Today’s Learning Objectives

1. Estimate the impact of alternative power technologies in aviation
2. Identify critical steps to develop successful alternative power ecosystem for the aviation industry
3. Utilize the toolkit developed alongside ACRP Research Report 236
1.0 Continuing Education Units (CEUs) are available to Accredited Airport Executives (A.A.E.)

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Contact AICP, not TRB, with questions
Questions and Answers

Please type your questions into your webinar control panel

We will read your questions out loud, and answer as many as time allows

#TRBwebinar
Adam Bouchard

- Vice President of Operations for the Hillsborough County Aviation Authority
- Previously progressive leadership roles for American Airlines in Nashville, Los Angeles, and Chicago
Today’s Speakers

Gaël Le Bris
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WSP USA, Inc.

Scott Cary
scott.cary@nrel.gov
National Renewable Energy Laboratory (NREL)
Preparing Airports for Electric Aviation
Electrification & Hydrogen Technologies in Airports
TRB Webinar

Gaël Le Bris, C.M., P.E.
Vice President, Aviation Planning
WSP USA
A Journey Toward Fly Net Zero

- Aviation accounts for 2% of CO₂ emissions & 3.5% of climate change’s drivers.
- Aviation has worked on keeping its emissions in check for over two decades.
- Aviation has a plan to achieve net-zero by 2050.
A Journey Toward Fly Net Zero

**Small GA**
- 100LL
- Unleaded Avgas
- Electric Propulsion Systems

**Urban Air Mobility**
- Electric Propulsion Systems

**Regional Aviation**
- SAF
- Electric & Hybrid Propulsion Systems
- SAF + Electric Hybridization?
- Hydrogen as a Jet-Fuel?

**Longer Range**
- SAF
- Hydrogen as a Jet-Fuel?
- Fully-Electric?

**Time**
- Short-term
- Medium-term
- Long-term
What is an Electric Aircraft?

Electrification & Hydrogen Technologies in Airports
What is an Electric Aircraft?

**Turboelectric**
- Fuel → Turboshaft → Generator → Motor + Propeller

**Series/Parallel Partial Hybrid**
- Fuel → Turboprop → Generator → Motor + Propeller

**Series Hybrid**
- Fuel → Turboshaft → Generator → Motor + Propeller

**Parallel Hybrid**
- Battery → Motor → Turboprop

**Battery Electric**
- Battery → Motor + Propeller

**Fuel Cell Electric**
- Fuel Cell → Motor + Propeller

**Legend:**
- Chemical Energy
- Mechanical Energy
- Electrical Energy
What is Advanced Air Mobility?

**Use Cases/Missions:**
- **On-demand intra-urban transportation**
  - VTOL aircraft (1-5 pax)
  - Range: 10-20 miles

**Use Cases/Missions:**
- **On-demand regional transportation**
  - V/STOL aircraft (1-19 pax)
  - Range: 10-70 miles

**Use Cases/Missions:**
- **Last-mile cargo delivery**
  - Small UAS (<250 lbs.)
  - Range: 10-30 miles

**Use Cases/Missions:**
- **Heavier air cargo deliveries**
  - Larger UAS (>250 lbs.), STOL
  - Range: 10-70 miles

**Use Cases/Missions:**
- **Medical supply delivery**
  - Small UAS (medical emergency supply)
  - Range: 10-30 miles

**Use Cases/Missions:**
- **Medevac**
  - Larger UAS, V/STOL & CTOL aircraft
  - Range: 10-70 miles
Electric Aircraft are on the Horizon

A Possible Timeline to Electric Aviation

Small Aircraft Powered with Batteries
Regional Acft Powered with Fuel Cells
Larger Aircraft (TBD)

1st electric commercial flight (air taxi)
1st regional e-aircraft certified
Regional airlines & private owners embrace e-aircraft
About 2% of the U.S. fleet is electric
Emergence of electric propulsion for larger aircraft

202?
2025
2030
2035
2040
Potential Impact on the Aviation Demand

- Electric aviation promises lower OPEX to flight operators.
- This could make point-to-point air mobility more accessible.
- General aviation facilities could become local transportation hubs for communities and see their capacity better utilized.
- Commercial service airports will accommodate more small commuter aircraft with STOL and VTOL capabilities.

➢ The novelty of electric aviation, the uncertainty around certification, and the lack of visibility on the future demand does not make it easy for planners & decision makers.
Opportunities & Challenges for Airports & Communities

➢ Electric aircraft are significantly **quieter & cleaner** than ICU-powered aircraft.

➢ Hub airports are becoming **intermodal nodes**.

➢ **Mobility-as-a-service (MaaS)** can enable a better integration of these modes.

➢ With AAM, smaller aviation facilities may become **local mobility hubs**.

➢ **Supply chains** are needed to meet power requirements & deliver new fuels.

➢ **On-airport power generation** and microgrid can help address these needs.

➢ Airports can increase **energy resilience** and **community resilience**.
The Stakeholder Ecosystem is Expanding

- Airport operator
- AAM providers and their flight operators
- Existing flight operators (including GA community)
- Aircraft rescue and firefighting (ARFF)
- FAA ADO and AFS
- Air traffic control tower (ATCT)
- Aircraft ground support providers
- Fixed-base operators (FBO)
- Utility providers and hydrogen suppliers
- Maintenance, repair, and overhaul (MRO)
- Ground transportation (TNC, transit authority, etc.)
- Local governments
- Metropolitan & regional planning organizations
- Communities and small businesses
- Building and land-owners
Navigating Operational Safety at Aviation Facilities

Anatomy of Electric Aircraft Operations

- Wind Effects
- VTOL Rescue
- New Flight Procedures
- More Diverse Fleet Mix
- Jet Blast/Downwash
- Human Factor
- Hydrogen Fire
- Firefighting
- Occupational Hazards
- Thermal Runaway
- Pedestrian Safety
- Electrification & Hydrogen Technologies in Airports
Navigating Operational Safety at Aviation Facilities

“Most Wanted”: Atypical Configurations

⚠️ **Overall Risk:**

Unusual propulsion systems & lower noise increase risk on the ramp.

📅 **Current Conditions & Trends:**

Over 100 e-aircraft projects with atypical config. (ACRP RR 236).

📝 **Assessment:**

Risk should be assessed for each type or novel configuration.

💡 **Potential Mitigation:**

- Joint training sessions with the ramp community.
- Specific configurations may warrant visual aids (e.g., markings).
Navigating Operational Safety at Aviation Facilities
“Most Wanted”: Accident Increases in Severity

⚠️ **Overall Risk:**

Battery fire/runaway or leak/explosion of hydrogen tank following a high-energy safety occurrence (e.g., runway excursion).

📅 **Current Conditions & Trends:**

• Airliners already carry powerful batteries (e.g., A350, 787).
• Large aviation hydrogen tanks & pods are novel (even per other transportation industry standards).

🔍 **Assessment and Mitigation:**

Batteries/hydrogen tanks and pods, by design, should not increase the severity of such occurrences (assuming reasonable scenarios) and should be able to withstand some of them (e.g., runway excursions).
Navigating Operational Safety at Aviation Facilities

“Most Wanted”: Hydrogen Storage & Distribution

⚠️ **Overall Risk:**

H₂ and hydrogen carriers would be new gases/fluids at airports to be stored, transported, and processed—inducing new hazards.

📅 **Current Conditions & Trends:**

Safety standards exist for their safe storage and handling in other industries/non-aviation contexts.

🔍 **Assessment and Potential Mitigation:**

- The supply chains for aviation hydrogen are to be developed.
- Firefighting standards already exist for hydrogen technologies.

   NFPA guidance on fueling systems to be revised.
Navigating Operational Safety at Aviation Facilities

Typology of Operators and Services

<table>
<thead>
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<th>Type</th>
<th>Who provide safety management?</th>
<th>Who provide operational safety?</th>
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<td>Vertistop</td>
<td>Flight operators</td>
<td>Pilots</td>
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<tr>
<td>Vertiport/Vertihub</td>
<td>Flight operators, Vertiport operator?</td>
<td>Pilots &amp; ground handlers</td>
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</tr>
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<td>Airport, ATCT, Flight operators</td>
<td>ATCT, pilots, ground handlers, airport staff</td>
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Note: Heliports are not required to comply with Part 139 requirements. Also, Part 139 typically does not apply to airports served by air carriers performing unscheduled operations with small aircraft (<31 seats) and GA facilities.
# Navigating Operational Safety at Aviation Facilities

## Typology of Operators and Services

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Emerging Aviation “Fuels”

Various energy systems and configurations are considered.

<table>
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<tr>
<th>Techno.</th>
<th>All Electric</th>
<th>Turboelec.</th>
<th>Series Hybrid</th>
<th>Parallel Hybrid</th>
<th>Series/Parallel Hybrid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Batteries</td>
<td>Electricity</td>
<td>Electricity + Fuel</td>
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How to “refuel” these aircraft?

<table>
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<tr>
<th>Airport Solution</th>
<th>Batteries</th>
<th>Fuel Cells</th>
</tr>
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<tr>
<td>Fixed Airport Units</td>
<td>Electric Chargers</td>
<td>Hydrant system</td>
</tr>
<tr>
<td>Mobile Airport Units</td>
<td>Superchargers on Truck or Trailer</td>
<td>Tanker (Truck)</td>
</tr>
<tr>
<td>Swap of Energy Containers</td>
<td>Battery Swap</td>
<td>Container Swap</td>
</tr>
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</table>

These technologies have different pros and cons, as well as different implications for airport stakeholders in terms of operations, design, and planning.
Emerging Aviation “Fuels”
Recharging Aircraft with Batteries

- Off-Airport Production or On-Site Generation (e.g., Microgrid)
- Airport Power Management to Share the Resource Between Users
- Power Back Up Solutions to Increase Resilience
- Fixed Chargers at the Gate (Above-Ground or Underground Hatch)

Charging Stations (Source: Pipistrel)
Emerging Aviation “Fuels”
Recharging Aircraft with Batteries

Battery Inventory

Battery Swap

Mobile Chargers
Emerging Aviation “Fuels”

Power Supply Requirements

- Airports are on the forefront of the Electrification of Everything.

- E-aircraft are among other emerging electricity users that need to be accounted for.

- Power supply & management is now a critical element of aviation resilience.

- Utility master plans should aim to address these challenges.

- Airports need to have a holistic approach of electrification.
Emerging Aviation “Fuels”
The “Electrification of Everything”

Emerging Ground Access Modes & Techs

Greener Passenger Terminal
Source: Indianapolis Airport Authority

Airside Electrification
- General Aviation/Air Taxi
- Regional Aviation
- Electric GSE

Electrification & Hydrogen Technologies in Airports
Emerging Aviation “Fuels”
Refueling Aircraft with Fuel Cells
Emerging Aviation “Fuels”
Methods to Produce Hydrogen

Source: U.S. DOE
Emerging Aviation “Fuels”
Hydrogen Supply Chains at Airports

Note: LOHCs (Liquid Organic Hydrogen Carriers) are organic compounds that can absorb and release hydrogen through hydrogenation/dehydrogenation reactions. Visible candidates for LOHC systems include carbon dioxide/methanol (CH$_3$OH), benzene/cyclohexane, toluene/methylcyclohexane (MHC), naphthalene/decalin, N-ethylcarbazole (NEC)/perhydro-NEC, dibenzyltoluene (DBT)/perhydro-DBT.
Planning for eAircraft at Airports

— Incorporating electric aircraft trends and requirements into master planning (see ACRP Research Report 236).

— Once e-aircraft will start being adopted by flight operators: aircraft/airport compatibility studies.

— Need for an industry playbook providing guidance on compatibility studies... What about an “EACG” or “VACG”?
Planning for eAircraft at Airports
Policy Considerations: Impact on Fuel Revenues

Aviation fuel taxes in Colorado:

• **Aviation Fuel Excise Tax** on aviation gasoline (6¢ per gallon) & fuel (4¢ per gallon) with exemptions for air carriers.
• **Aviation Fuel Sales Tax** on aviation jet fuel used in turbo-propeller or jet engine aircraft.
• **Special Taxation Districts**: RTD (Regl. Transportation District) and RTA (Rural Transportation Authority) sales tax.
• **Flowage Fees**: Aviation fuel or gasoline can be subject to a fuel flowage (in-plane) fee imposed by the airport.

During FY 2019-2020, **$26.4 million** of state aviation fuel tax revenues were collected. These tax revenues support, develop, and maintain the Colorado aviation system.

Battery-electric and hydrogen-electric aircraft will not use conventional aviation fuels. Hybrid-electric aircraft will use less fuels than conventional aircraft.

Food for thought:

— What will be the impact of electric aviation implementation on fuel revenues over time?
— How can this loss of revenue be offset?
— Should electric aircraft pay the difference? Or should electric aviation be incentivized?
— Should emerging aviation “energy vectors” (electricity and hydrogen) be taxed?
Policy Considerations: Utilities

— Policies should articulate the purpose of **electric metering** and allow for billing aviation tenants and users.

— Should direct aircraft recharge be allowed in hangars? Who will pay to facilitate this in terms of **airport electric infrastructure**? How should it be regulated (if applicable)?

— Is there any conflict with other policies such as **grant assurances**?

— The electric aircraft infrastructure is not eligible for most existing funding programs. Should **new funding mechanisms** be introduced?

— Where do we draw the line between **transmission, storage, and charging infrastructure**?

— What **does electrification mean** to airports, their community, and local governments?
Paving the Way for Electric Aviation

Guidance & Standards

State & Regional Roadmaps

Planning & Designing for eAircraft
Further Reading


— Advanced Air Mobility is Coming. Are We Ready? SAE International, 2022

— Advanced Air Mobility: Challenges and Opportunities for Airports & Vertiports. AAAE, 2022

— Safety Considerations on the Operation of eVTOL Aircraft at Airports and Vertiports. Proceedings of Forum 78, VFS, 2022

— Way of the Future: Airports at the Horizon of 2040 and 2070. TR News 331, Transportation Research Board, 2021

— Washington Electric Aircraft Feasibility Study. WSP/WSDOT, 2020
Further ACRP Reading

ACRP Research Report 236: Preparing Your Airport for Electric Aircraft & Hydrogen Technologies

ACRP Research Report 243: Urban Air Mobility: An Airport Perspective
Fly safe!

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- Wind
- Water
- Geothermal

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- State, Local, and Tribal Governments

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- Energy Security and Resilience
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NREL helps bridge the gap from basic science to commercial application.
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Industry aims for net zero carbon by 2050:
International Civil Aviation Organization and International Air Transport Association are both working towards that long-term target.

Petroleum-based fuels transitioning to sustainable alternatives:
U.S. Department of Energy Sustainable Aviation Fuel Grand Challenge aims to meet 100% of aviation fuel demand by 2050.
Alternatives include sustainable aviation fuel, hydrogen, power-to-liquids, and electric

Partnerships are reaching across the aviation sector:
Airports, airline companies, new entrants, utilities, and fuel providers are seeing an increasingly heterogenous and complex energy landscape for net zero aviation.
Sustainable Aviation Ecosystem
Holistic, sustainable energy solutions to achieve deep decarbonization of the aviation ecosystem

An ecosystem of partnerships are needed for realizing Sustainable Aviation

Required Capabilities: Research, Analysis, Modeling, Validation/Deployment

An ecosystem of partnerships are needed for realizing Sustainable Aviation
Airport/Base System

- Administration building tools
  - Systems Integration
  - Grid Planning and Services
  - Analysis and Modeling
  - Advanced Computing

- Offsite Capabilities

- Low-carbon freight transport

- Low-carbon ground support equipment

- Sustainable aviation fuel

- Aircraft development support

- Building loads at terminals

- Low-carbon shuttles

- Energy storage

- On-site renewables production

- Electric aircraft charging

- Sustainable aviation fuel

- Hydrogen

- Geothermal/ground source heat pumps

- Fuel farm

- EV charging at parking facility
Aircraft Transformation

- Power Unit
- Advanced Composites
- Advanced Propulsion
- Energy Storage
- Energy Management and System Controls

eVTOL
Regional Air Mobility
Turbine Aircraft
Questions?

Sustainable Aviation
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NRELc
Other Events for You:

June 5, 2023
Airfield Pavement Markings—Removal and Temporary Applications

June 14, 2023
Practices in Airport Emergency Response

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