environmental impact
- Continued improvements come with large technological risk
- COVID-19 pandemic has hit the aerospace sector particularly hard and the industry has considerably reduced ability to undertake research to advance new technologies
- Manufacturers have limited financial incentive to develop technologies to reduce noise and emissions
- Government resources help mitigate technological risk and incentivize aviation manufacturers to invest in and develop cleaner, quieter technology



# FAA R&D Efforts Relating to Aircraft Technology

## Continuous Lower Energy, Emissions & Noise (CLEEN) Program

- FAA partnership with industry - 100% industry cost share
- Focus on aircraft and engine technologies (CLEEN Phases I-III) and development of high performance fuels (CLEEN Phase III)
- Conducting ground and/or flight test demonstrations to accelerate maturation of certifiable aircraft and engine technologies
- Mature technologies from TRL 3-5 to TRL 5-7
- Individual companies use knowledge gained to improve their design methods

## ASCENT COE Efforts on Innovation and Technology

- FAA partnership with academia - 100% in-kind cost share*
- Focus on broad range of innovation solutions (technology, fuels, ops, etc.)
- Conducting ground and/or flight test demonstrations to accelerate maturation of certifiable aircraft and engine technologies
- Advance technologies at any TRL, but with understanding that FAA has a focus on applied R&D
- Universities use knowledge gained to improve knowledge broadly, but there are opportunities to examine specific technologies under Non Disclosure Agreements (NDAs)

ASCENT AVIATION SUSTAINABILITY CENTER

Continuous Lower Energy, Emissions & Noise CLEEN Federal Aviation Administration

NextGEN

For more information:

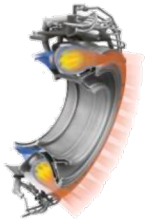
ASCENT: www.ascent.aero/ CLEEN: www.faa.gov/go/cleen/

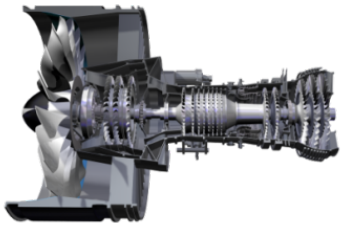
* Universities can apply for a cost share reduction to a 25/75 split instead of 50/50

# Continuous Lower Energy, Emissions & Noise (CLEEN) Program

- FAA led public-private partnership with 100% industry cost share
- Reducing fuel burn, emissions and noise via aircraft and engine technologies and alternative jet fuels
- Conducting ground and/or flight test demonstrations to accelerate maturation of certifiable aircraft and engine technologies

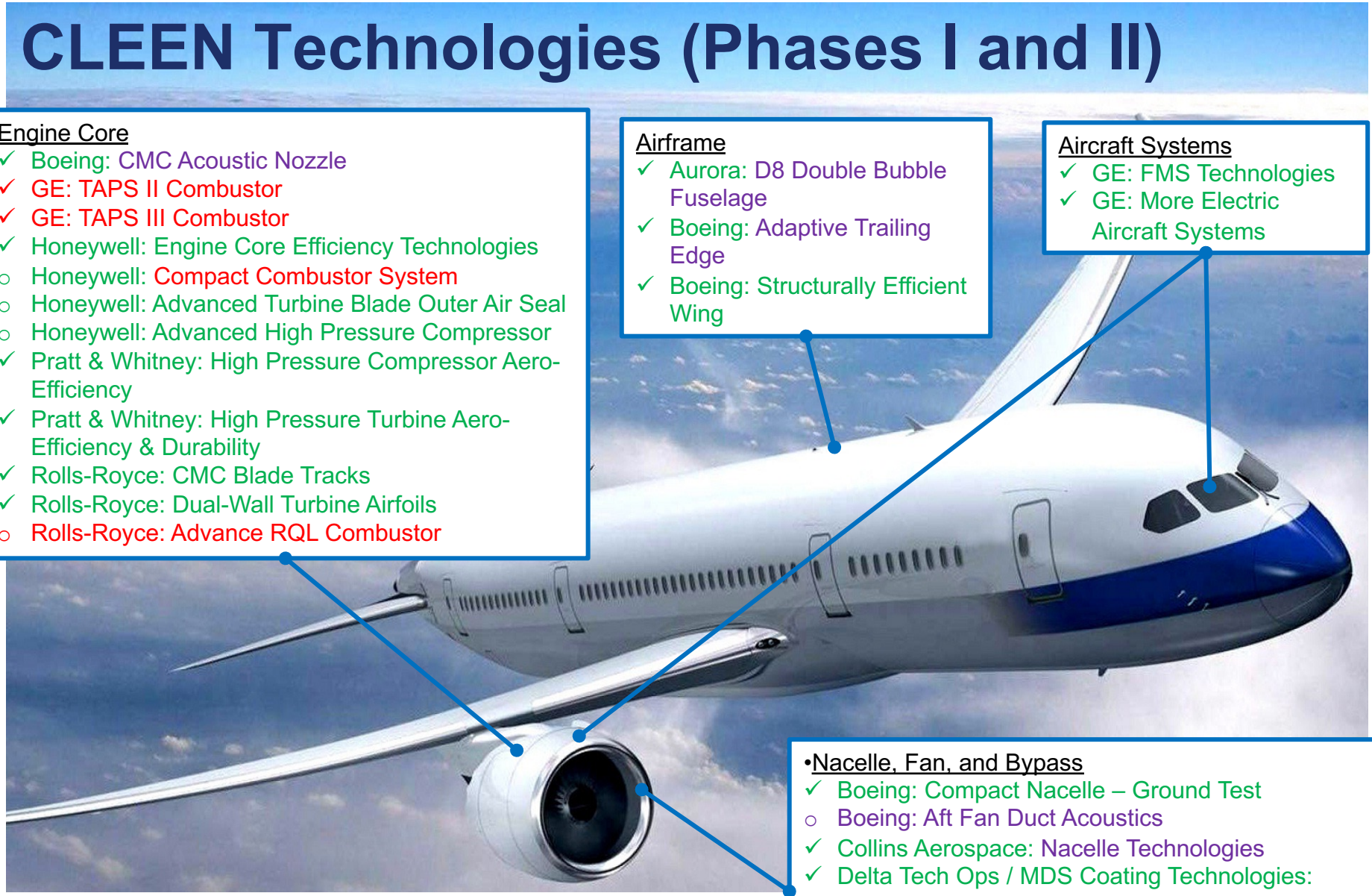
| | Phase I | Phase II | Phase III |
|---|---|---|---|
| Time Frame | 2010-2015 | 2016-2020 | 2021-2025 |
| FAA Budget | ~$125M | ~$100M | TBD |
| Noise Reduction Goal | 25 dB cumulative noise reduction cumulative to Stage 5 ***and/or reduces community noise exposure (new goal for Phase III)*** | | |
| Fuel Burn Goal | 33% reduction | 40% reduction | -20% re: CAEP/10 Std. |
| $NO_X$ Emissions Reduction Goal | 60% landing/take-off $NO_X$ emissions | 75% landing/take-off $NO_X$ emissions (-70% re: CAEP/8) | |
| Particulate Matter Reduction Goal | | | Reduction relative to CAEP/11 Std |
| Entry into Service | 2018 | 2026 | 2031 |





For more information on CLEEN program: http://www.faa.gov/go/cleen

# CLEEN Technologies (Phases I and II)



**Engine Core**
- ✓ Boeing: CMC Acoustic Nozzle
- ✓ GE: TAPS II Combustor
- ✓ GE: TAPS III Combustor
- ✓ Honeywell: Engine Core Efficiency Technologies
- ○ Honeywell: Compact Combustor System
- ○ Honeywell: Advanced Turbine Blade Outer Air Seal
- ○ Honeywell: Advanced High Pressure Compressor
- ✓ Pratt & Whitney: High Pressure Compressor Aero-Efficiency
- ✓ Pratt & Whitney: High Pressure Turbine Aero-Efficiency & Durability
- ✓ Rolls-Royce: CMC Blade Tracks
- ✓ Rolls-Royce: Dual-Wall Turbine Airfoils
- ○ Rolls-Royce: Advance RQL Combustor

**Airframe**
- ✓ Aurora: D8 Double Bubble Fuselage
- ✓ Boeing: Adaptive Trailing Edge
- ✓ Boeing: Structurally Efficient Wing

**Aircraft Systems**
- ✓ GE: FMS Technologies
- ✓ GE: More Electric Aircraft Systems

•**Nacelle, Fan, and Bypass**
- ✓ Boeing: Compact Nacelle – Ground Test
- ○ Boeing: Aft Fan Duct Acoustics
- ✓ Collins Aerospace: Nacelle Technologies
- ✓ Delta Tech Ops / MDS Coating Technologies: Leading Edge Protective Blade Coatings
- ✓ GE: Open Rotor
- ○ GE: Low Pressure Ratio Advanced Acoustics
- ○ Honeywell: Advanced Acoustic Fan and Liners
- ✓ Pratt & Whitney: Geared Turbofan Technologies

Fuel
$NO_x$
Noise

✓ Completed Effort
○ Continuing in FY21

# Aircraft Technology Innovation Portfolio

https://ascent.aero/topic/Aircraft-Technology/

ASCENT's aircraft technology innovation research advances the industry state-of-the-art and expands the technical knowledge base.

## ASCENT Aircraft Technology Innovation Projects

- 010- Aircraft Technology Modeling and Assessment
- 037 - CLEEN II System Level Assessment
- 047 - Clean Sheet Supersonic Aircraft Engine Design and Performance
- 050 - Over-Wing Engine Placement Evaluation
- 051 - Combustion concepts for next-generation aircraft engines to reduce fuel burn and emissions
- 052 - Comparative Assessment of Electrification Strategies for Aviation
- 055 - Noise Generation and Propagation from Advanced Combustors
- 056 - Turbine Cooling Through Additive Manufacturing
- 059 - Jet Noise Modeling to Support Low Noise Supersonic Aircraft Technology Development
- 063 - Parametric Noise Modeling For Boundary Layer Ingesting Propulsors
- 064 - Alternative Design Configurations to Meet Future Demand
- 066 - Evaluation of High Thermal Stability Fuels
- 067 - Impact of Fuel Heating on Combustion and Emissions
- 068 - Combustor Wall Cooling Concepts for Dirt Mitigation
- 070 - Reduction of nvPM emissions via innovation in aero-engine fuel injector design
- 071 - Predictive Simulation of Soot Emission in Aircraft combustors
- 074 - Low Emissions Pre-Mixed Combustion Technology for Supersonic Civil Transport
- 075 - Improved Engine Fan Broadband Noise Prediction Capabilities
- 076 - Improved Open Rotor Noise Prediction Capabilities
- 077 - Noise Measurements for UAS/UAM Vehicles and Identify Noise Reduction Opportunities
- 079 (NEW) - Novel Noise Liner Development Enabled by Advanced Manufacturing

# FAA R&D Direction on Sustainable Aviation Fuels

**Testing**
accelerate SAF development

- Test fuels
- Improve testing methods
- Conduct evaluation
- Streamline approval

**Analysis**
environmental and economic sustainability

- Lifecycle emissions
- Cost reduction
- Supply potential
- Supply chain opportunities

**Coordination**
support SAF deployment

- Public-private partnership – *CAAFI*
- U.S. interagency cooperation
- International cooperation – *ICAO*

**Considerable energy going to support efforts at ICAO**

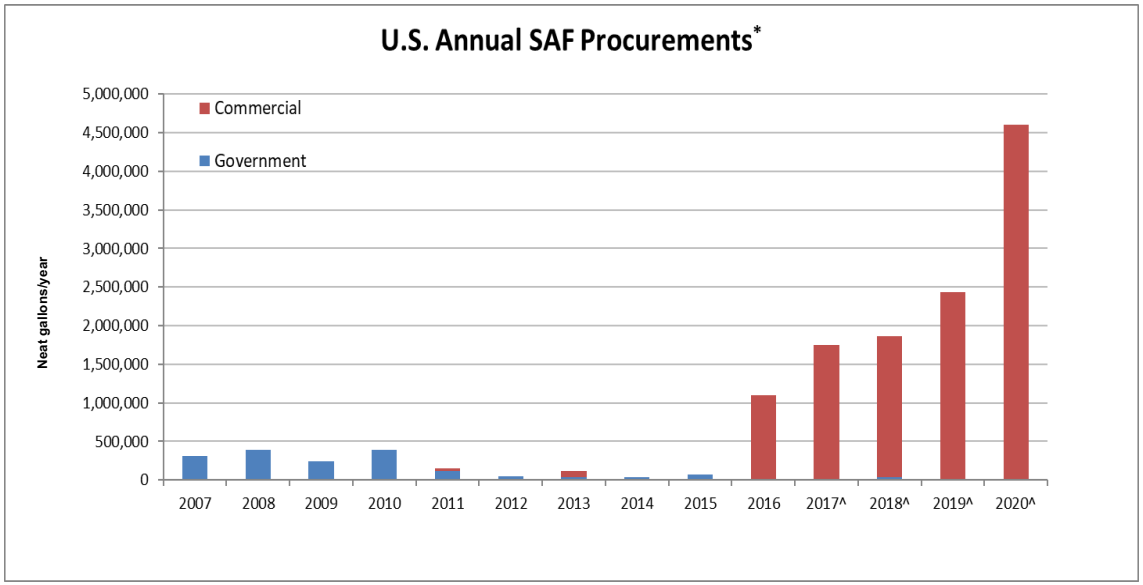
**Looking to utilize R&D to go beyond 50% to higher SAF blend levels**

**Seeking means to reduce SAF costs while increasing their environmental benefits**

# Where we stand on U.S. SAF commercialization

**Initiation under way, still early, but growing**

- **Five years of sustained & increasing commercial use**
- **4.6M gallons in 2020 – 190% increase over 2019**
- **Commercial & General Aviation engaged**
- **Two facilities in operation**
- **Two facilities under construction, others in development**
- **Cost delta still a challenge, and renewable diesel favored**
- **New parties interested in SAF**




*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.
^ 2017-2020 calculation incorporates data reported by EPA for RFS2 RINs for renewable jet fuel.

# Airline & Producer Offtake agreements

## Demonstration of broad airline industry commitment



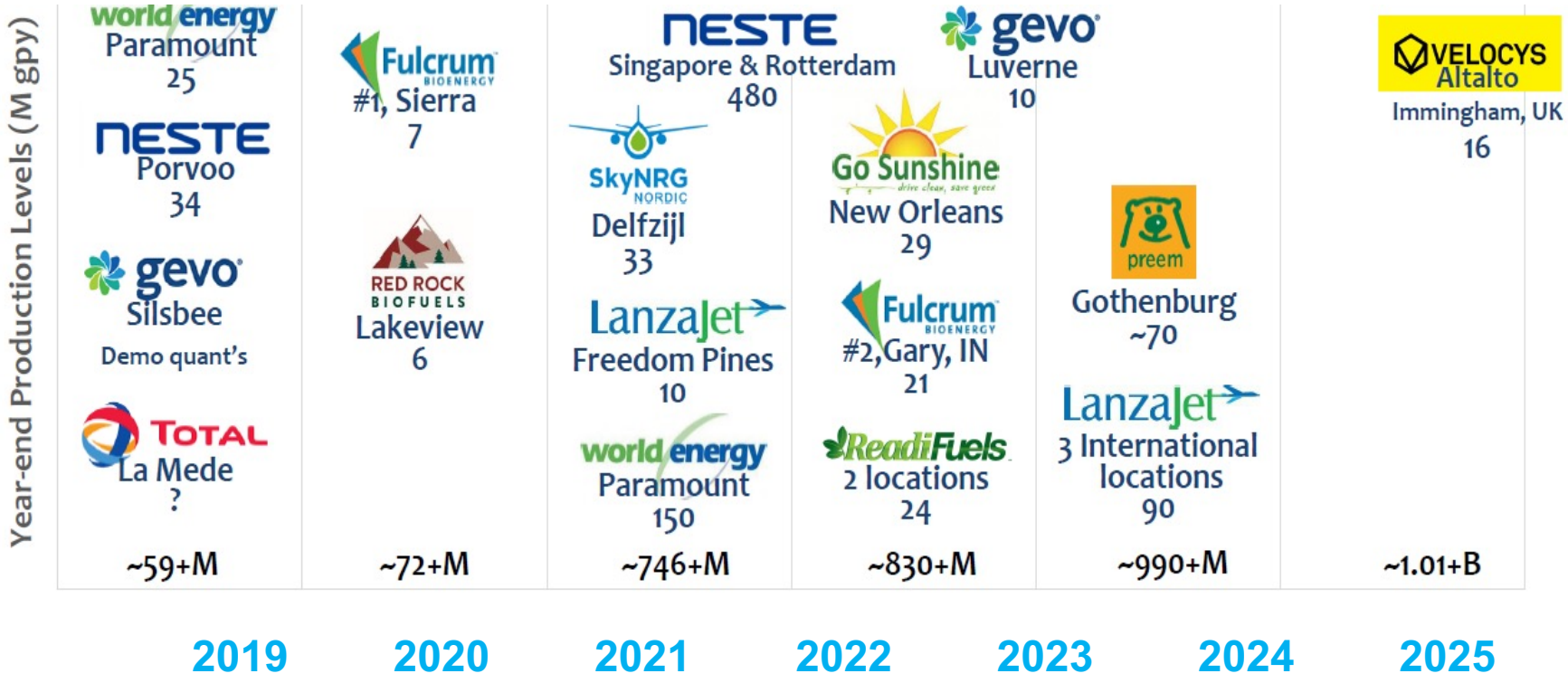
Collectively, announced airline offtake agreements total $6.4B and >350M gpy

Credit: CAAFI

Federal Aviation Administration

# Worldwide SAF production Projection

## Announced intentions with specific commitments to SAF




Credit: CAAFI. Not comprehensive; CAAFI estimates (based on technology used) where production slates are not specified

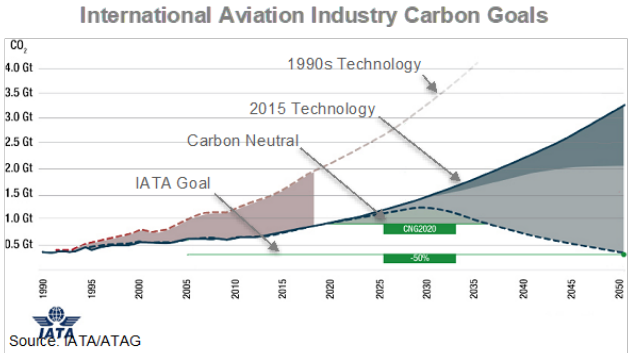
Federal Aviation Administration

# Sustainable Aviation Fuels and CORSIA

CORSIA
CARBON OFFSETTING AND REDUCTION SCHEME FOR INTERNATIONAL AVIATION

***Two means for an aeroplane operator to comply with CORSIA***

1. Offsetting with Emissions Units
2. Emissions Reductions from CORSIA Eligible Fuels




***Two types of CORSIA Eligible Fuels (CEF)***

- "CORSIA Sustainable Aviation Fuel": renewable or waste-derived fuel
- "CORSIA Lower Carbon Aviation Fuel": fossil-based fuel

$$Emissions\ Reduction = 3.16 * \left[\sum Neat\ Fuel\ Mass * \left(1 - \frac{Life\ Cycle\ Emissions}{89\ g\ CO2/MJ}\right)\right]$$

***To be eligible for CORSIA, a fuel needs to meet the CORSIA Sustainability Criteria as certified by ICAO Council Approved Sustainability Certification Scheme (SCS)***

# CORSIA Eligible Fuels – Key Documents

There are a number of ICAO documents that contain information related to CORSIA Implementation

## Annex 16 Volume IV

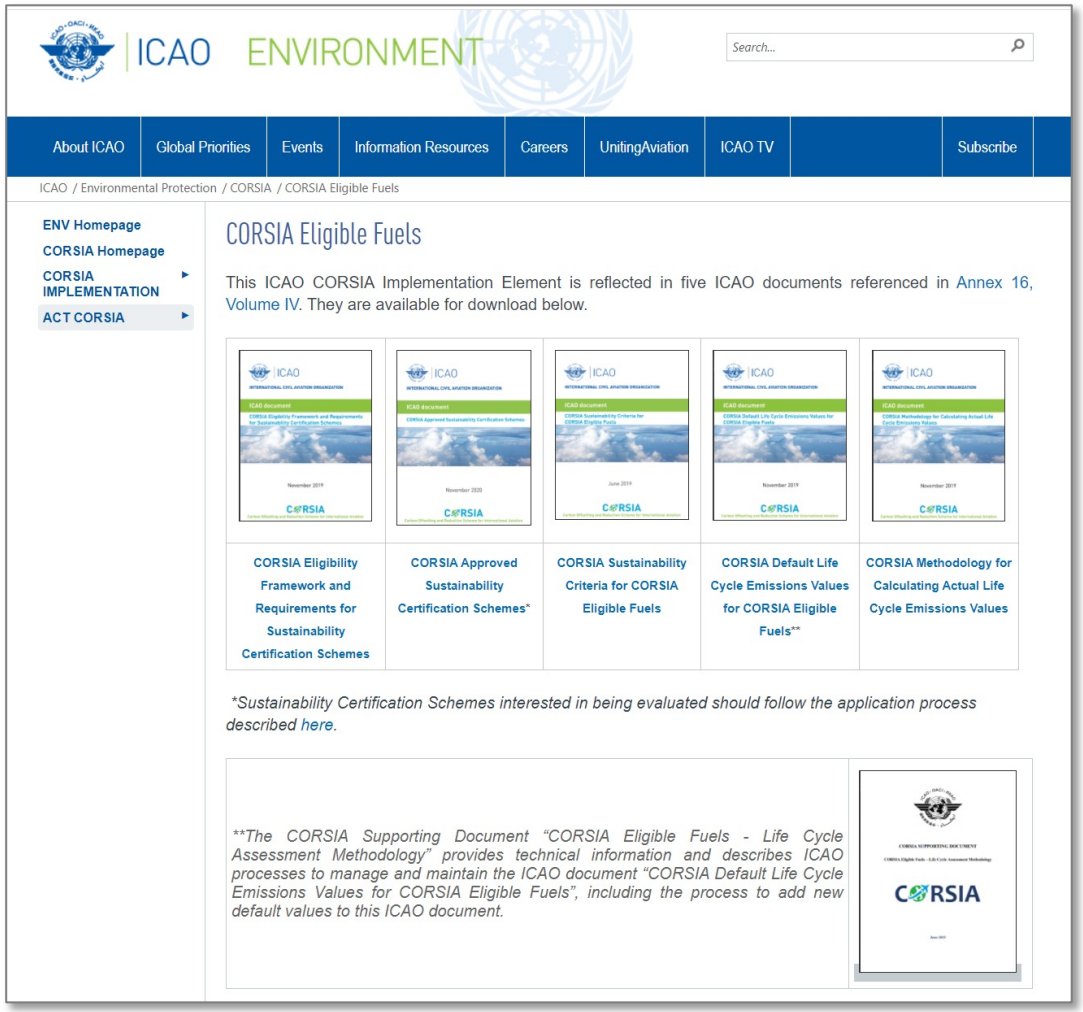
•See: https://www.icao.int/environmental-protection/CORSIA/Pages/SARPs-Annex-16-Volume-IV.aspx

## CORSIA Implementation Elements

•See: https://www.icao.int/environmental-protection/CORSIA/Pages/implementation-elements.aspx

## Five ICAO documents relate to CORSIA Eligible Fuels

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



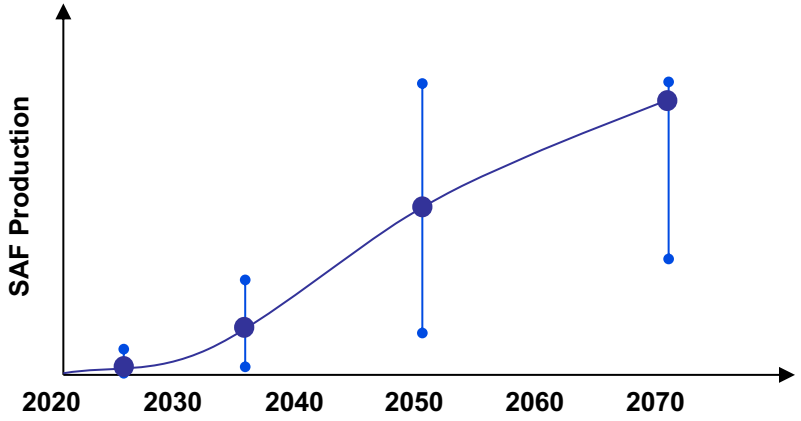

For additional information on CORSIA Eligible Fuels:
https://www.icao.int/environmental-protection/CORSIA/Pages/CORSIA-Eligible-Fuels.aspx

Federal Aviation Administration

# Future Fuel Production

- ICAO have considerable ongoing work to project future SAF production with consideration input from FAA and ASCENT P1 / Volpe / DOE ANL Team

- Team looking carefully at SAF production from biomass, wastes, waste $CO/CO_2$ gases and atmospheric $CO_2$
- Working to quantify infrastructure challenges associated with hydrogen use by commercial aviation
- Team considering fuel volumes, life cycle GHG emissions, investment requirements, etc.




| Fuel Category | Fuel Types in Category |
|---|---|
| **Sustainable Aviation Fuels (SAF)** | Biomass-based fuel |
| | Solid and liquid waste-based fuels |
| | Gaseous waste-based fuels |
| | Atmospheric $CO_2$-based fuels |
| **Lower Carbon Aviation Fuels (LCAF)** | Lower carbon petroleum fuels |
| **Non drop-in fuels** | Electricity |
| | Liquefied gas aviation fuels |
| | Cryogenic hydrogen |

# Hydrogen Use in Aviation

- MIT and WSU through ASCENT COE Projects 52 and 80 are examining potential paths for using renewable electricity in aviation[1]

- Using renewable hydrogen for fuel production would provide an immediate reduction in carbon footprint of aviation and enable the use of sustainable aviation fuels (low carbon fertilizers and fuel production)
- There are considerable waste and biomass resources in the U.S. that could be sustainably produced, at lower costs than either cryogenic hydrogen or power-to-liquids, and that would use today's infrastructure[2]
- Makes logical sense to use these resources now and to leverage our current infrastructure. Could also use biomass with power-to-liquids.
- In the future, if we need more jet fuel than can be provided from waste and biomass resources, then power-to-liquid fuels could be a viable solution. It could be produced from renewable electricity via hydrogen as an intermediary while enabling us to use our existing infrastructure

1. See ascent.aero and look for Projects 52 and 80

2. For additional details on potential for wastes as a SAF feedstock, see: http://caafi.org/focus_areas/docs/US_WasteFeedstockPotential.pdf

# Efforts to Support Decision-Making

- Using research portfolio to ensure we have a robust assessment of a wide range of economic and environmental impacts that could result from aviation noise, emissions, and energy policy.
- R&D program informing decision making:

  *Long-term aspirational CO2 goal (ongoing)*

  *Supersonic Aircraft Noise (ongoing)*

  *Fuel Composition (ongoing)*

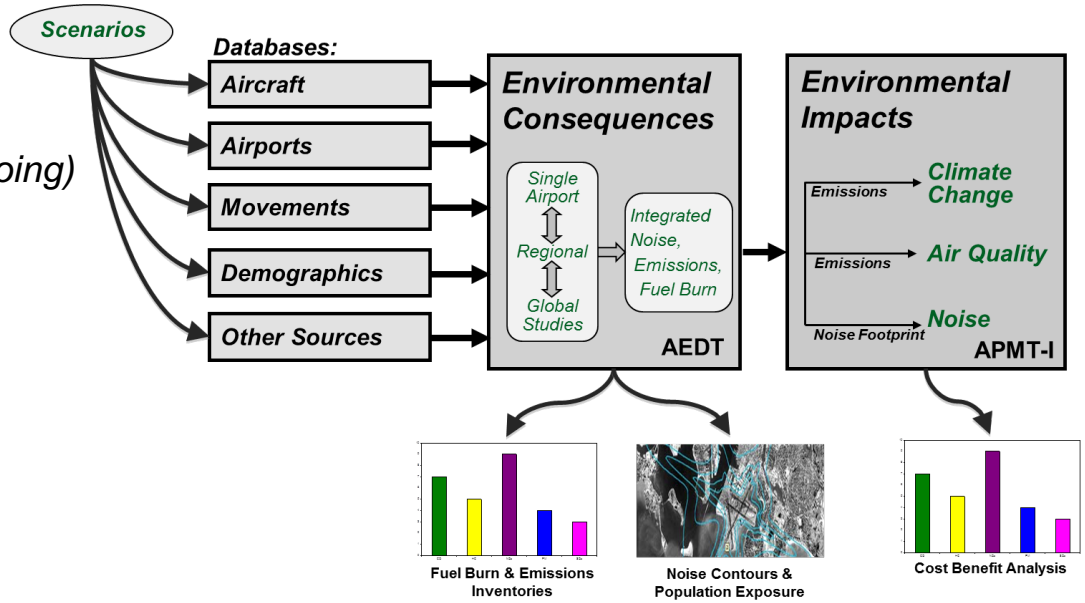
  *ICAO CAEP/11 PM Standard (2019)*

  *CORSIA (2019)*

  *ICAO CAEP/10 $CO_2$ Standard (2016)*

  *ICAO CAEP/9 Noise Standard (2013)*

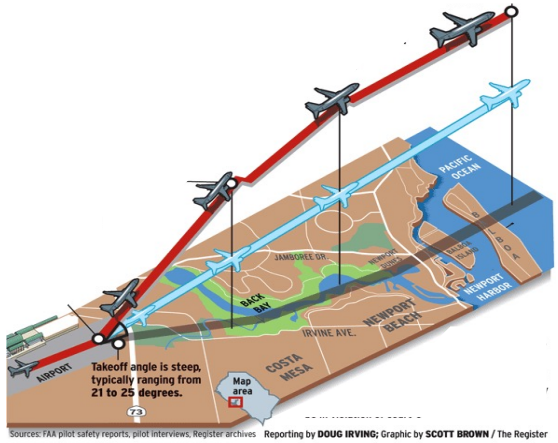
  *ICAO CAEP/8 NOx Standard (2010)*




- Volpe Center and ASCENT Center of Excellence universities working directly with FAA to develop data and tools to inform decision making.

# Our Direction

- Utilizing a comprehensive approach to address environmental challenges
- Working with a broad range of stakeholders to understand issues and develop solutions
- Over past few years, have placed more focus on innovation to overcome environmental challenges
- Continuing to seek partnerships for our R&D efforts
- With the right investments and partnerships, aviation can meet the environmental challenges of the 21st century



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