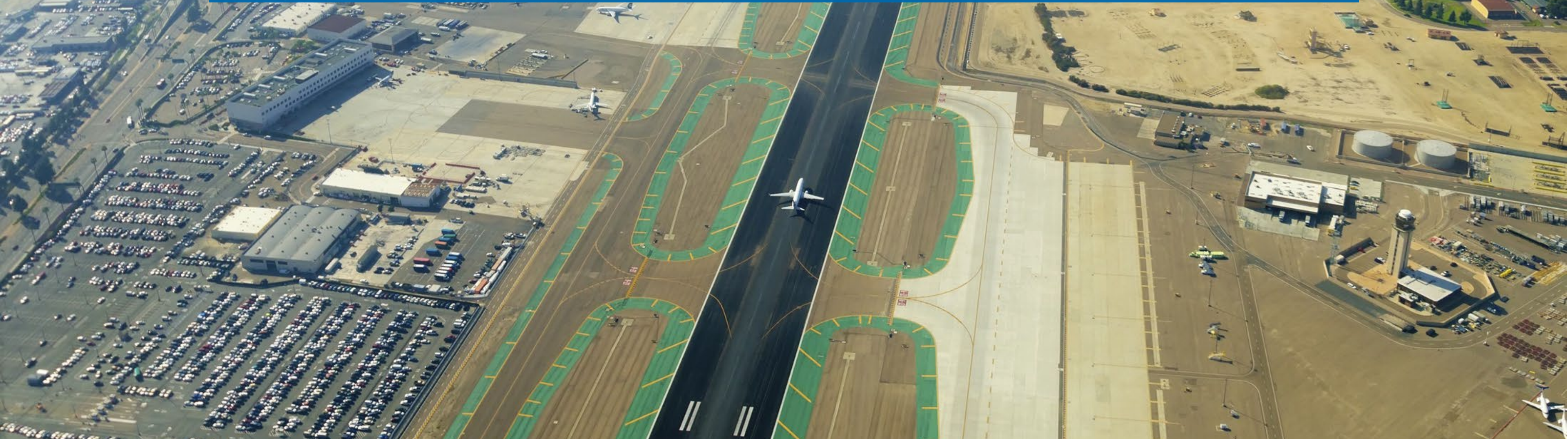
Electrification and Hydrogen Technologies in Airports

May 25, 2023



NATIONAL ACADEMIES Sciences Engineering Medicine

TRB TRANSPORTATION RESEARCH BOARD

ACRP AIRPORT COOPERATIVE RESEARCH PROGRAM

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

American Association of Airport Executives (AAAE)

1.0 Continuing Education Units (CEUs) are available to Accredited Airport Executives (A.A.E.)

Report your CEUs:

www.aaae.org/ceu

American Institute of Certified Planners Certification Maintenance Credits (CM)

1 American Institute of Certified Planners Certification Maintenance Credits

You must attend the entire webinar

Log into the American Planning Association website to claim your credits

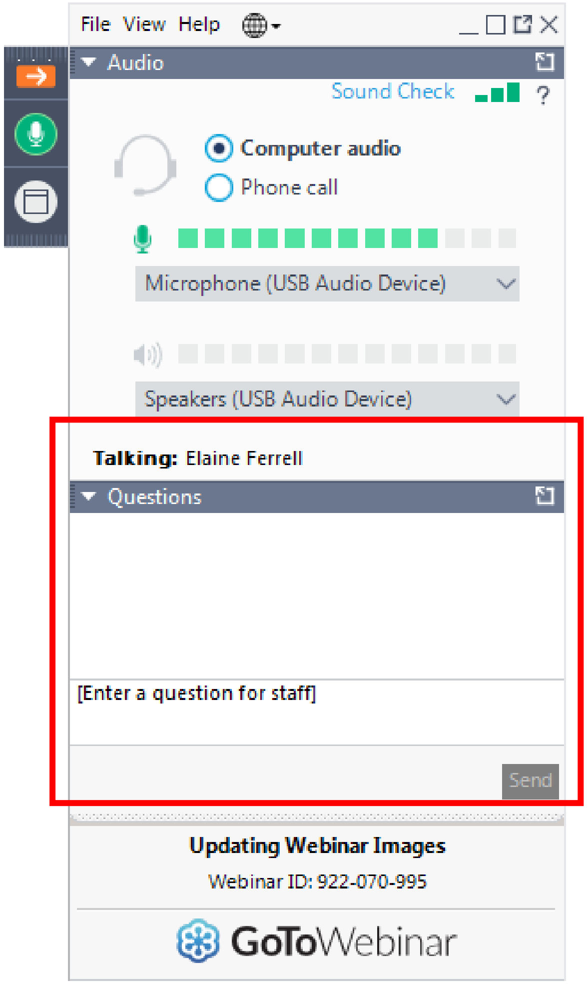
Contact AICP, not TRB, with questions

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
- Helps lead lines of business, including Airfield Operations, Terminal Operations, Security Operations Compliance, and Emergency Management and Resilience

Today's Speakers

Gaël Le Bris
GAEL.LEBRIS@wsp.com
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

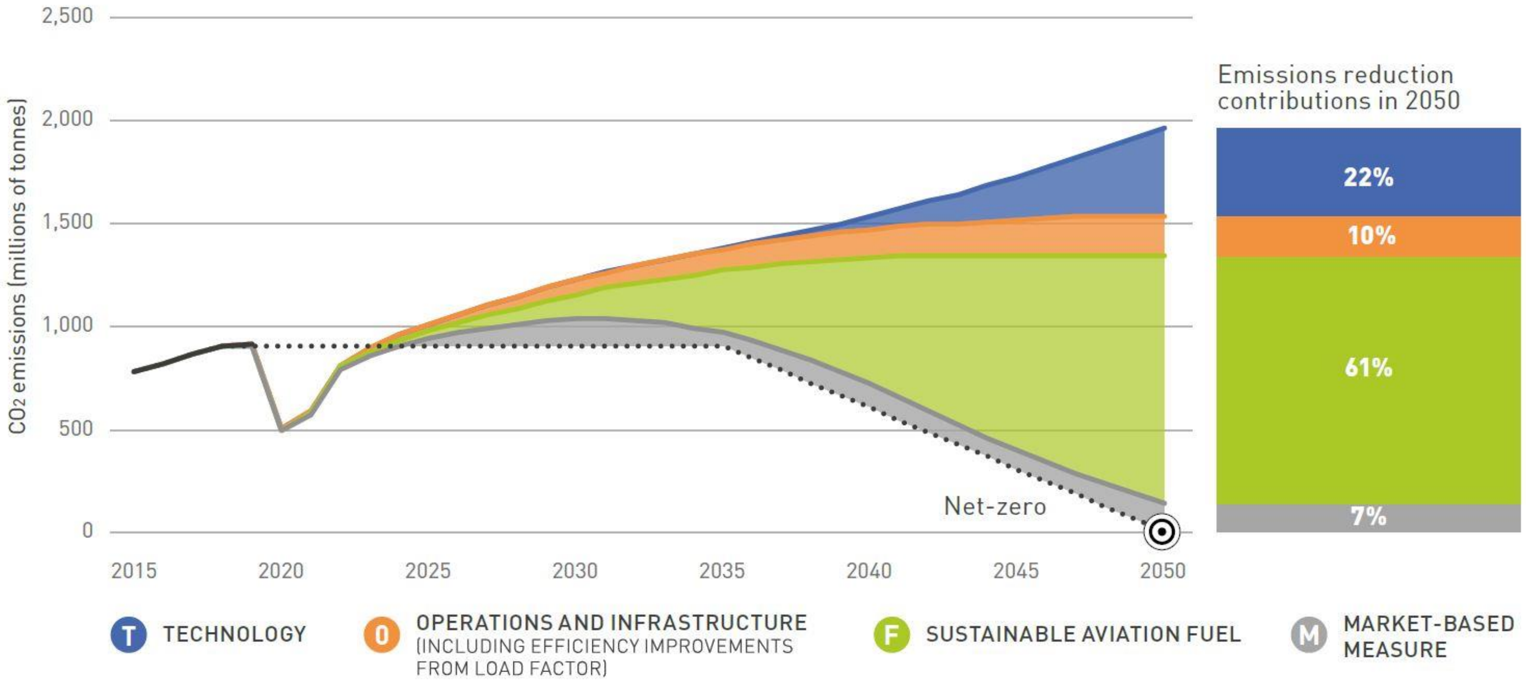
Gaël Le Bris, C.M., P.E.

Vice President, Aviation Planning

WSP USA

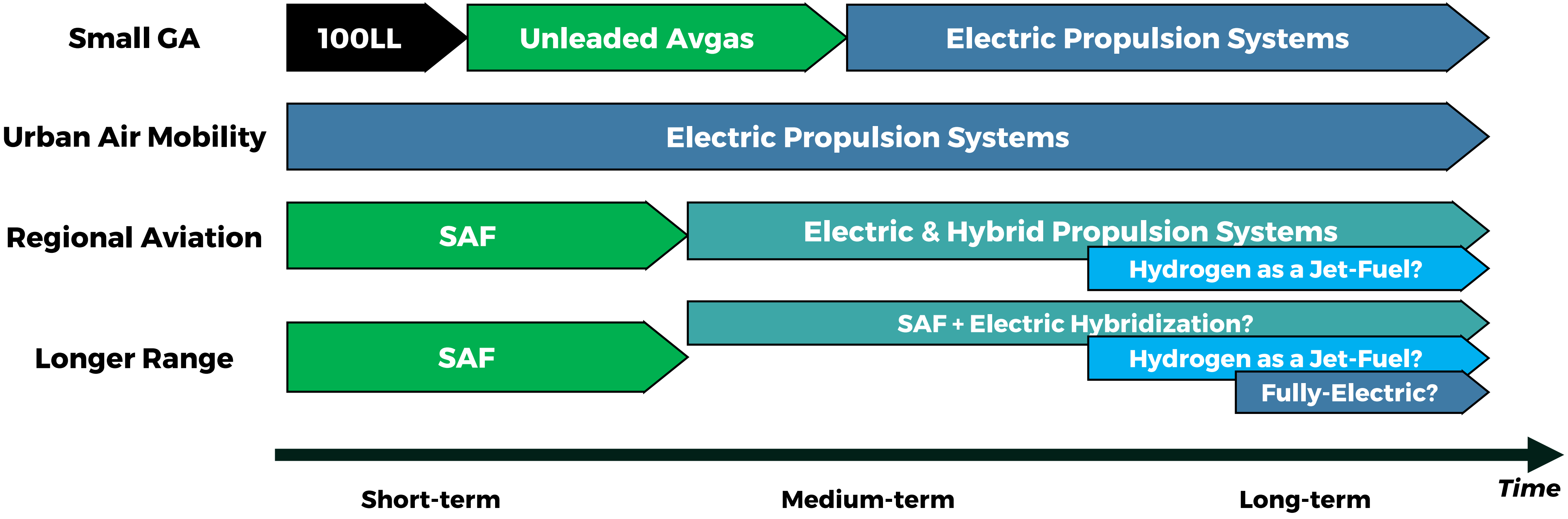
A Journey Toward Fly Net Zero

- Aviation accounts for 2% of CO_2 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.

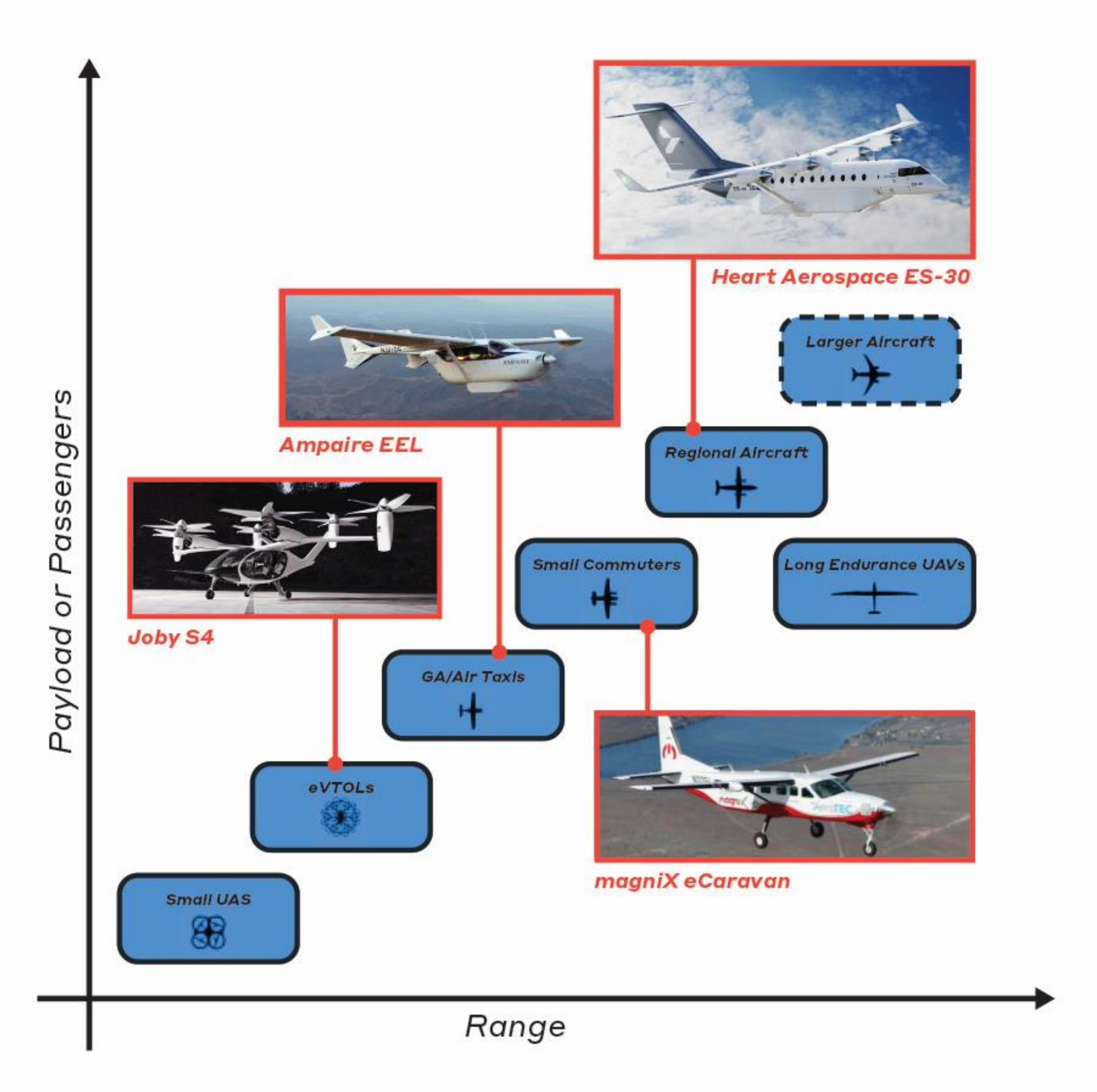


Source: ATAG

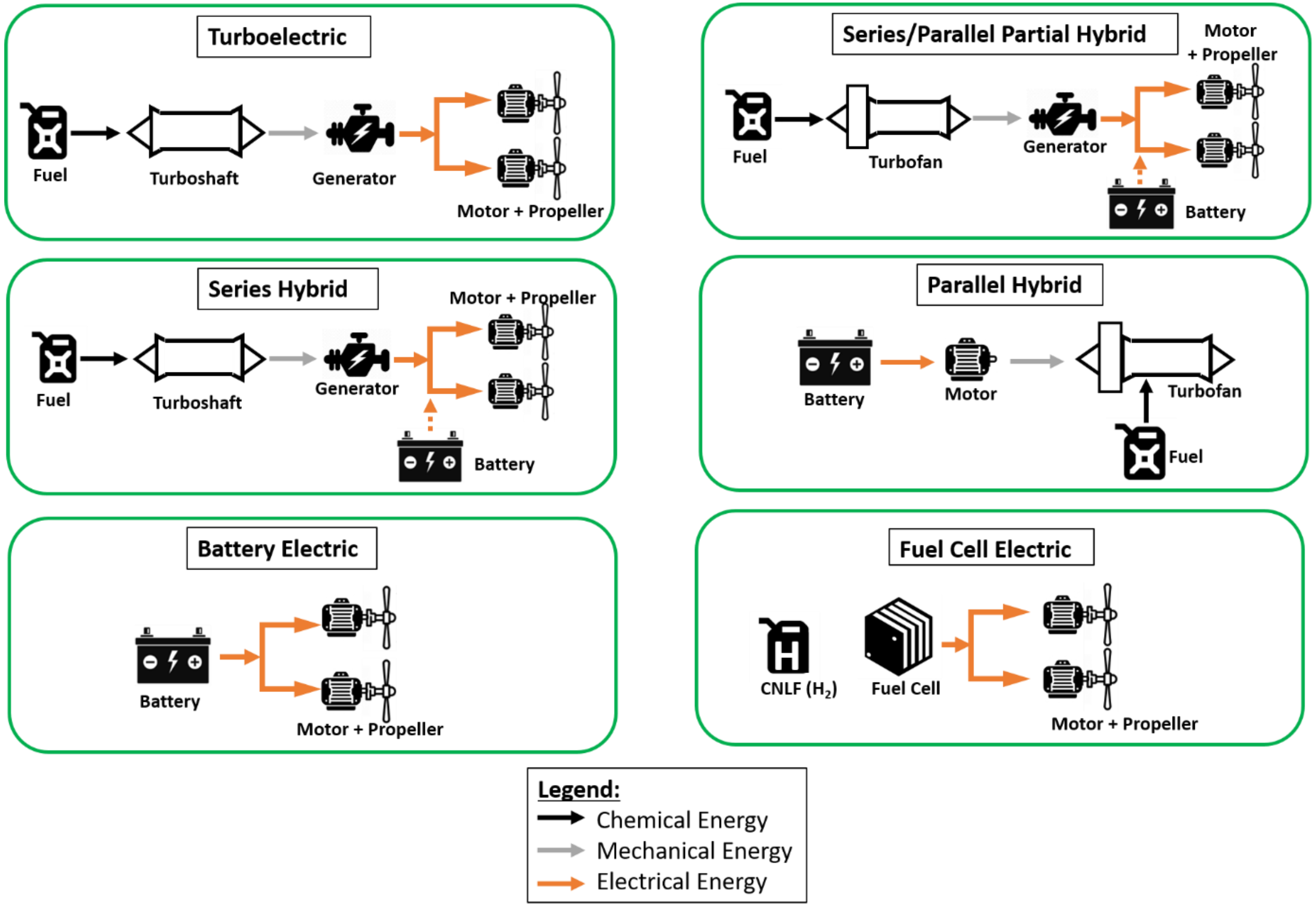
A Journey Toward Fly Net Zero



What is an Electric Aircraft?



What is an Electric Aircraft?



What is Advanced Air Mobility?

AAM

UAM

Use Cases/Missions:

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

RAM

Use Cases/Missions :

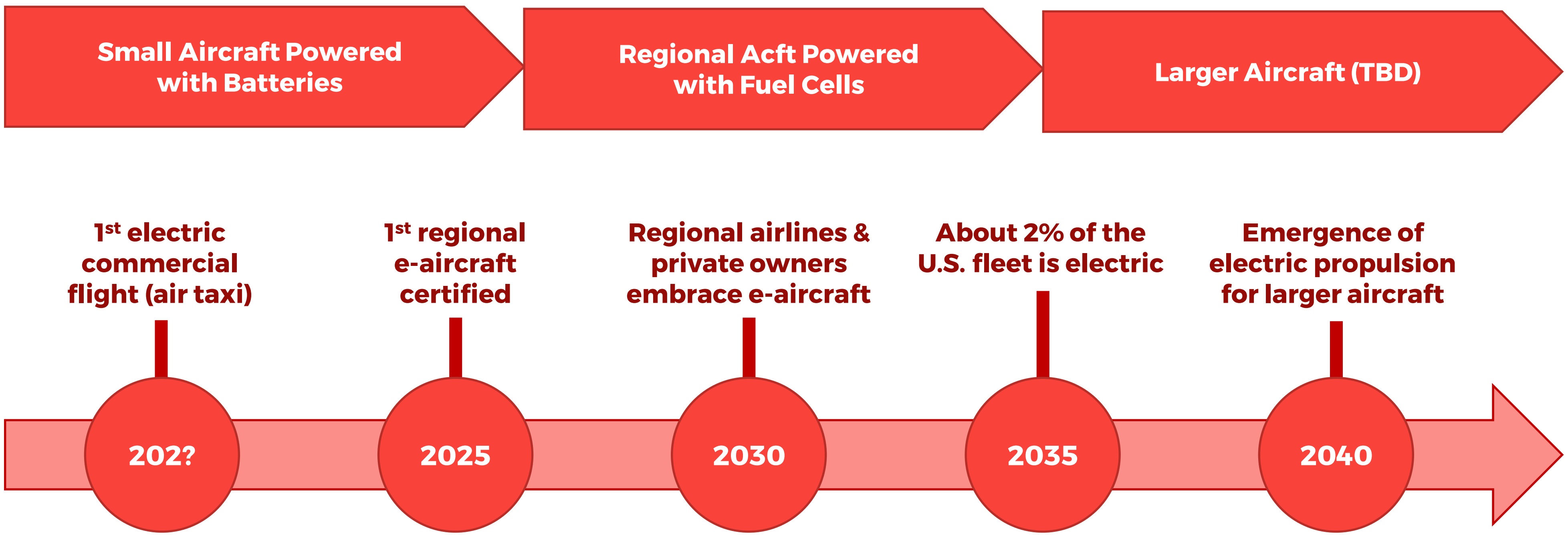
- ***On-demand regional transportation***
  - *V/STOL aircraft (1-19 pax)*
  - *Range: 10-70 miles*

Use Cases/Missions:

- ***Last-mile cargo delivery***
  - *Small UAS (<250 lbs.)*
  - *Range: 10-30 miles*
- ***Medical supply delivery***
  - *Small UAS (medical emergency supply)*
  - *Range: 10-30 miles*
- ***Heavier air cargo deliveries***
  - *Larger UAS (>250 lbs.), STOL*
  - *Range: 10-70 miles*
- ***Medevac***
  - *Larger UAS, V/STOL & CTOL aircraft*
  - *Range: 10-70 miles*

Electric Aircraft are on the Horizon

A Possible Timeline to Electric Aviation



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.**

Source: Eve Air Mobility

Source: Zero Avia

Opportunities & Challenges for Airports & Communities

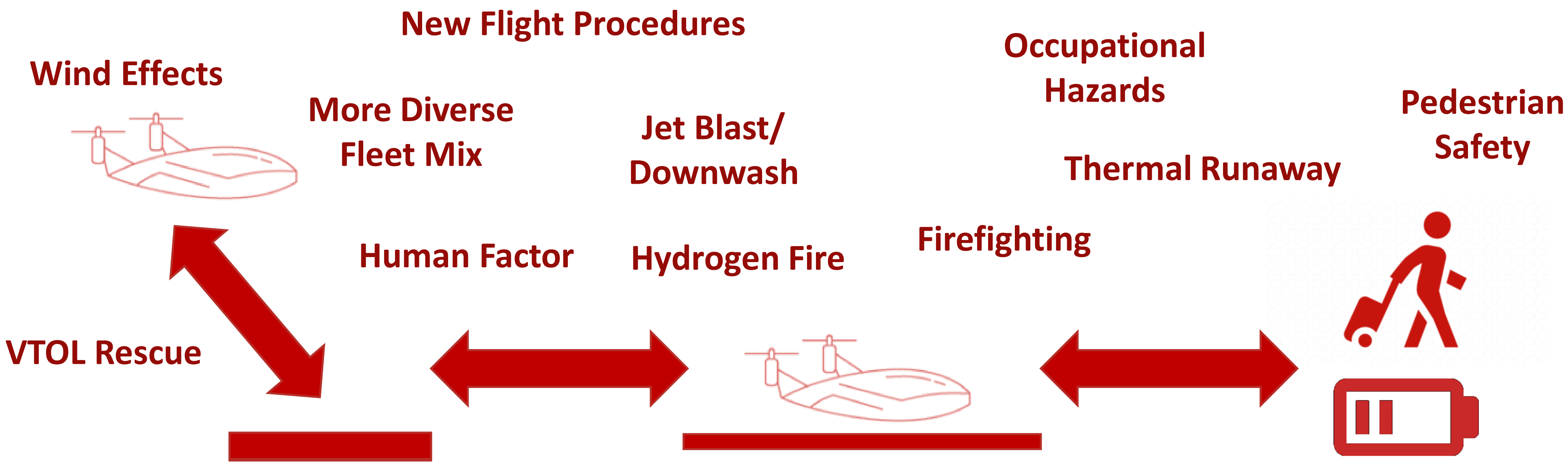
- Electric aircraft are significantly **quieter & cleaner** than ICU-powered aircraft.
- Hub airports are becoming **intermodal nodes**.
- **Mobility-as-a-service (MaaS)** can enable a better integration of these modes.
- With AAM, smaller aviation facilities may become **local mobility hubs**.
- **Supply 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



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:

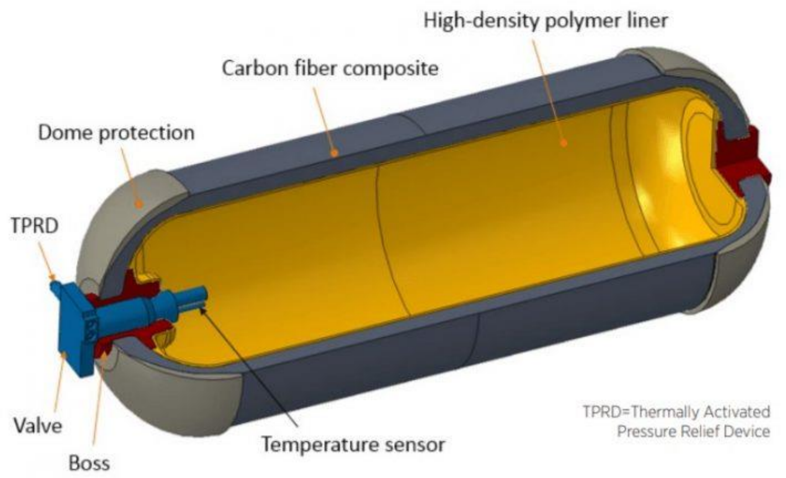
H_2 and hydrogen carriers would be new gases/fluids at airports to be stored, transported, and processed–inducing new hazards.

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

	Who provide safety management?	Who provide operational safety?
Vertistop	Flight operators	Pilots
Vertiport/Vertihub	Flight operators Vertiport operator?	Pilots & ground handlers
Vertiport Network	Flight operators Vertiport operator?	Pilots, ground handlers, vertiport staff
Vertiport at Non-Certified Airport	Flight operators Airport operator?	Pilots, ground handlers, airport staff
Vertiport at Part 139 Airport	Airport, ATCT, Flight operators	ATCT, pilots, ground handlers, airport staff

Growing Complexity & Traffic

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 (<31seats) and GA facilities.

Navigating Operational Safety at Aviation Facilities

Typology of Operators and Services

	Who provide safety management?	Who provide operational safety?
Vertistop	Flight operators	Pilots
Vertiport/Vertihub	Flight operators Vertiport operator?	Pilots & ground handlers
Vertiport Network	Flight operators Vertiport operator?	Pilots, ground handlers, vertiport staff
Vertiport at Non-Certified Airport	Flight operators Airport operator?	Pilots, ground handlers, airport staff
Vertiport at Part 139 Airport	Airport, ATCT, Flight operators	ATCT, pilots, ground handlers, airport staff

Growing Complexity & Traffic

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 (<31seats) and GA facilities.

Emerging Aviation "Fuels"

- ✈ Various energy systems and configurations are considered.

Techno.	All Electric	Turboelec.	Series Hybrid	Parallel Hybrid	Series/Parallel Hybrid
Batteries	Electricity	Electricity + Fuel	Electricity + Fuel	Electricity + Fuel	Electricity + Fuel
Fuel Cells	Hydrogen	Hydrogen + Fuel	Hydrogen + Fuel	Hydrogen + Fuel	Hydrogen + Fuel

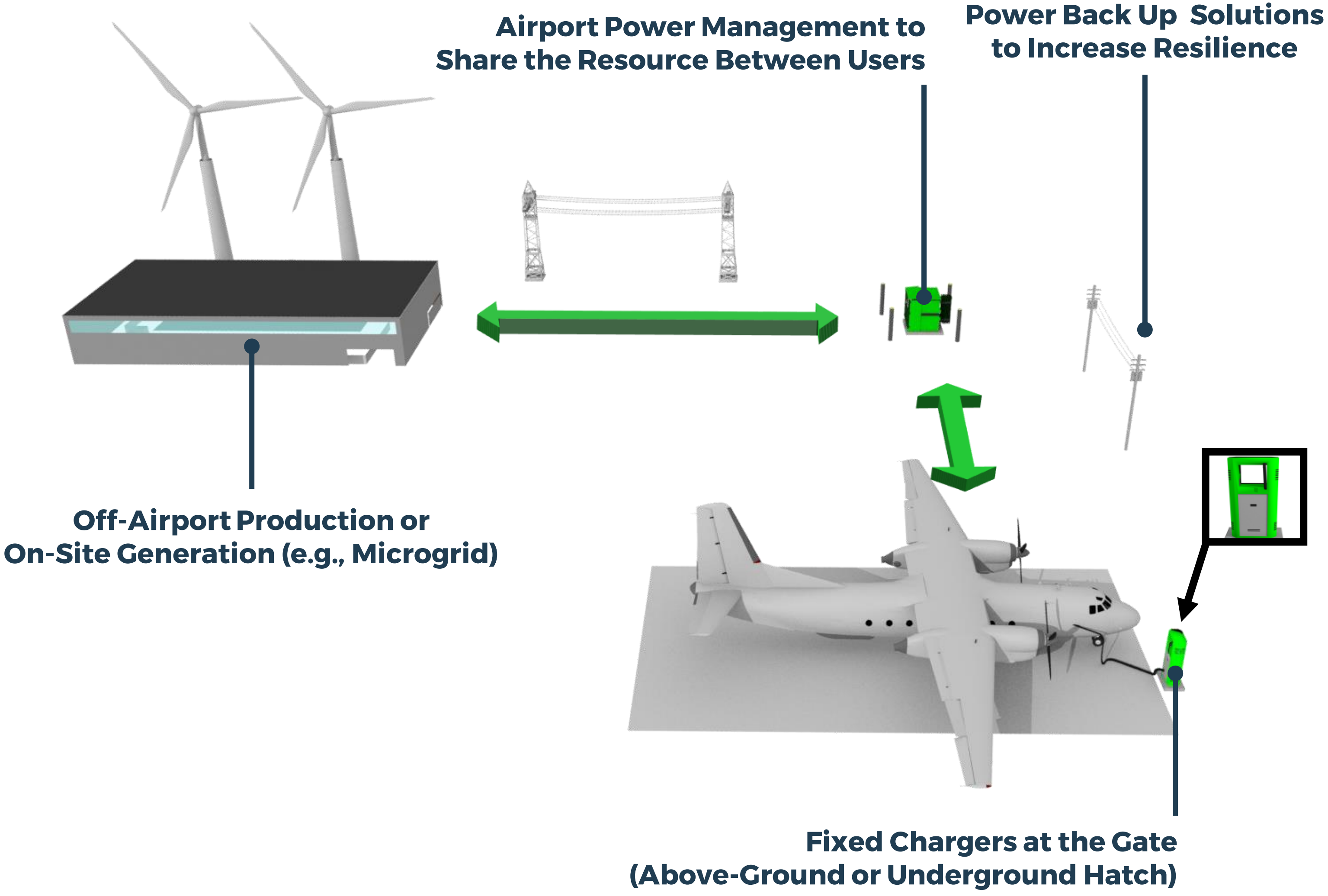
- ✈ How to "refuel" these aircraft?

Airport Solution	Batteries	Fuel Cells
Fixed Airport Units	Electric Chargers	Hydrant system
Mobile Airport Units	Superchargers on Truck or Trailer	Tanker (Truck)
Swap of Energy Containers	Battery Swap	Container Swap

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

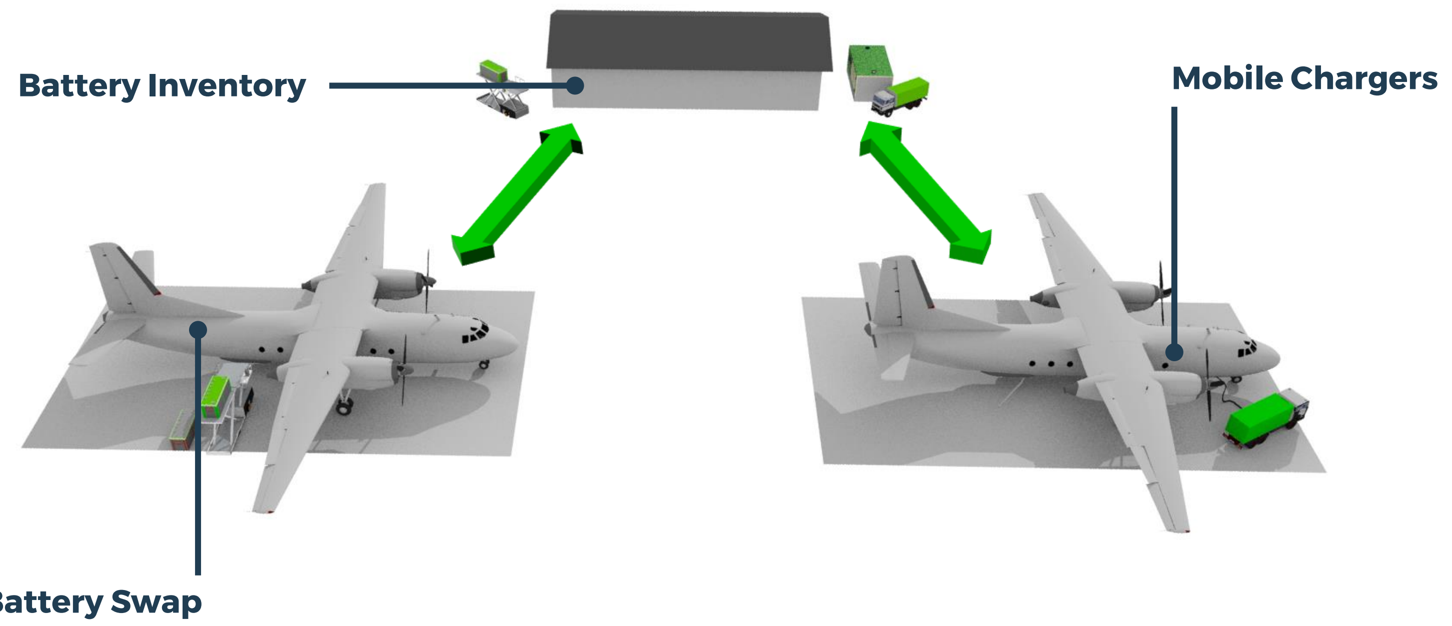



Charging Stations (Source: Pipistrel)


Hatch for 400Hz AC

Emerging Aviation "Fuels"

Recharging Aircraft with Batteries



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

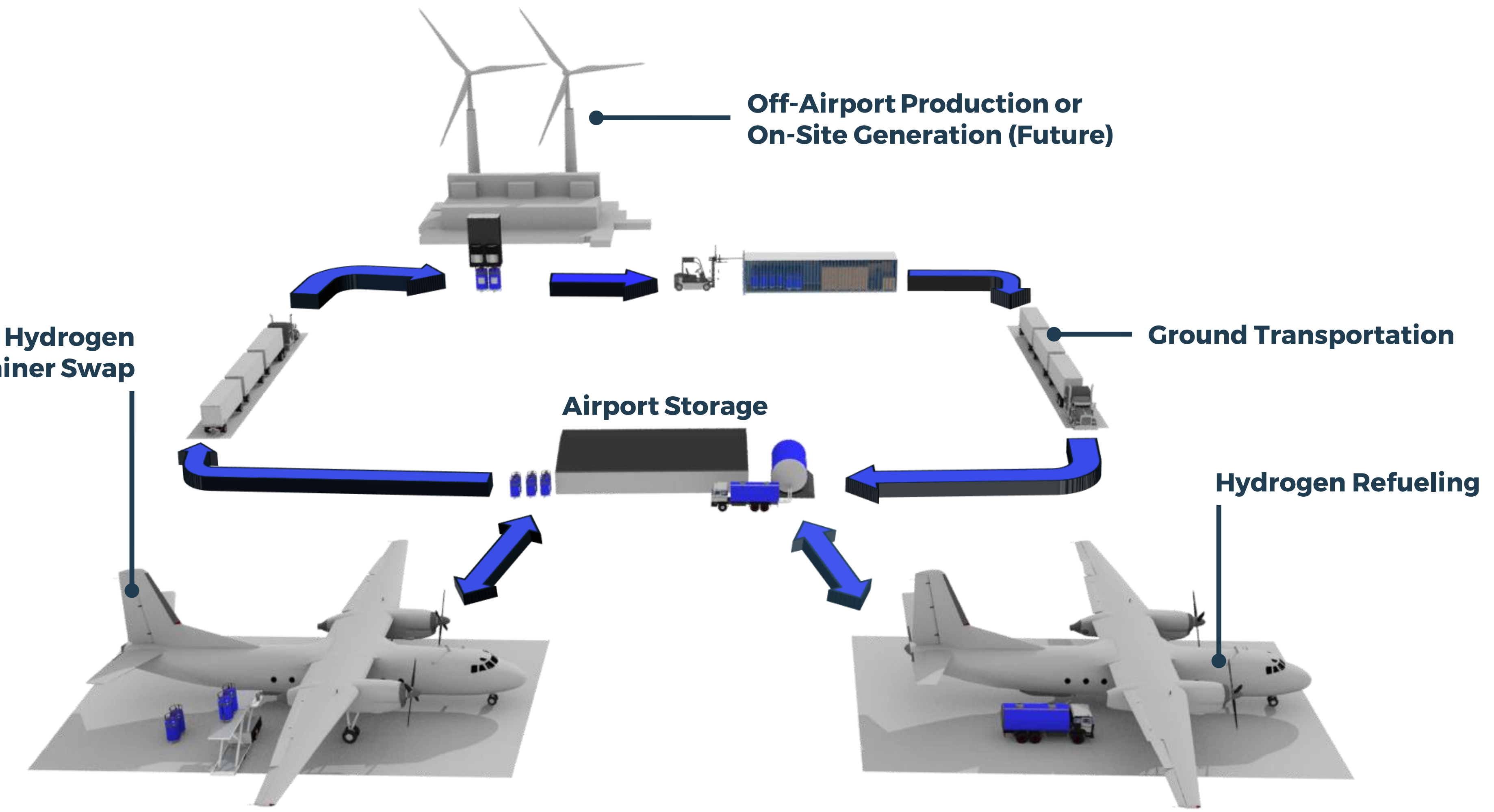
Airside Electrification

General Aviation/Air Taxi

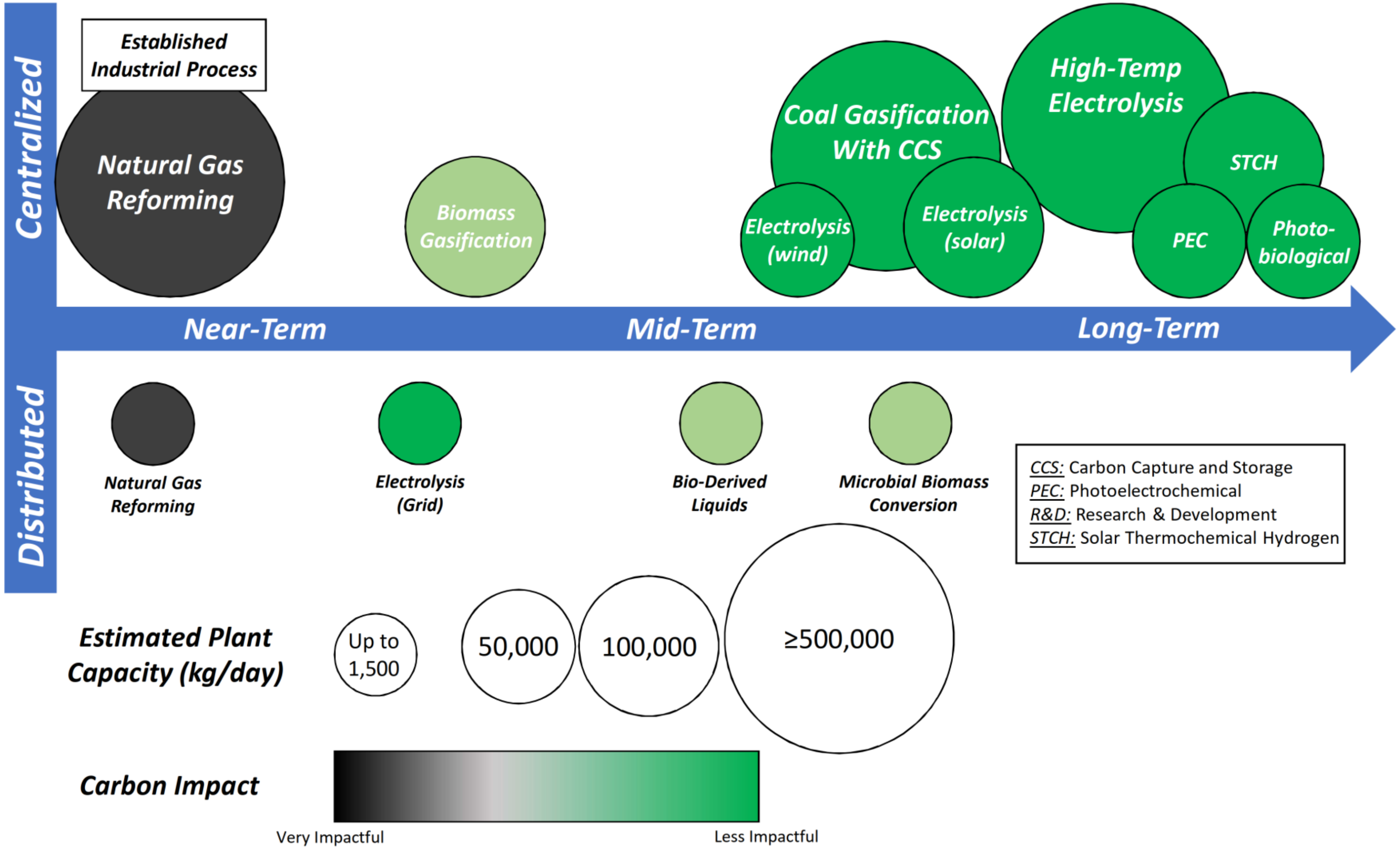
Regional Aviation

Electric GSE

Emerging Aviation “Fuels”
Refueling Aircraft with Fuel Cells



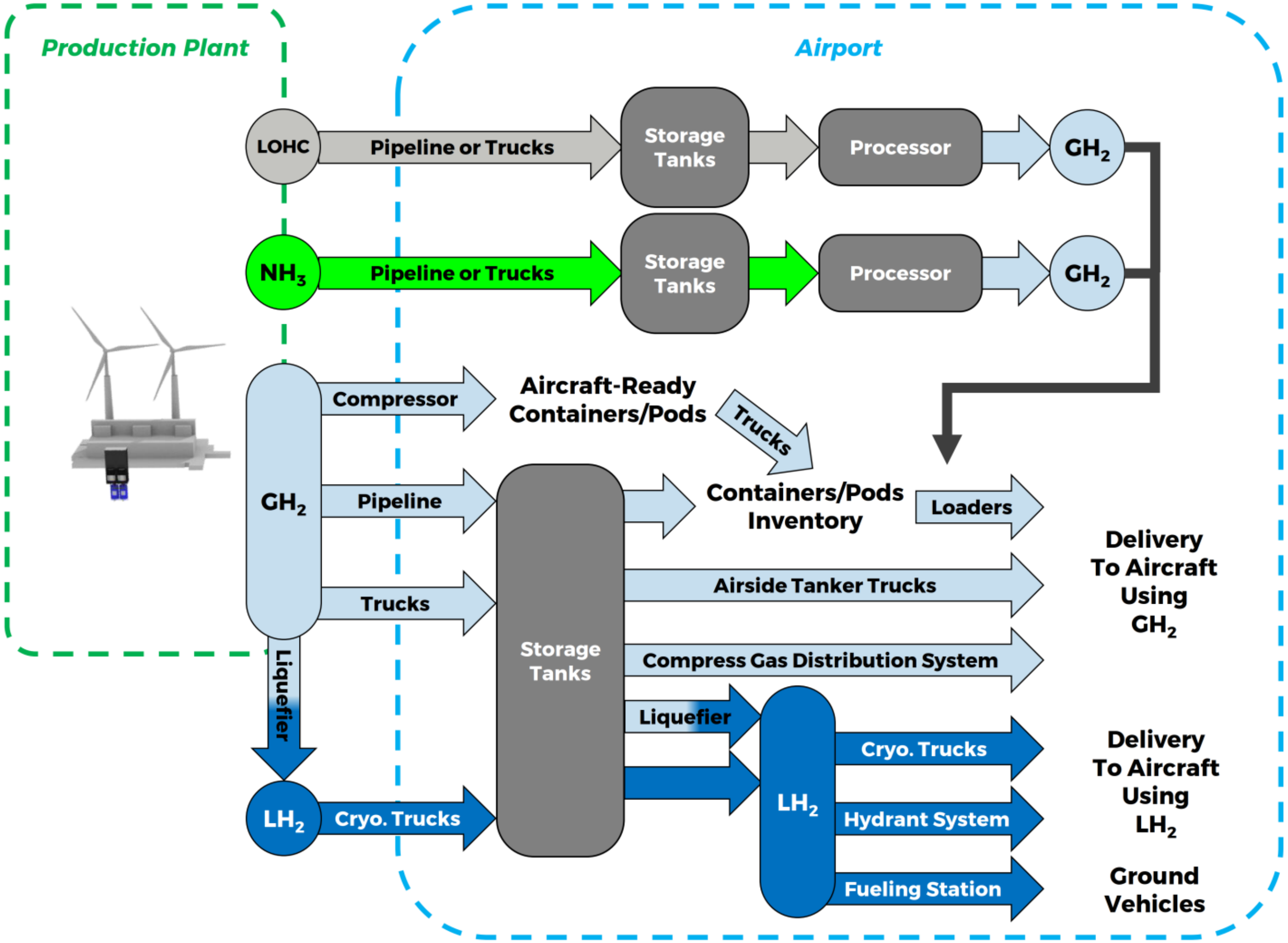
Emerging Aviation "Fuels"
Methods to Produce Hydrogen



Source: U.S. DOE

Emerging Aviation "Fuels"

Hydrogen Supply Chains at Airports



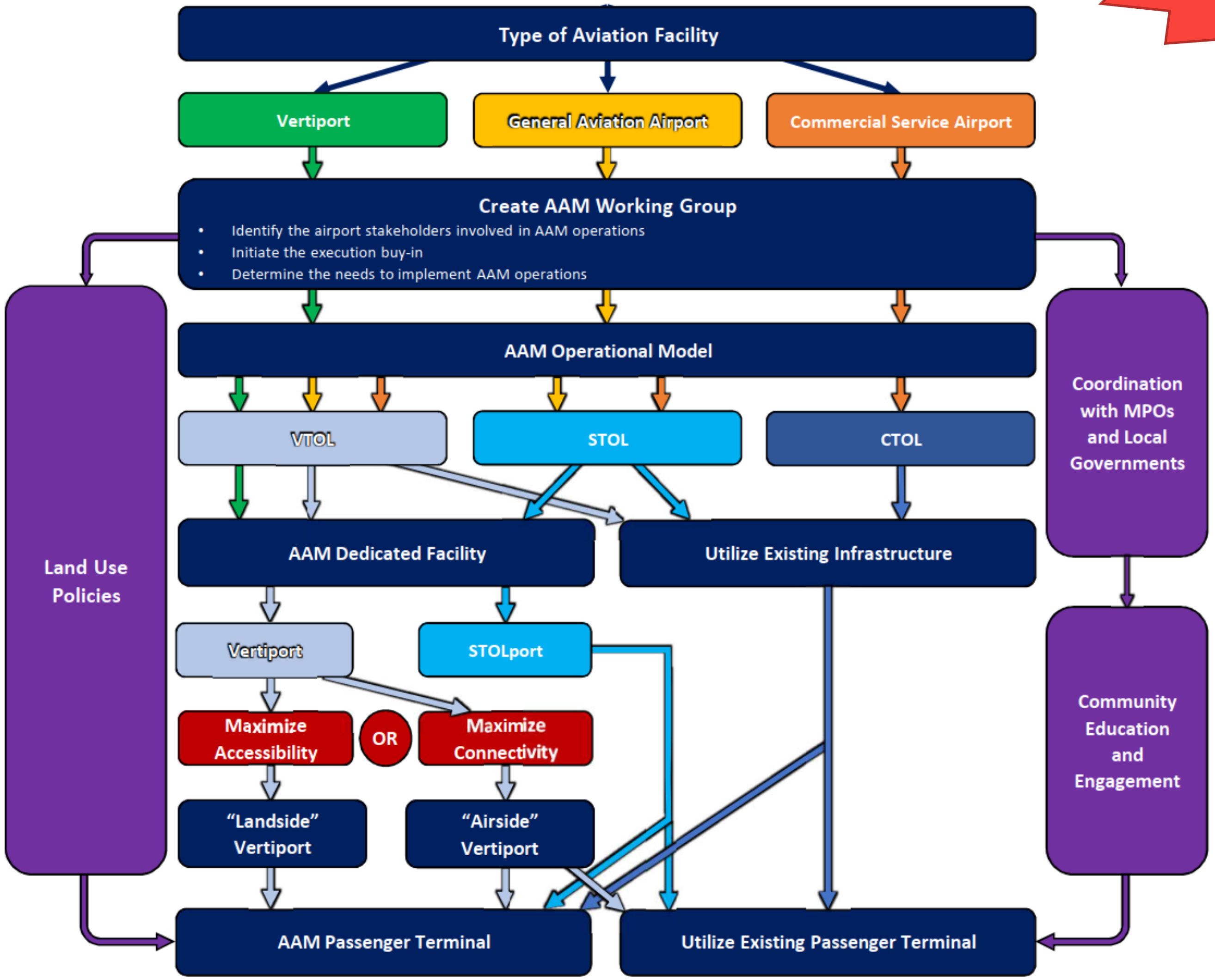
Note: ***LOHCs (Liquid Organic Hydrogen Carriers)*** *are organic compounds that can absorb and release hydrogen through hydrogenation/dehydrogenation reactions. Viable candidates for LOHC systems include carbon dioxide/methanol (CH_4), benzene/cyclohexane, toluene/methylcyclohexane (MHC), naphthalene/decalin, N-ethylcarbazole (NEC)/perhydro-NEC, dibenzytoluene (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

ACRP RR 243



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?**

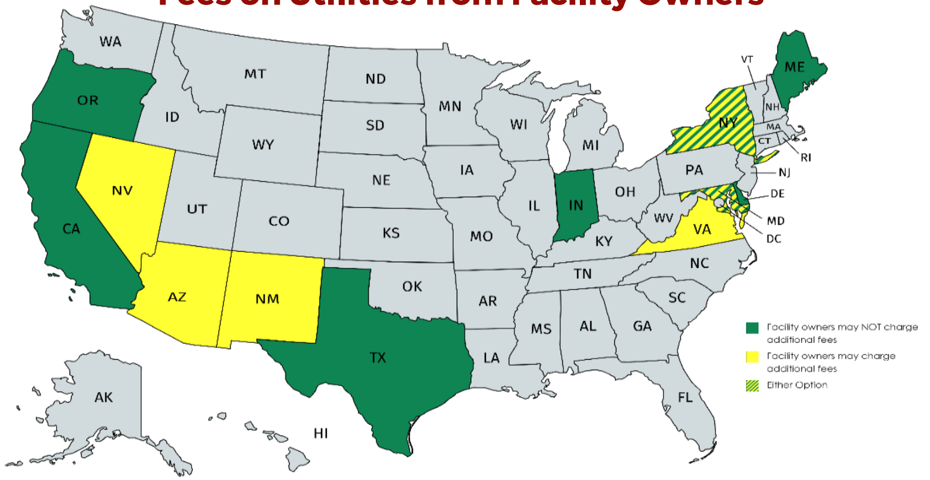
— **Should emerging aviation “energy vectors” (electricity and hydrogen) be taxed?**

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?

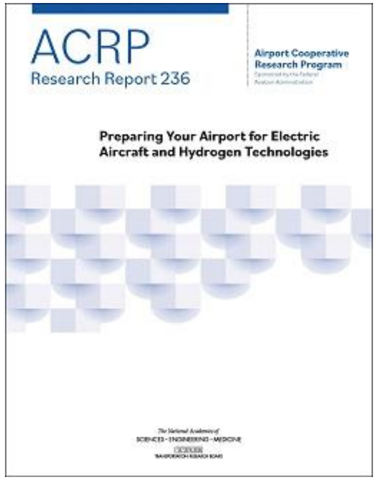
State Laws and Regulations on Electric Submetering

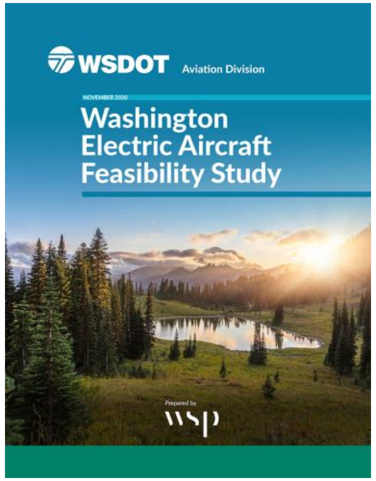
State Laws and Regulations on Additional Fees on Utilities from Facility Owners



Paving the Way for Electric Aviation

Guidance & Standards → State & Regional Roadmaps → Planning & Designing for eAircraft





Further Reading

— *An Airport & Vertiport/Aircraft Compatibility Approach of Electric Vertical Takeoff & Landing Aircraft Design*. Proceedings of Forum 79, VFS, 2023

— *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!

Gaël Le Bris, C.M., P.E.
Vice President, Aviation Planning
gael.lebris@wsp.com

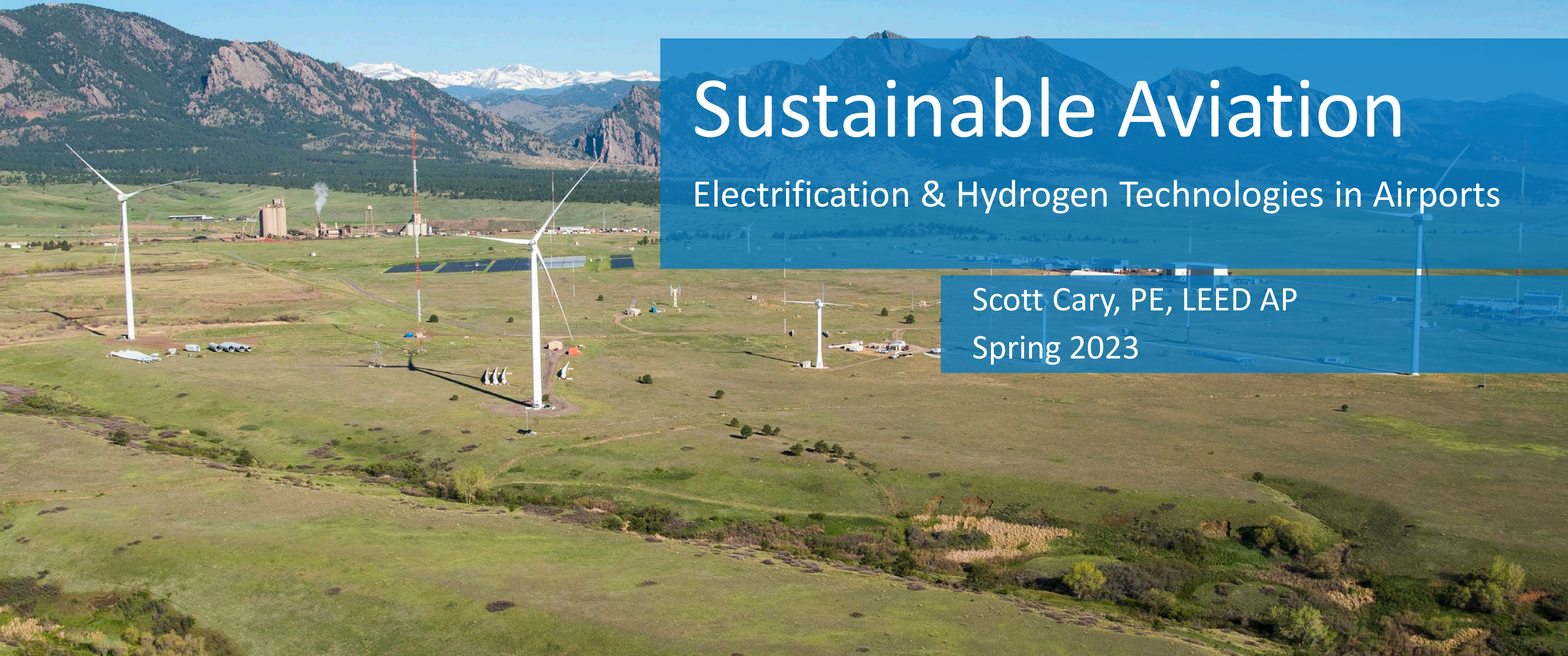
wsp.com

Sustainable Aviation

Electrification & Hydrogen Technologies in Airports

Scott Cary, PE, LEED AP

Spring 2023



NREL Science Drives Innovation

Renewable Power

Solar

Wind

Water

Geothermal

Sustainable Transportation

Bioenergy

Hydrogen and Fuel Cells

Transportation and Mobility

Energy Efficiency

Advanced Manufacturing

Buildings

State, Local, and Tribal Governments

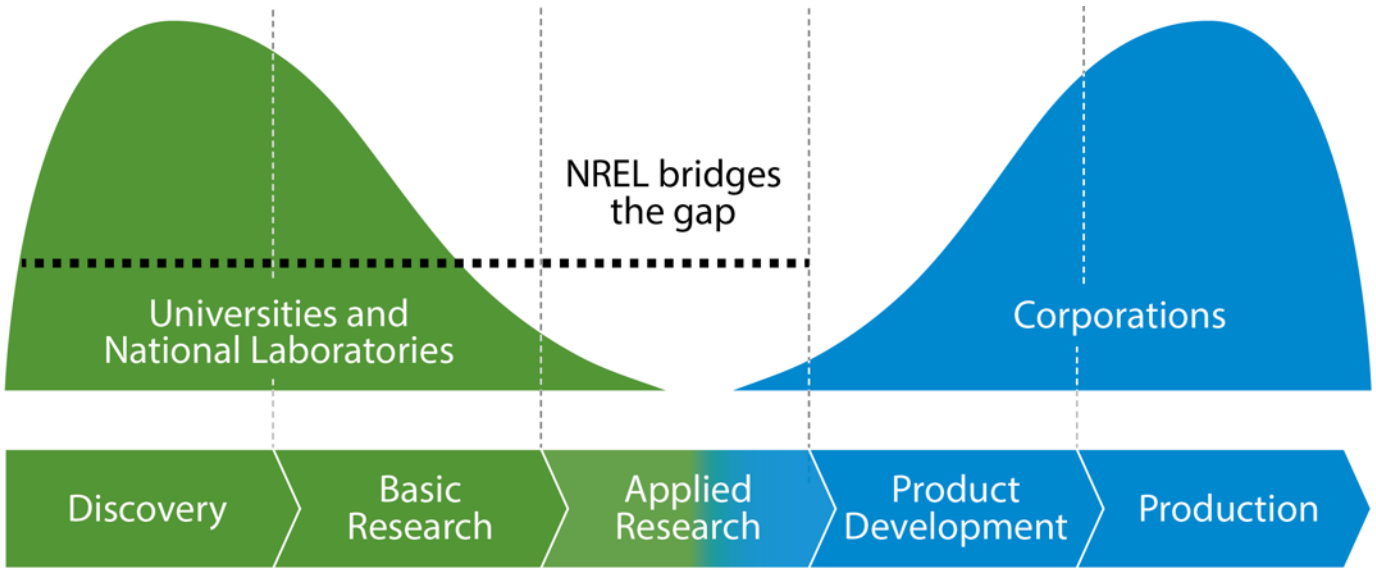
Energy Systems Integration

Energy Security and Resilience

Grid Modernization

Integrated Energy Solutions

We Reduce Risk in Bringing Innovations to Market



NREL helps bridge the gap from basic science to commercial application	**Forward-thinking innovation yields disruptive and impactful results to benefit the entire U.S. economy**	**Accelerated time to market delivers advantages to American businesses and consumers**

Sustainable Aviation Overview

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:

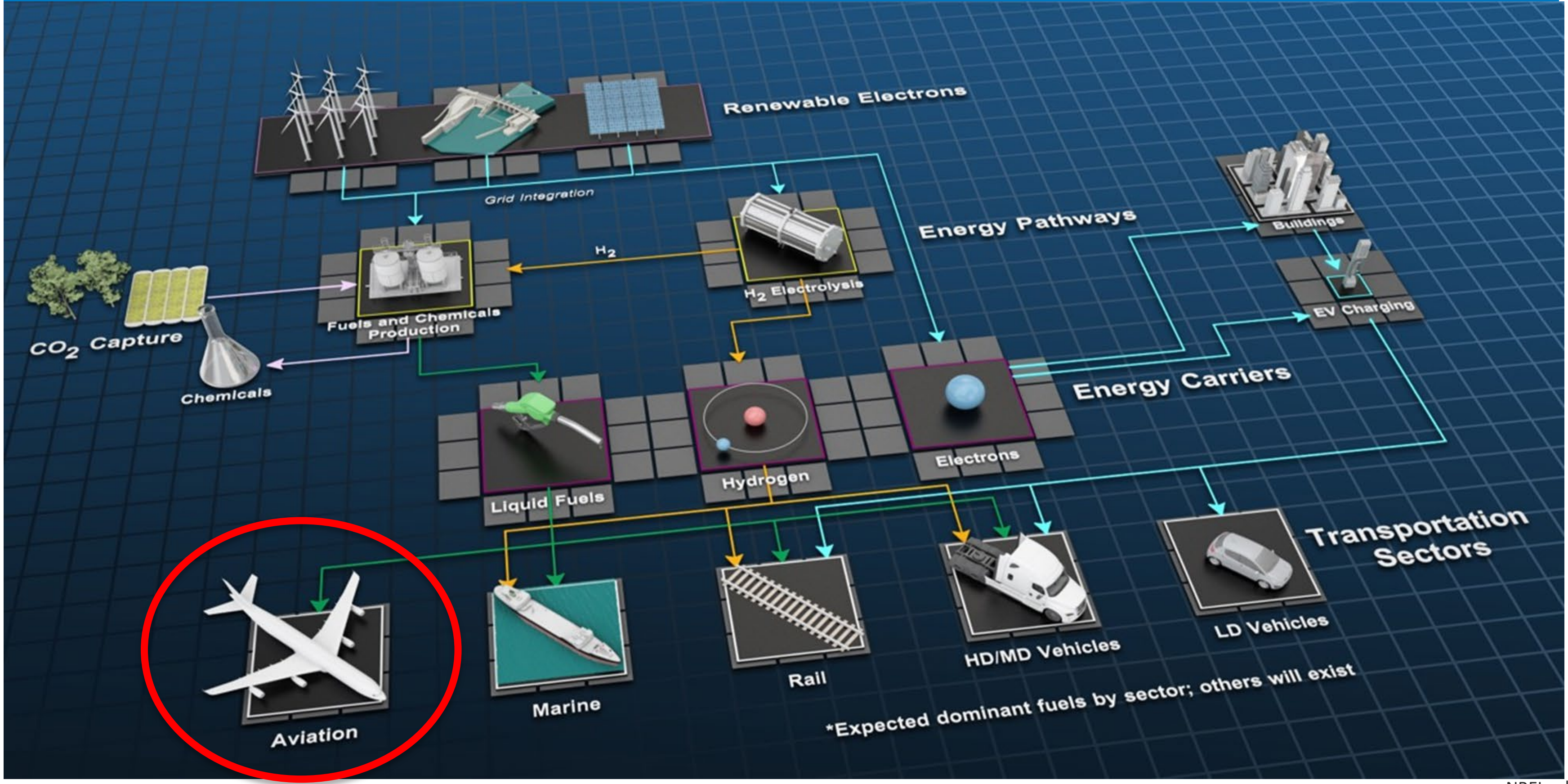
U.S. Department of Energy Sustainable Aviation Fuel Grand Challenge aims to meet 100% of aviation fuel demand by 2050.

Alternatives include sustainable aviation fuel, hydrogen, power-to-liquids, and electric

Partnerships are reaching across the aviation sector:

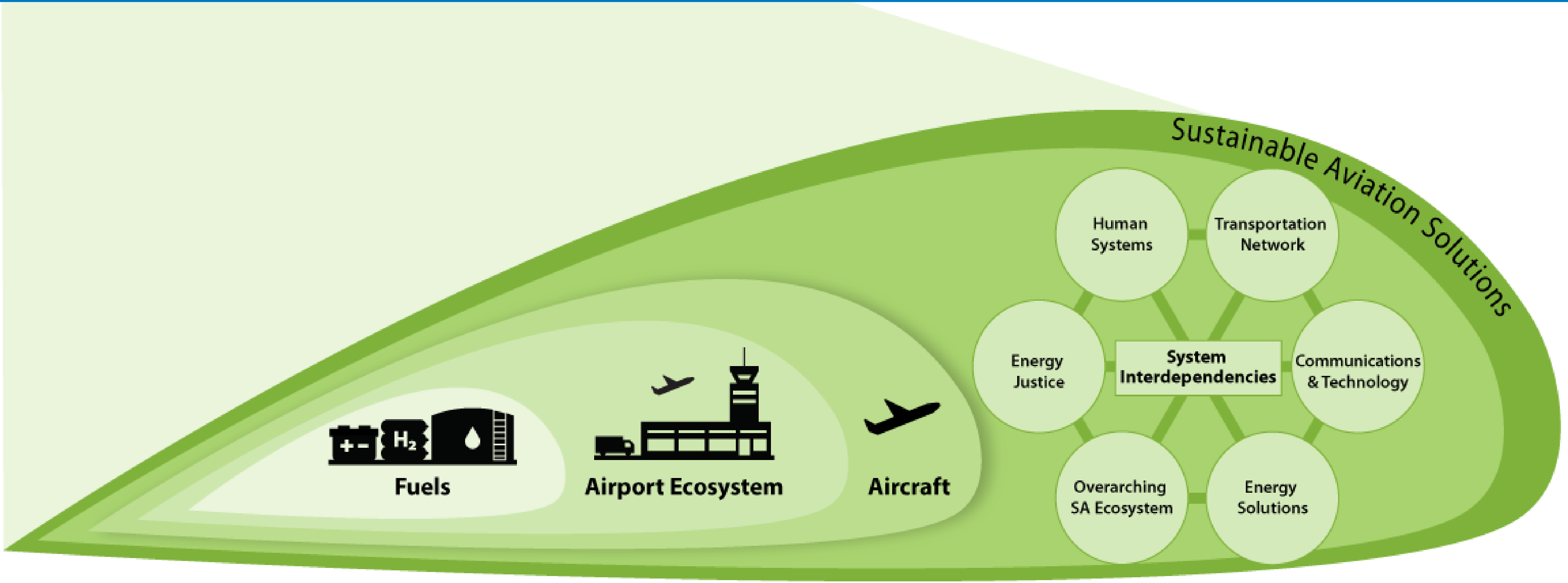
Airports, airline companies, new entrants, utilities, and fuel providers are seeing an increasingly heterogenous and complex energy landscape for net zero aviation.

Sustainable Aviation



Sustainable Aviation Ecosystem

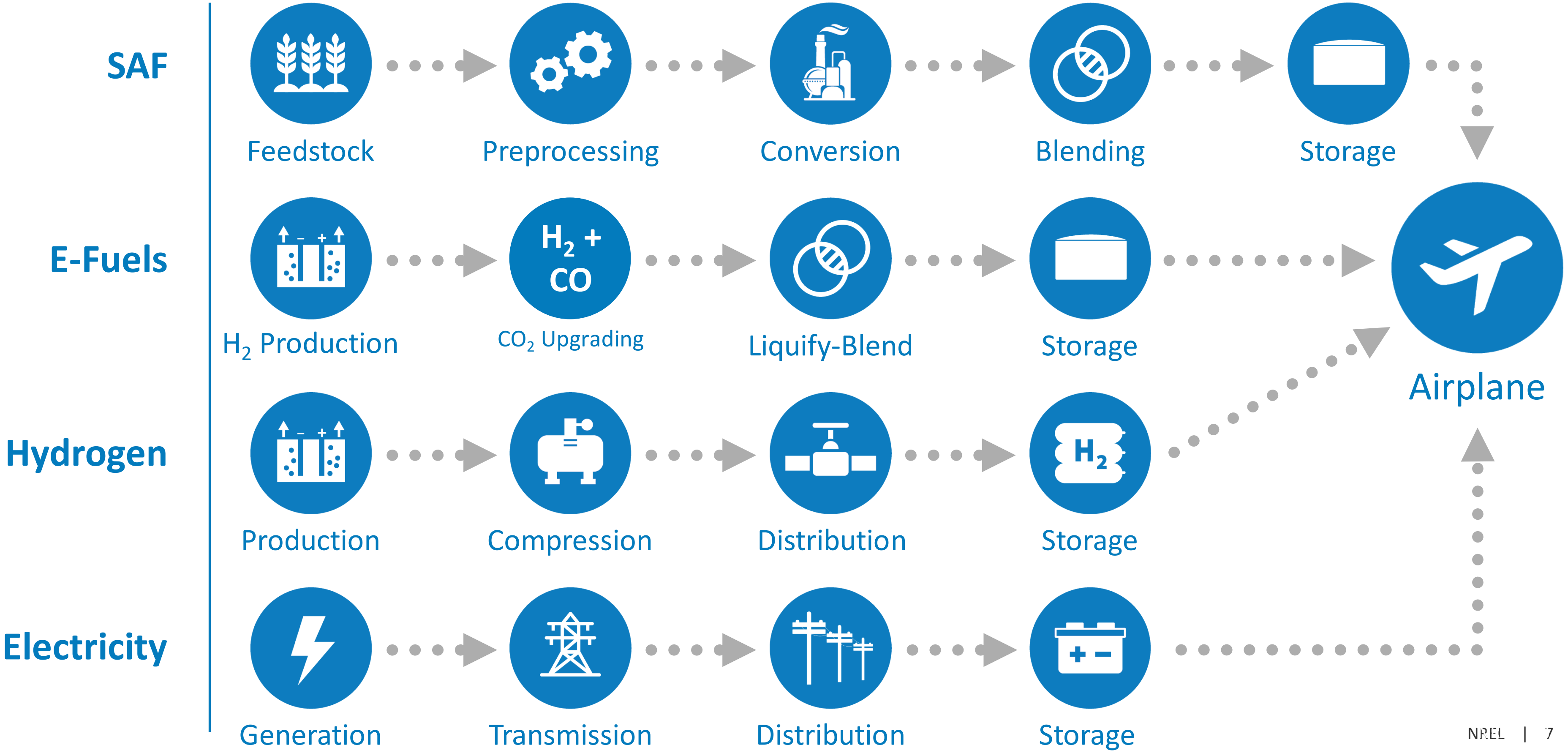
Holistic, sustainable energy solutions to achieve deep decarbonization of the aviation ecosystem



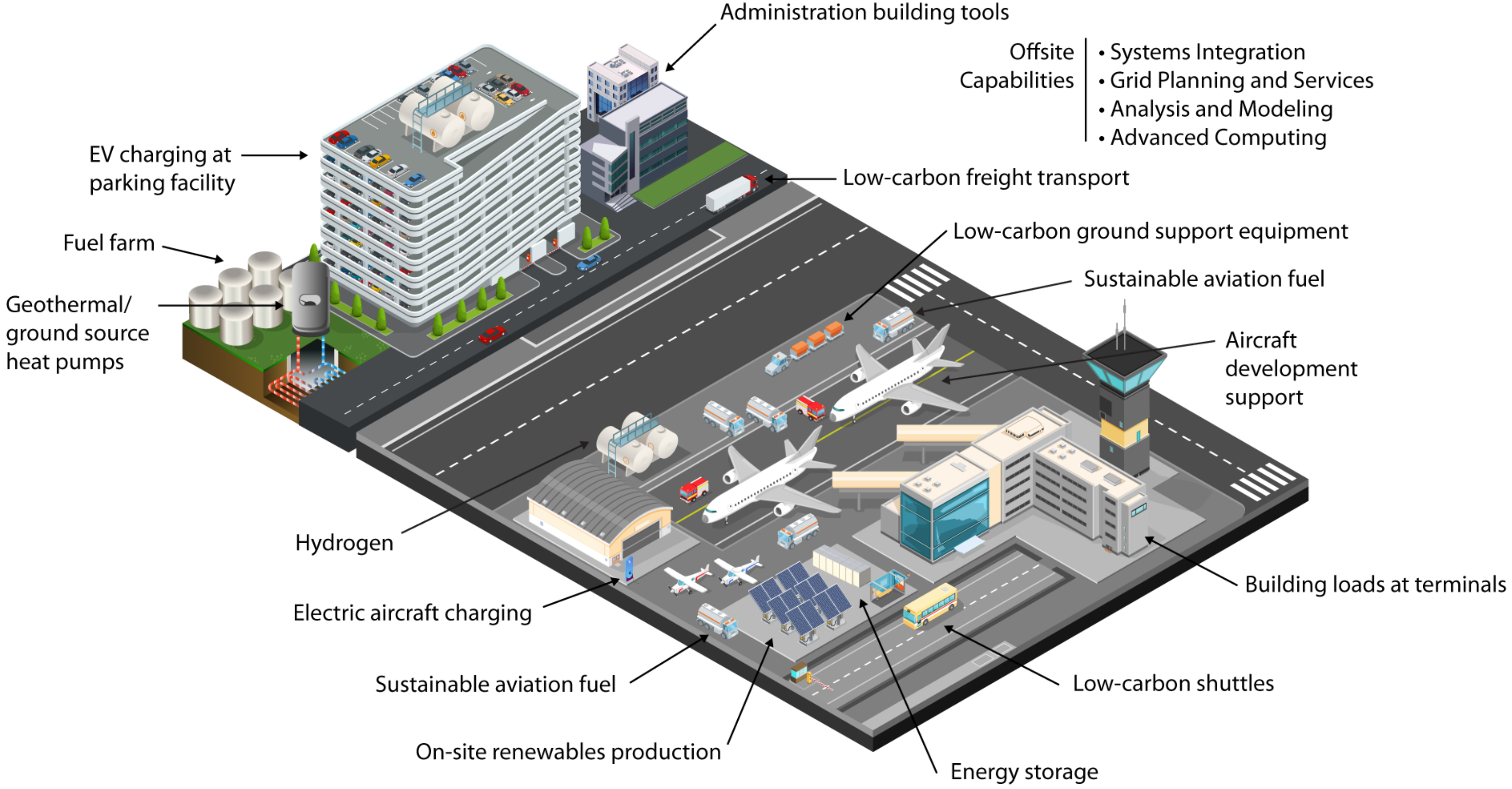
Required Capabilities: Research, Analysis, Modeling, Validation/Deployment

An ecosystem of partnerships are needed for realizing Sustainable Aviation

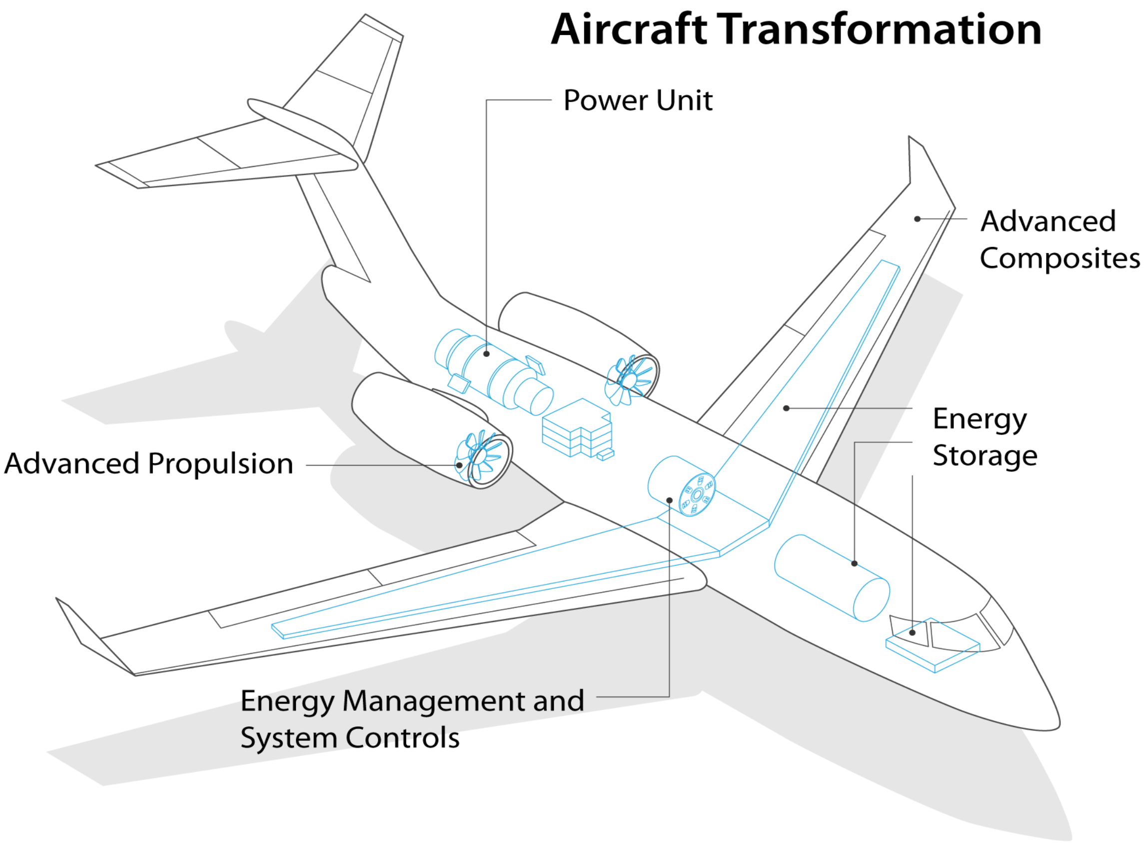
Next-Gen Aviation Energy Supply Chain



Airport/Base System



Aircraft



eVTOL

Regional Air Mobility

Turbine Aircraft

Questions?

Sustainable Aviation

Scott.Cary@nrel.gov

Thank You

All graphics and images from NREL.

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

NREL
Transforming ENERGY

Adam Bouchard
ABouchard@TampaAirport.com
Hillsborough County Aviation Authority

Gaël Le Bris
GAEL.LEBRIS@wsp.com
WSP USA, Inc.

Scott Cary
scott.cary@nrel.gov
NRELC

Other Events for You:

June 5, 2023

Airfield Pavement Markings—Removal and Temporary Applications

June 14, 3023

Practices in Airport Emergency Response

https://www.nationalacademies.org/trb/events

NATIONAL ACADEMIES Sciences Engineering Medicine

TRB TRANSPORTATION RESEARCH BOARD

TRB Weekly

Subscribe to the newsletter for the most recent TRB news & research:

https://bit.ly/ResubscribeTRBWeekly

Get involved with TRB

Receive emails about upcoming webinars:

https://mailchi.mp/nas.edu/trbwebinars

Find upcoming conferences:

https://www.nationalacademies.org/trb/events

@NASEMTRB

@NASEMTRB

Transportation Research Board

Get Involved with TRB

Be a Friend of a Committee [bit.ly/TRBcommittees]

- Networking opportunities
- May provide a path to Standing Committee membership

Join a Standing Committee [bit.ly/TRBstandingcommittee]

Work with CRP [https://bit.ly/TRB-crp]

Update your information [www.mytrb.org]

Getting involved is free!

TRB’s Podcast!

Have you heard TRB’s Transportation Explorers?

Listen on [our website](#) or subscribe wherever you listen to podcasts!

#TRBExplorers

Get involved with ACRP

ACRP AIRPORT COOPERATIVE RESEARCH PROGRAM

1. Join the ACRP IdeaHub community
2. Volunteer for a project panel
3. Prepare a research proposal
4. Answer an ACRP survey
5. Apply the research results

Visit us online:

www.trb.org/ACRP

Other Ways to Participate

ACRP AMBASSADOR

Become an Ambassador. Ambassadors represent ACRP at events and conferences across the country!

ACRP CHAMPION

Sponsor or become an ACRP Champion. The champion program is designed to help early- to mid-career, young professionals grow and excel within the airport industry.

ACRP IMPACTS ON PRACTICE

Visit ACRP's Impacts on Practice webpage to submit leads on how ACRP's research is being applied at any airport.

Visit us online:
www.trb.org/ACRP

ACRP Recorded Webinars

Have you missed a past ACRP webinar that you wish you could have attended?

No worries! All ACRP webinars are recorded and posted to TRB's website for viewing at any time.

There are over 100 webinar recordings on a variety of aviation topics available to you at:

https://www.nationalacademies.org/events

Select "Past Events" tab and search for "TRB Webinars".