ASCENT SAF Research Overview & Update

Michael P Wolcott
Director
Washington State University

James Hileman
FAA Program Manager

Nathan Brown, Anna Oldani, Prem Lobo
FAA Project Managers
PRESENTATION OUTLINE

• Introduction to ASCENT
• SAF Research Strategies & Programs
• Inventory of Specific SAF Projects
• Emerging Program Support
• Questions & Discussion
**Lead Universities:**
Washington State University (WSU)
Massachusetts Institute of Technology (MIT)

**Core Universities:**
Boston University (BU)
Georgia Institute of Technology (Ga Tech)
Missouri University of Science and Technology (MS&T)
Oregon State University (OSU)
Pennsylvania State University (PSU)
Purdue University (PU)
Stanford University (SU)
University of Dayton (UD)
University of Hawaii (UH)
University of Illinois at Urbana-Champaign (UIUC)
University of North Carolina at Chapel Hill (UNC)
University of Pennsylvania (UPenn)
University of Tennessee (UT)
University of Washington (UW)

**For more information:** ascent.aero

**Advisory Committee - 57 organizations:**
- 5 airports
- 4 airlines
- 9 NGO/advocacy
- 8 aviation manufacturers
- 10 feedstock/fuel manufacturers
- 21 R&D, service to aviation sector
ASCENT Mission

FAA
Environment & Energy

ICAO - International Civil Aviation Organization

NOISE

AIR QUALITY

ENERGY

FAA CENTER OF EXCELLENCE FOR ALTERNATIVE JET FUELS & ENVIRONMENT
ASCENT Support & Coordination

ASCENT COE:
- In operation: 2013 to present
- $15M+ annual funding level
- $81.6M funding to date

FAA COE research requires 100% cost share. This has led to significant collaboration among universities, industry, and international research programs.
SAF Research Strategies & Programs
Global Jet Fuel Use

- Global jet fuel use is driven by long-haul aviation
- SAF only option through 2050 for long distances

Data analysis conducted by the U.S. DOT Volpe Center using the Aviation Environmental Design Tool (AEDT)

Flights over 1,000 nm represent 20% of operations and 65% of total fuel burn
Flights less than 500 nm represent 50% of operations and 15% of total fuel use
Energy Carriers for Aviation – A Typology

Drop-in or near-drop-in SAF

- **Fossil Jet-A**: Fossil H₂
- **Waste- and biomass-based SAF**: Biomass and wastes; currently supplemented by H₂ produced from SMR
- **Power-and-biomass-to-Liquid (PBtL)**: Biomass feedstock and H₂ produced from renewable electricity
- **Power-to-Liquid**: H₂ produced from low-carbon electricity

Non-drop-in energy carriers

- **Hydrogen**: H₂ produced from low-carbon electricity or SMR with CCS
- **Battery**: –

* Using carbon from waste streams provides a carbon benefit if the carbon content of the waste stream would have been released to the atmosphere anyways.

Substantial Low Carbon Electricity Required for Hydrogen Production

---

Slide adapted from MIT LAE (Project 52/80), courtesy Florian Allroggen
Airports as Energy Hubs: Global picture

- Replacing jet fuel with cryogenic hydrogen would require considerable electricity to electrolyze water and compress it to a cryogenic state.
- Power-to-liquids would require comparable energy as cryogenic hydrogen, but without requiring infrastructure changes.

**Electric power consumption of fuel production**

*Broken down by process step, in GW*

<table>
<thead>
<tr>
<th>Process</th>
<th>Power Consumption (GW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LH₂ Combustion</td>
<td>221.0</td>
</tr>
<tr>
<td>Electrolysis 186GW</td>
<td>186.0</td>
</tr>
<tr>
<td>CO₂ Capture 75GW</td>
<td>75.0</td>
</tr>
<tr>
<td>Total 264GW</td>
<td>264.0</td>
</tr>
</tbody>
</table>

*Values are annual average power demand.*

**Electric energy consumption of fuel production**

*In GW, by airport*

- London Heathrow Apt
- Dubai International
- Los Angeles International Apt
- New York J F Kennedy International Apt
- Singapore Changi Apt
- Paris Charles de Gaulle Apt
- Frankfurt International Apt
- San Francisco International Apt
- Seoul Incheon International Airport
- Tokyo Narita Intl
- Hong Kong International Apt
- Doha
- Beijing Capital Intl Apt
- Amsterdam
- Sydney Kingsford Smith Apt
- Bangkok Suvarnabhumi International Apt
- Shanghai Pudong International Apt
- Chicago O’Hare International Apt
- Madrid Barajas Apt
- Abu Dhabi International Apt

*Highest Airport LH₂ Pathway Electricity Requirements (GW)*

**Preliminary Results from Ongoing Research in ASCENT Project 52 for flights greater than 1,000 km**

For comparison:
- U.S. power generation capacity (2019): 1.2 TW
- Cumulative global PV capacity (2019): 627 GW

Graphic and data courtesy of MIT from ASCENT Project 52
Hydrogen Use in Aviation

MIT and WSU through A001 and A052 have been examining potential paths for using renewable electricity in aviation

*Hydrogen is the key to unlocking the potential of SAF*

- 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
- 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
Analysis: Novel SAF Production

A080 will evaluate costs and lifecycle GHG for hydrogen, power-to-liquid (PtL) fuels, and how they can be integrated with biomass technologies.

- Address recent interest in both green hydrogen and PtL concepts for aviation.
- Intense electricity demand must be factored into lifecycle and techno-economic evaluations.
- Provide recommendations for alternative uses and future directions as resource availability changes with time.

Graphic and data courtesy of WSU from ASCENT Project 80
Testing/Certification/Qualification: Beyond 50%

*New ASCENT direction to support higher blend limits of alternative fuels*

- Current ASTM D7566 specifications limit most pathways to 50% by volume blending with conventional jet fuel
- Need to ensure fuels are drop-in compatible with existing and legacy systems
- Developing new ASCENT project(s) to isolate fuel properties that constrain blend volumes and develop fuel evaluations that support higher blend limits
ICAO Fuels Task Group (FTG) and Long-Term Aspirational Goal Task Group (LTAG-TG)

- FTG working across five subgroups with a focus on maintaining the fuels-related sections of Annex 16 Vol IV (CORSIA).

- LTAG-TG working to inform 41st ICAO Assembly in October 2022 on feasibility of a long-term global aspirational goal for international civil aviation CO₂ emissions reductions.

- LTAG-TG Fuels Sub-Group focused on fuel production and lifecycle GHG emissions projections out to 2070.

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>Task Number</th>
<th>Task Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>ILUC</td>
<td>S.01.01</td>
<td>Computation of induced land use change emissions for SAF for use in CORSIA</td>
</tr>
<tr>
<td></td>
<td>S.01.02</td>
<td>Low ILUC risk practices</td>
</tr>
<tr>
<td></td>
<td>S.03</td>
<td>Co-processing of esters and fatty acids in petroleum refineries – just ILUC calculation</td>
</tr>
<tr>
<td></td>
<td>S.04.02</td>
<td>Methodology refinements – ILUC</td>
</tr>
<tr>
<td>Core LCA</td>
<td>S.01.03</td>
<td>Feedstocks classification</td>
</tr>
<tr>
<td></td>
<td>S.02</td>
<td>Computation of default core LCA emission values for SAF for use in CORSIA</td>
</tr>
<tr>
<td></td>
<td>S.03</td>
<td>Co-processing of esters and fatty acids in petroleum refineries – methodology for conducting LCA and default core LCA values</td>
</tr>
<tr>
<td></td>
<td>S.04.01</td>
<td>Methodology refinements – core LCA</td>
</tr>
<tr>
<td>Emission Reductions</td>
<td>S.04.03</td>
<td>Methodology refinements – Emission Credits</td>
</tr>
<tr>
<td></td>
<td>S.11</td>
<td>Double counting</td>
</tr>
<tr>
<td></td>
<td>S.12</td>
<td>ILUC Permanence</td>
</tr>
<tr>
<td>All FTG</td>
<td>S.05</td>
<td>CORSIA Package Updates</td>
</tr>
<tr>
<td>Sustainability</td>
<td>S.06</td>
<td>Sustainability criteria</td>
</tr>
<tr>
<td></td>
<td>S.07</td>
<td>SCS Requirements</td>
</tr>
<tr>
<td>Technology and Production</td>
<td>S.08</td>
<td>Technology evaluation</td>
</tr>
<tr>
<td></td>
<td>S.09</td>
<td>Fuel Production Evaluation</td>
</tr>
<tr>
<td></td>
<td>S.10</td>
<td>Guidance on Potential Policies and Coordinated Approaches for the Deployment of SAF</td>
</tr>
</tbody>
</table>
Lifecycle GHG Emissions and Sustainability

- FAA and ASCENT P01 / Volpe / ANL Team providing key data and leadership to determine how SAF and Lower Carbon Aviation Fuels (LCAF) are credited within CORSIA
- Continue to develop core life cycle emissions values for SAF made from waste CO emissions, jatropha, and co-processing of biomaterials with petroleum in today’s refineries
- Continue to develop a life cycle analysis methodology for LCAF to determine fuel eligibility under sustainability criteria 1 and amount of crediting
- Sustainability criteria being developed for LCAF based on the list of SAF criteria – have also revised the SAF criteria
- Sustainability Certification Schemes have been approved by the ICAO Council and posted on the CORSIA Eligible Fuel website
- FAA continues to help convene a series of meetings with CAEP Members and Observers on LCAF to help overcome current impasse

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

- Sales location
- Emission criteria
- Feedstock
- Approved fuel pathway
- Fuel produced
- Year of production

- Loan Guarantee
- State policy
- Producers tax credit
- Blender tax credit
- Renewable Fuel Standard

De-risk
Policy Approach
Emission based
Production based
ASCENT/FAA SAF Program Focus

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 integration
- Public-private partnership – CAAFI
- U.S. interagency cooperation
- International cooperation – ICAO
SAF Project Inventory
SAF Production

A001- Regional Supply Chain
Develop tools to assess the economic and environmental sustainability of SAF production in support:
• ICAO/CORSIA (FTG & LTAG)
• CAAFI & Regional supply chains

A093- Global Supply Chain Evaluation
Work with international partners to make these tools globally relevant.

A052-Electrification Strategies
A080- H2 Use in SAF Production
Assess the role and potential of electrification strategies for SAF production.
SAF Testing/Certification/Qualification

A031- Clearing House Alternative Jet Fuel Test and Evaluation to Support the ASTM International Approval Process
In collaboration with industry, conduct combustion testing of novel drop-in jet fuels to ensure they are safe for use and conduct research to improve the certification process

A025- Rapid Infrared Fuel Prescreening
A065A/B- Rapid Prescreening Approaches
Examine novel methods for fuels prescreening to reduce the time and cost to ensure novel jet fuels are safe for use
SAF Property Database

A033- Alternative Fuels Testing Database Library
Establish a foundational database of information about current and newly emerging SAF

A090- World Fuels Survey
Assess and catalog fuels produced globally
SAF - Fuel/Engine Compatibility – 100% SAF

A066- Evaluation of High Thermal Stability Fuels
Testing high thermal stability fuels for emission reduction

A67- Impact of Fuel Heading on Combustion and Emissions
Evaluating fuel heating to optimize combustor efficiency

A073- Combustor Durability Evaluation with use of SAF
Conduct experiments to understand changes in combustor and turbine life with use of Alternative Jet Fuels with fuels that lack sulfur content and have reduced soot emissions.

A088- Fuel Compatibility with Non-metallic Materials
Develop a method to rapidly assessing the compatibility of candidate SAFs with non-metallic materials.

A089- Compositional Effects on Dielectric Constant
Examine how hydrocarbon composition affects the dielectric constant of a fuel, a key fuel property that aircraft use to determine the amount of fuel onboard an aircraft.
Climate Projects

A021- Improving Climate Analysis Tools (Completed in 2021)
A022- Evaluation of FAA Climate Tools
Tool support to model the climate impact of aviation and support the Aviation Environmental Portfolio Tool (AMPT). Addresses impact of GHG and non-GHG impacts.

A058- Improving Policy Analysis Tools to Evaluate Higher-Altitude Aircraft Operations
A083- Environmental Impacts of High Altitude and Space Vehicles
Aimed at environmental impact of future aircraft technologies, especially supersonics and commercial space vehicles.

A078- Contrail Avoidance Decision Support and Evaluation
Understand contrail formation and development of persistent cloudiness.
Emission Reductions & Measurements

A039- Naphthalene Removal (Project Completed in 2021)
Understand role of naphthalene removal for nvPM benefits in local air quality and contrails

A018- Community Measurements of Aviation Emissions on Ambient Air Quality
Evaluate the contribution of aviation sources to nvPM and other air pollutant concentrations in communities surrounding an airport.

A002- Ambient Condition Correction for nvPM Emission Measurements
A081- Measurement and Prediction of nvPM size and number emissions from sustainable and conventional aviation fuels
A070- nVPM Reduction via Aero-Engine Fuel Injector Design
A087- Measurement of nvPM for Boeing Eco-Demonstrator burning SAF
Understand how atmospheric conditions, engine design, and fuel composition (SAF & Conventional) influence nvPM production for emission improvements.

A048- Analysis to Support Development of an Engine nvPM Standard
Support for standards development around nvPMs
Emerging Program Support
# SAF Grand Challenge Roles (in MOU)

## DOE
- Continue investments and develop expertise in sustainable technologies to develop cost effective low carbon liquid fuels and enabling coproducts from renewable biomass and waste feedstocks
- Continue a significant multi-year SAF scale-up strategy committed to in FY21
- R&D aimed at creating new pathways toward higher SAF production
- Advance environmental analysis of SAF
- Collaborate with EPA to expedite regulatory approvals of SAF with significant life-cycle GHG reductions

## DOT/FAA
- Develop overall strategy to decarbonize aviation
- Coordinate ongoing SAF testing and analysis
- Work with standards organizations to ensure safety and sustainability of SAF
- Continue International technical leadership
- Promote end use of SAF
- Support infrastructure and transportation systems that connect SAF feedstock producers, SAF refiners, and aviation end users.
- Collaborate with EPA to expedite regulatory approvals of SAF with significant life-cycle GHG reductions

## USDA
- Continue investments and build expertise in sustainable biomass production systems
- Decarbonize supply chains
- Invest in bio-manufacturing capability & workforce development
- Community and individual education
- Provide outreach & technology transfer to producers, processors and communities to accelerate adoption and participation
- Commercialization support
- Collaborate with EPA to expedite regulatory approvals of SAF with significant life-cycle GHG reductions

SAF Grand Challenge MOU available at: [https://www.energy.gov/sites/default/files/2021-09/S1-Signed-SAF-MOU-9-08-21_0.pdf](https://www.energy.gov/sites/default/files/2021-09/S1-Signed-SAF-MOU-9-08-21_0.pdf)
SAF GC Roadmap – Action Areas

1. (FI) Feedstock Innovation – Support and conduct R&D on sustainable feedstock supply that enables system innovations across the range of SAF-relevant feedstocks and identify optimization to reduce cost, technology uncertainty, and risk; increase yield and sustainability; and optimize SAF precursors (e.g., ethanol and isobutanol).

2. (CT) Conversion Technology Innovation – Support and conduct R&D, through pilot scale for technology improvements/carbon intensity reductions for both processes that are already commercial, or nearing commercialization and processes that will be ready for commercialization beyond 2030 but need to be developed now.

3. (SC) Building Supply Chains – Support SAF production expansion through supply chains, ensuring R&D transitions from pilot to large scale and field validation and demonstration projects, validating supply chain logistics, enabling public–private partnerships, supporting development of bankable business models, and collaborating with regional, state, and local stakeholders.

4. (PA) Policy and Valuation Analysis – Provide data, tools, and analysis to support policy decisions and maximize social, economic, and environmental value of SAF, including evaluation of existing and new policies.

5. (EU) Enabling End Use – Facilitate the end use of SAF by civil and military users by addressing critical barriers, including efficient evaluation of fuel engine and aircraft performance and safety, advancement of certification and qualification processes, expansion of existing blend limits, and integration of SAF into fuel distribution infrastructure.


ASCENT Projects either directly address or provide data to support every action area.

Data & Analysis
Tools & Modeling
Testing & Methods
Regional Supply Chain Configuration
• Feedstock availability,
• Strategic plant siting,
• Optimal transportation solutions

Performance Assessment
• Basic conversion economics,
• Qualifying policy & support,
• Fuel characterization

Technical support available to analyze potential SAF supply chains
QUESTIONS