FAA CENTER OF EXCELLENCE FOR ALTERNATIVE JET FUELS & ENVIRONMENT

ASCENT Sustainable Aviation Fuel and Emission Research

Seattle Tacoma International Airport Stakeholder Advisory Roundtable

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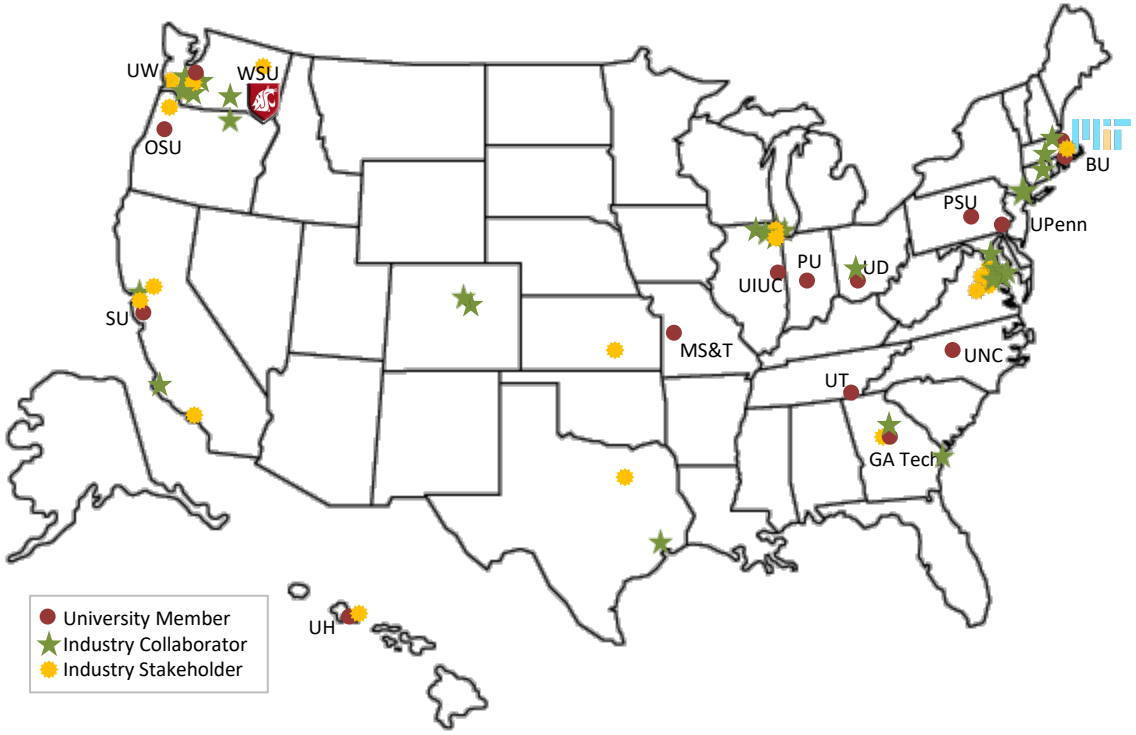
Agenda

- ASCENT Overview
- What are Sustainable Aviation Fuels (aka Alternative Jet Fuel)?
- Sustainable Aviation Fuels Projects
- Emission Reduction Projects Related to Local Air Quality Issues and Climate Change

FAA Centers of Excellence (COE)

FAA Office of Environment and Energy relies on university centers of excellence to:

- Provide scientific-knowledge to inform decision making on environment and energy matters;
- Enable the introduction of innovative solutions to cost-effectively mitigate the environmental impacts of aviation; and
- Support the instruction of hundreds of professionals with knowledge of the environmental challenges facing aviation.
- Engage industry partners through cost-sharing and advisory committee participation
- ASCENT is comprised of 16 partner universities and over 60 industry partners



ASCENT Research Themes

https://ascent.aero/project/

Six Primary Areas Research Themes

- Sustainable Aviation Fuels (aka Alternative Jet Fuels)
- Emissions
- Noise
- Operations
- Aircraft Technology Innovation
- Tools

New topics around:

- Supersonics
- Rotorcraft & UAVs

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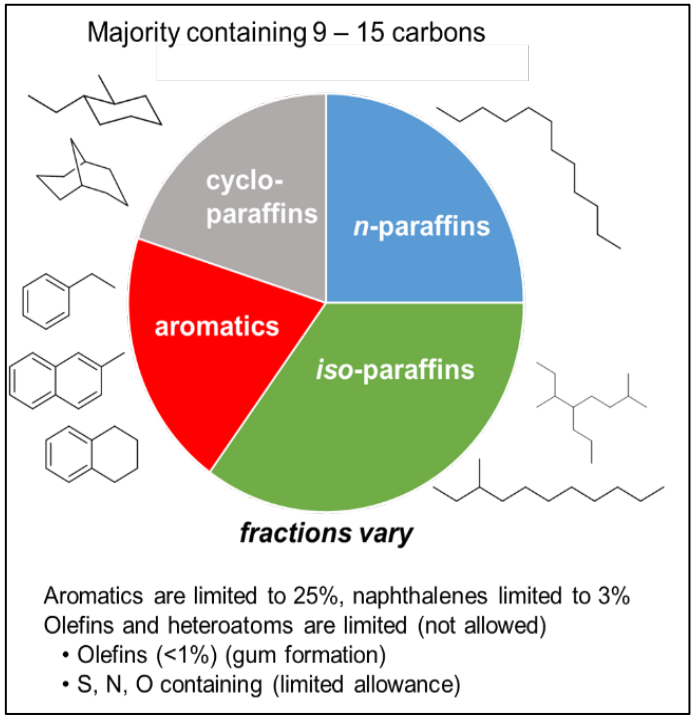
Benefits of Sustainable Aviation Fuels (SAF)

- SAFs are "drop-in" liquid aviation fuels
- SAF reduce GHG and air quality emissions substantially – best near-term path to aviation de-carbonization
- Viable technologies exist - seven alternative fuels currently approved for use, more under evaluation for approval
- Scalable feedstocks
- Widely accepted by airlines, business & general aviation
- Broadly supported among federal agencies as meeting critical goals - climate, energy security, rural economic development
- Critical to international efforts to address aviation emissions

What is Sustainable Aviation Fuel (SAF?)

- Liquid hydrocarbon fuels derived from biomass and waste sources
  - Forest and wood mill residuals and other woody biomass
  - Non-recyclable materials sourced from municipal solid waste (MSW)
  - Landfill or other industrial gases
  - Waste Fats, Oil and Greases (FOGs)
  - Agricultural waste
  - Oils from oilseed cover crops such as camelina, carinata, rapeseed
  - Future- potentially direct carbon capture, waste CO_2 streams, waste-water sludge
- Meets ASTM "synthetic aviation fuel specification (D7566)- Seven approved fuel conversion pathways. Does not consider sustainability criteria
- Environmental benefits
  - Reduced lifecycle CO_2 emissions compared to petroleum jet- up to 80%, or beyond with carbon capture
  - Low sulfur and aromatic content=improved air quality
  - Low non-volatile particulate matter (nvPM)= fewer particulate emissions
  - Improved soil and water quality
  - Decreased forest fire risk
  - Economic use of waste materials



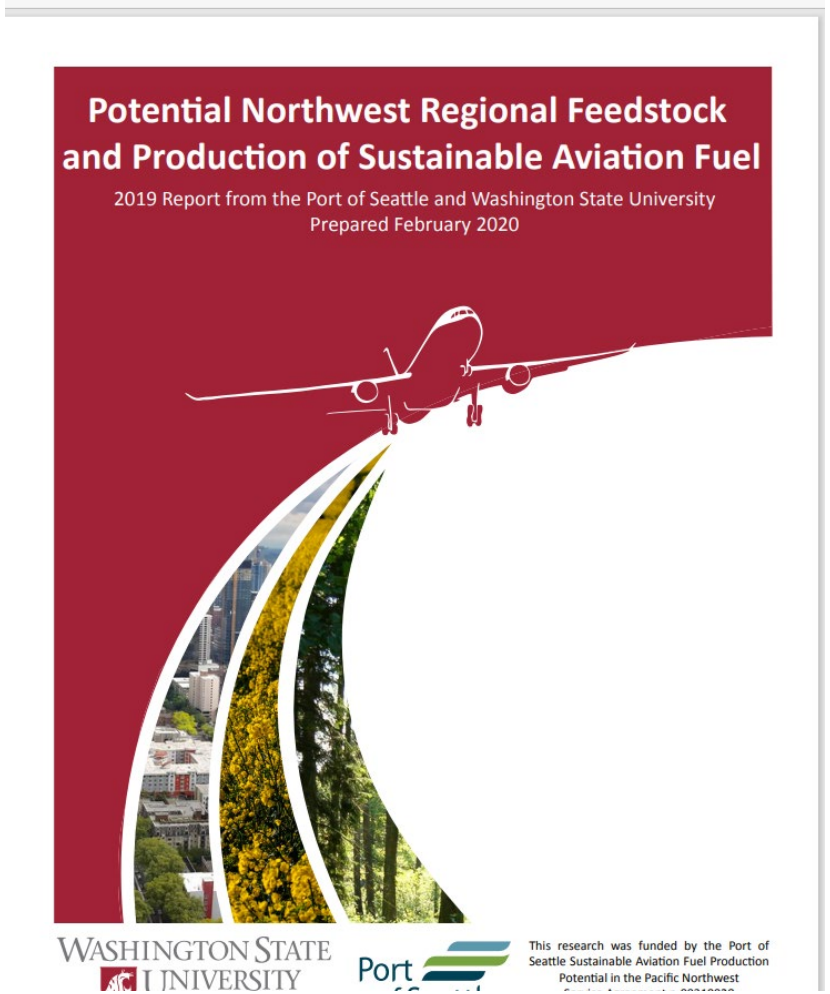
Source: Holladay, J., *Jet Workshop: Feedstock-product interface*, Department of Energy, PNNL, 2018 (presentation)

What Makes SAF a "Drop-In" Fuel

- Approved SAF can be used, at up to 50% blend with petroleum jet, in aircraft engines and **existing** fuel delivery, storage and distributions systems, including airport hydrant systems, without any modifications
- SAF may require blending infrastructure depending how neat (i.e., pure) fuel is delivered from the production facility to the airport
- Testing required post-blending to demonstrate conformance to jet fuel specification (D1655)
- Port of Seattle Infrastructure Feasibility Study, https://www.portseattle.org/sites/default/files/2018-03/Aviation_Biofuel_Infrastructure_Report_Condensed.pdf

ASCENT Project 001

- Regional Supply Chain Analysis
  - Pacific Northwest (Washington State University)
    - Informed Port of Seattle report on PNW feedstocks
    - Basis for Port/King County feasibility study on MSW-to-Liquid Fuels
  - Hawaii and the Tropics (University of Hawaii)
  - Southeast United States (University of Tennessee, Knoxville)
- Decision Support Tools for Biorefinery Siting
- Economic and Life Cycle Assessments to Support ICAO Regulations
- Environmental Services Benefits (WSU and Pennsylvania State University)



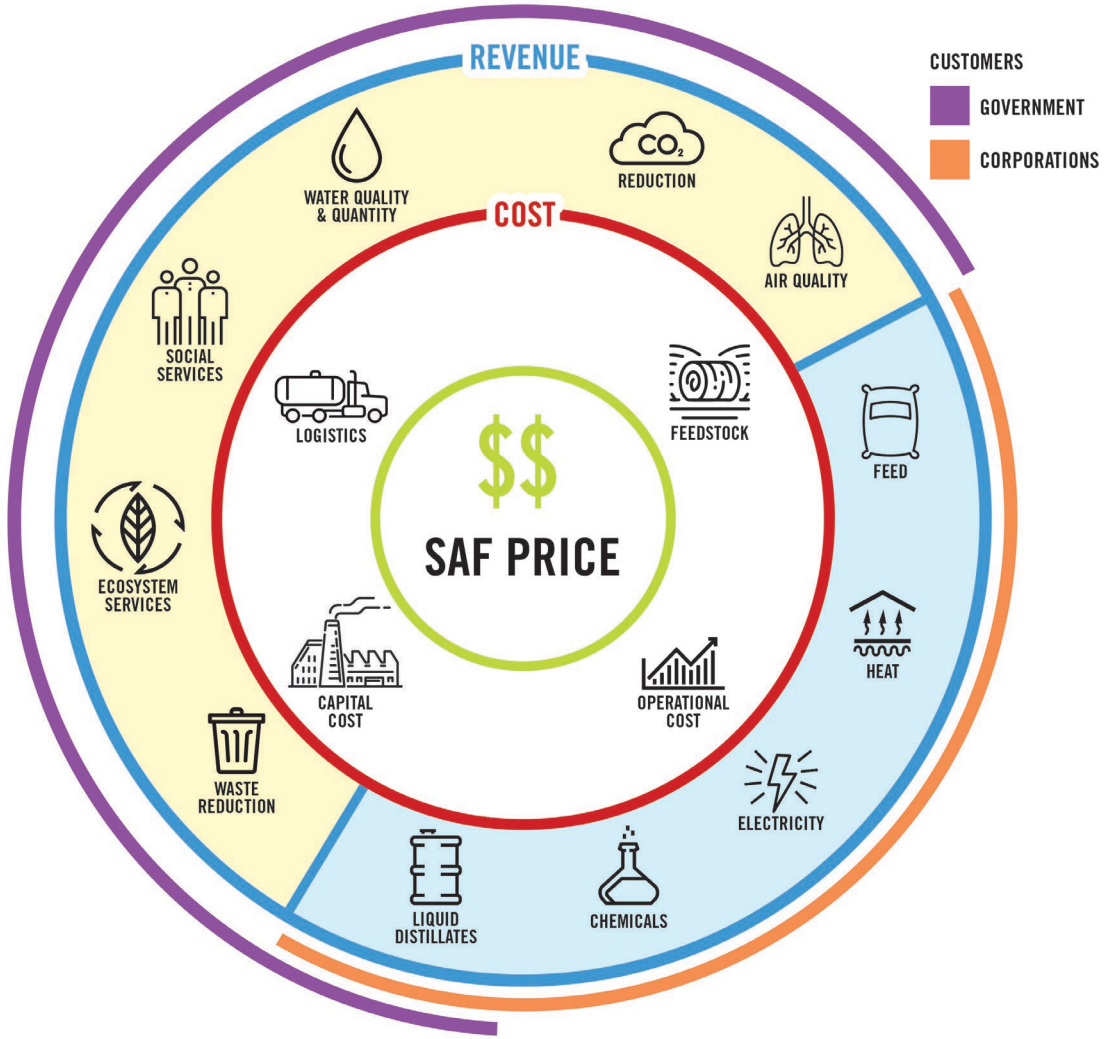
ASCENT 001 publications available at https://ascent.aero/topic/alternative-fuels/

PofSeattleWSU2019updated_appendix.pdf (portseattle.org)

Environmental Services Benefits

Attempt to disconnect the cost comparison between SAF cost & fossil based on energy content and valorize environmental service benefits (improved air quality, water quality, waste reduction, etc.)

- Survey of domestic and international environmental policy
- Assessment of supply chain designs that support sale of both commodities (e.g., fuel) and services.
- Construction and validation of model to assess scenarios that evaluate the role of services in revenue generation and profitability.
  - Large corporate sustainability programs internalize externalities (i.e., environmental impacts) into cost of doing business-"own the impact"



ASCENT/NJFCP 025-030,034, 065

A series of projects aimed at developing a more fundamental understanding of jet fuel combustion to aid in developing and streamlining ASTM certification standards for fuels.

- National Jet Fuel Combustion Program (NJFCP)
  - Projects 025-030: Chemical Kinetics, Combustion Tests, Modeling & Evaluation
  - Project 029: Atomization Tests
  - Project 030: Referee Swirl-Stabilized Combustor Evaluation/Support
  - Project 034: Overall NJFCP Program Integration & Testing
    - Developing pre-screening tool for new fuels entering ASTM evaluation and qualification processes
    - α and β testing using small volumes (milliliters to litres) for fit-for-purpose testing
    - Work with fuel producers up front to reduce time and cost for full ASTM approval
    - Prescreening work is being continued under projects 025 and 065a
    - Learnings published by AIAA, "Fuel Effects & Operability of Aircraft Turbine Combustors" https://arc.aiaa.org/doi/book/10.2514/4.106040

NJFCP research is conducted by the University of Dayton, University of Illinois, Stanford University, Purdue University, Georgia Institute of Technology, Oregon State University and supported by numerous industry partners

ASCENT Emission Research

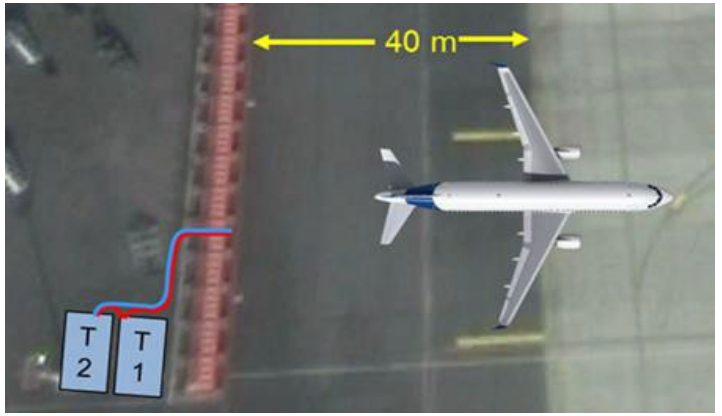
- ASCENT Emission Research used to inform Airport Cooperative Research Report (ACRP-02-80)
- https://www.trb.org/ACRP/Blurbs/177509.aspx

ASCENT 002- Non-volatile PM Emissions Measurements (Dr. Philip Whitefield, Missouri University of Science & Technology)

- Purpose
  - The FAA along with the EPA, NASA, Transport Canada, have committed to underwrite studies, that address research needs that relate to corrections for ambient conditions, engine-to-engine variability and fuel composition to establish a regulatory standard to nvPM number and mass-based emissions.
  - This work is driven by the critical needs in the development of the ICAO aircraft engine nvPM standard.

ASCENT 002- Recent Accomplishments

- NASA/DLR Multidisciplinary Airborne eXperiments/Emission and Climate Impact of Alternative Fuels- Second Campaign
- Specific ground measurement research objectives include:
  - Obtain real-time on-line emissions measurements of non-volatile particulate matter (nvPM), total particulate matter (PM), and hydrocarbons as a function of both engine thrust and fuel composition
  - Link ground-based measurements to North American nvPM Reference System and to in-flight measurements
  - Potential development of LTO-to-cruise correlation for nvPM
  - Evaluation of potential air quality effects due to emissions



Emissions source:
DLR ATR A320/V2527-A5 (#2)

ASCENT 018 - Community Measurements of Aviation Emissions Contribution to Ambient Air Quality

Objective

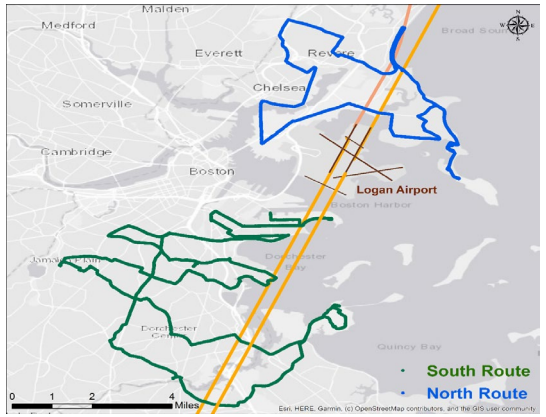
- Measure aviation-related air pollution such as ultrafine particles (UFP) using a stationary and mobile monitoring platform near Boston Logan International Airport.
- Quantify the contribution of flight activity to community air pollution.

Project Benefits

- Improved understanding of aviation-related UFP in communities near airports.
- Pairing of empirical monitoring data and source attribution models to validate dispersion air pollution models that could be applied at airports across the US.

Major Accomplishments (to date):

- We have collected air pollution data at stationary sites across multiple years during COVID-19.
- Over 700 hours of mobile air pollution data has been collected covering a wide variation of meteorology and ramp-up of aviation activities.



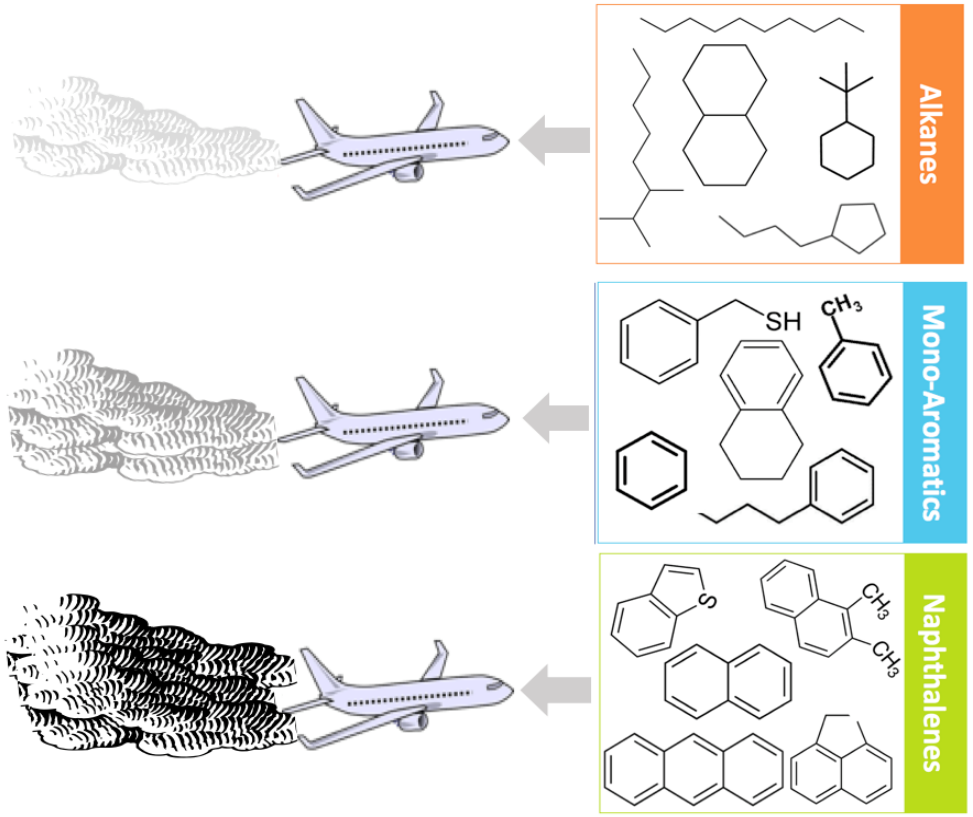
ASCENT 039- Naphthalene Removal Assessment (Dr. Raymond Speth & Dr. Steven Barrett MIT)

Motivation

nvPM cause and effect

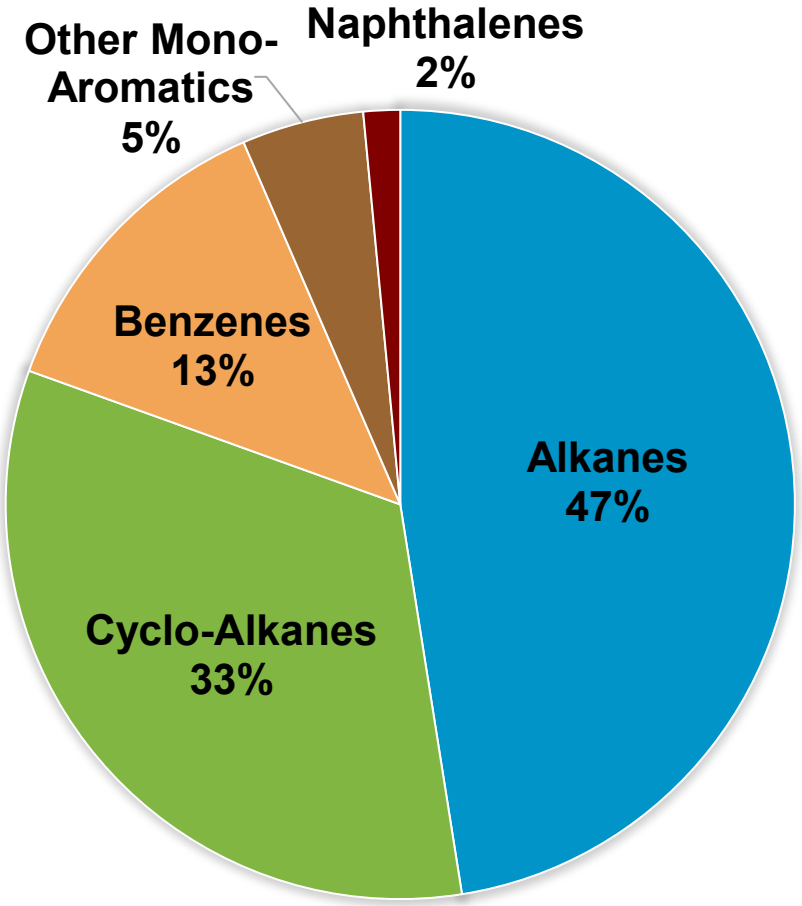
1. Aviation-attributable non-volatile particulate matter (nvPM) emissions contribute to:
   - Air quality related **health effects** (Hoek et al. 2013)
   - Aviation's climate impact through **direct & indirect radiative forcing** and **contrail formation**

2. Naphthalenes in jet fuel have been identified as **disproportionate contributors to nvPM emissions** compared to other fuel species (Moore et al. 2015, Brem et al. 2015)



ASCENT 039- Naphthalene Removal Assessment

Motivation



Typical jet fuel composition

Naphthalene Removal

3 On average, naphthalenes constitute **less than 2% of the total composition of jet fuel**, and less than 10% of the total aromatic content (PQIS, 2013)

4 There are **industry-standard finishing processes** that, with minimal changes, could be used to eliminate naphthalenes in jet fuel feedstocks (Gary et al. 2007)

ASCENT 039- Naphthalene Removal Assessment

Conclusions

- **Removing naphthalenes from jet fuel could reduce nvPM emissions by 15-40%**
- There are viable refinery processes for removing naphthalenes from jet fuel
- **Climate benefits of naphthalene removal are largely offset by additional CO_2 emissions at the refinery**
- **System-wide removal of naphthalene is unlikely to be cost beneficial**
- Lack of benefit for the simplest policy option suggests consideration of selective naphthalene removal
- Evaluating situations where selective removal provides benefits requires further refinement of AQ and contrail impact estimates

ASCENT 048- Analysis to Support the Development of an Engine nvPM Emissions Standard (MIT)

- Evolution of nvPM standards at ICAO CAEP
- CAEP/11 focused on developing nvPM standard levels from aircraft engines that improve health and climate impacts
- Support FAA to provide technical basis for implementation of nvPM standards
  - Assessment of new measurement systems
  - Use total LTO emissions/engine rated thrust as metric value
  - Applicability date of nvPM standard is 1 January 2023 for both in-production and new-type engines
  - Develop no-change criterion for when engines need remeasurement after small changes to engines

QUESTIONS & DISCUSSION

ASCENT Alternative Jet Fuels Research Portfolio

https://ascent.aero/topic/alternative-fuels/

Alternative jet fuels have the potential to provide benefits to the aviation industry in terms of energy security and reduction in greenhouse gases. Their production can support rural economic growth and job creation through the development of economically valuable feedstocks and fuel processing facilities.

ASCENT Alternative Jet Fuels Projects

- 001 – Alternative Jet Fuel Supply Chain Analysis
- 025 – 030 & 034 - National Jet Fuel Combustion Program
- 031 – Alternative Jet Fuels Test and Evaluation
- 052 – Comparative Assessment of Electrification Strategies for Aviation
- 065A/B – Fuel Testing Approaches for Rapid Jet Fuel Prescreening
- 066 – Evaluation of High Thermal Stability Fuels
- 080 – Hydrogen and Power-to-Liquid (PtL) Concepts for Sustainable Aviation Fuel Production

ASCENT Emissions Research Portfolio

https://ascent.aero/topic/emissions/

Demand for air transportation, both for passenger and cargo service, has been increasing and airports are expanding to accommodate it. This growth is accompanied by an increase of emissions from aircraft, ground services equipment and vehicle traffic on and near airports. All this activity impacts the local air quality around airports and human health.

ASCENT Emissions Projects

- 002 - Ambient Conditions Corrections for Non-Volatile PM Emissions Measurements
- 013 (COMPLETE) - Micro-Physical Modeling & Analysis of ACCESS 2 Aviation Exhaust Observations
- 014 (COMPLETE) - Analysis to Support the Development of an Aircraft CO2 Standard
- 018 - Community Measurement of Aviation Emission Contribution of Ambient Air Quality
- 019 - Development of Improved Aviation Emissions Dispersion Capabilities for AEDT
- 020 (COMPLETE) - Development of NAS wide and Global Rapid Aviation Air Quality
- 021 (COMPLETE) - Improving Climate Policy Analysis Tools
- 024 (COMPLETE) - Emissions Data Analysis for CLEEN, ACCESS, and Other Recent Tests
- 022 - Evaluation of FAA Climate Tools
- 039 - Naphthalene Removal Assessment
- 047 - Clean Sheet Supersonic Aircraft Engine Design and Performance
- 048 - Analysis to Support the Development of an Engine nvPM Emissions Standard
- 051 (NEW) - Combustion concepts for next-generation aircraft engines to reduce fuel burn and emissions
- 052 (NEW) - Comparative Assessment of Electrification Strategies for Aviation
- 058 (NEW) - Improving Policy Analysis Tools to Evaluate Aircraft Operations in the Stratosphere
- 064 (NEW) - Alternative Design Configurations to Meet Future Demand
- 067 (NEW) - Impact of Fuel Heating on Combustion and Emissions
- 068 (NEW) - Combustor Wall Cooling Concepts for Dirt Mitigation
- 069 (NEW) - Transitioning a research nvPM mass calibration procedure to operations
- 070 (NEW) - Reduction of nvPM emissions via innovation in aero-engine fuel injector design
- 071 (NEW) - Predictive Simulation of Soot Emission in Aircraft combustors
- 074 (NEW) - Low Emissions Pre-Mixed Combustion Technology for Supersonic Civil Transport

ASCENT Noise Research Portfolio

https://ascent.aero/topic/noise/

The growth in demand for passenger and cargo air transportation has pushed operators to increase the number and frequency of their scheduled flights. The expansion in operations and the changes to the airspace aimed at accommodating it have resulted in renewed public concern.

ASCENT Noise Projects (select projects from a total of 26)

- 003 - Cardiovascular Disease and Aircraft Noise Exposure
- 007 (COMPLETE) - Civil, Supersonic Over Flight, Sonic Boom (Noise) Standards Development
- 017 - Pilot Study on Aircraft Noise and Sleep Disturbance
- 038 – Rotorcraft Noise Abatement Procedures Development
- 041 - Identification of Noise Acceptance Onset for Noise Certification Standards of Supersonic Airplanes
- 044 - Aircraft Noise Abatement Procedure Modeling and Validation
- 049 (NEW) - Urban Air Mobility Noise Reduction Modeling
- 050 (NEW) - Over-Wing Engine Placement Evaluation
- 053 (NEW) - Validation of Low-Exposure Noise Modeling by Open-Source Data Mgmt and Visualization Systems Integrated w/ AEDT
- 055 (NEW) - Noise Generation and Propagation from Advanced Combustors
- 059 (NEW) - Jet Noise Modeling to Support Low Noise Supersonic Aircraft Technology Development
- 075 (NEW) - Improved Engine Fan Broadband Noise Prediction Capabilities
- 077 (NEW) - Measurements to Support Noise Certification for UAS/UAM Vehicles and Identify Noise Reduction Opportunities