ADVANCE MOBILITY NC

General Aviation Airport Energy Security Toolkit

JUNE 6, 2025

Contents

Acronyms

Term	Definition
AAM	Advanced Air Mobility
AATC	Atlanta Airlines Terminal Company
AC	Alternating Current or Advisory Circular (depending on context)
ACRP	Airport Cooperative Research Program
AIG	Airport Infrastructure Grant
AI/ML	Artificial Intelligence and Machine Learning
AIP	Airport Improvement Program
ALECP	Airport Lighting Equipment Certification Program
AMI	Advanced Metering Infrastructure
ANSI	American National Standards Institute
APA	Centennial Airport
ARA	Acadiana Regional Airport
ARFF	Aircraft Rescue and Fire Fighting
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
ASTM	American National Standards Institute
ATCT	Air Traffic Control Tower
ATL	Hartsfield-Jackson Atlanta International Airport
ATW	Outagamie County Regional Airport
AVX	AeroVironment
BOS	Boston Logan International Airport
BEV	Battery Electric Vehicle
BFI	King County International Airport-Boeing Field
BIL	Bipartisan Infrastructure Law
BMS	Building Management Systems
BNA	Nashville International Airport
BTL	Biomass-to-Liquid
BUF	Buffalo Niagara International Airport
CAC	Chemieanlagenbau Chemnitz
CAGR	Compound Annual Growth Rate
CCS	Combined Charging Standard
CEP	Clean Energy Plan
CFR	Code of Federal Regulations
CH_4	Methane
C_3H_6	Propylene
C_3H_8	Propane
C_4H	Butylene
C_4H_{10}	Butane
C_4H_{10}	Isobutane
CHA	Chattanooga Airport
CHP	Combined Heat and Power
CISA	Cybersecurity Information Sharing Act

Term	Definition
CLT	Charlotte Douglas International Airport
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO_2	Carbon Dioxide
C-PACE	Commercial Property Assessed Clean Energy
CRW	West Virginia International Yeager Airport
DAL	Dallas Love Field Airport
DC	Direct Current
DCFC	Direct Current Fast Charging
DEN	Denver International Airport
DFW	Dallas-Fort Worth International Airport
DSIRE	Database of State Incentives for Renewables & Efficiency
EAGLE	Eliminate Aviation Gasoline Lead Emissions
eCTOL	Electric Conventional Takeoff and Landing
EFVS	Enhanced Flight Vision Systems
eGSE	Electric Ground Support Equipment
EMS	Energy Management Systems
EPC	Energy Performance Contract
EPF	Emergency Power Facility
eSTOL	Electric Short Takeoff and Landing
EV	Electric Vehicle
eVTOL	Electric Vertical Takeoff and Landing
EXX	Davidson County Executive Airport
FAA	Federal Aviation Administration
FCEV	Fuel Cell Electric Vehicle
FERC	Federal Energy Regulatory Commission
FISMA	Federal Information Security Modernization Act
FMVSS	Federal Motor Vehicle Safety Standards
FOD	Foreign Object Debris
GA	General Aviation
GAMA	General Aviation Manufacturers Association
GAMI	General Aviation Modifications Inc.
GEACS	Global Electric Aviation Charging System
GDG	Diamond Green Diesel
GHG	Greenhouse Gas
GPU	Ground Powered Unit
GSA	Green Source Advantage
GSE	Ground Support Equipment
GW	Gigawatt
H_2	Hydrogen Gas
HC	Hydrocarbons
HDOT-A	Hawaii Department of Transportation, Airport Division
HEFA	Hydroprocessed Esters and Fatty Acids
HICEVs	Hydrogen Internal Combustion Engine Vehicles
HKY	Hickory Regional Airport

Term	Definition
HMGP	Hazard Mitigation Grant Program
HND	Henderson Executive Airport
HNL	Honolulu Daniel K. Inouye International Airport
HOV	High-Occupancy Vehicle
HPN	Westchester County Airport
HVAC	Heating, Ventilation, and Air Conditioning
HVO	Hydrotreated Vegetable Oil
HWD	Hayward Executive Airport
IAH	Houston George Bush Intercontinental Airport
ICE	Internal Combustion Engine
IECC	International Energy Conservation Code
IESNA	Illuminating Engineering Society of North America
IIJA	Infrastructure Investment and Jobs Act
IND	Indianapolis International Airport
IP	Internet Protocol
IT	Information Technology
ITC	Investment Tax Credit
IRS	Internal Revenue Service
JFK	John F. Kennedy International Air Terminal
JRF	Kalaeloa Airport
L1	Level 1
L2	Level 2
LAFD	Los Angeles Fire Department
LAWA	Los Angeles World Airports
LAX	Los Angeles International Airport
LED	Light Emitting Diodes
LEED®	Leadership in Energy and Environmental Design
LL	Low Lead
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MACRS	Modified Accelerated Cost-Recovery Systems
MALS	Medium-Intensity Approach Lighting System
MBS	Midland, Bay City, Saginaw
MCO	Orlando International Airport
MLC	McAlester Regional Airport
MQT	Marquette Sawyer Regional Airport
MS-ISAC	Multi-State Information Sharing and Analysis Center
MSP	Minneapolis-St. Paul International Airport
MTG	Methanol-to-Gasoline
MW	Megawatts
NAAQS	National Ambient Air Quality Standards
NBAA	National Business Aviation Association
NCAC	North Carolina Administrative Code
NCASP	North Carolina Aviation System Plan
NCCC	North Carolina Composting Council

Term	Definition
NCCETC	North Carolina Clean Energy Technology Center
NCDIT	North Carolina Department of Information Technology
NCDEQ	North Carolina Department of Environmental Quality
NCDOT	North Carolina Department of Transportation
NCECC	North Carolina Energy Conservation Code
NC-RETS	North Carolina Renewable Energy Tracking System
NCUC	North Carolina Utilities Commission
NEC	National Electrical Code
NERP	North Carolina Energy Regulatory Process
NFPA	National Fire Protection Association
NOTAM	Notice to Airmen
NOx	Nitrogen Oxides
NPDES	National Pollutant Discharge Elimination System
NTO	New Terminal One
OCW	Washington-Warren Field Airport
OE	Office of Electricity
OEMs	Original Equipment Manufacturers
ORD	Chicago O'Hare International Airport
OUAIP	Office of Urban Agriculture and Innovative Production
OXC	Waterbury-Oxford Airport
PAFI	Piston Aviation Fuels Initiative
PCA	Pre-Conditioned Air
PDM	Pre-Disaster Mitigation Program
PDK	Dekalb-Peachtree Airport
PDX	Portland International Airport
PEO	Penn Yan Airport
PHEV	Plug-In Hybrid Electric Vehicle
PHL	Philadelphia International Airport
PIT	Pittsburgh International Airport
PM	Particulate Matter
PPE	Personal Protection Equipment
PPSB	Private Protective Services Board
PURPA	Public Utility Regulatory Policies Act
PV	Photovoltaic
QF	Qualifying Facilities
RBAC	Recycling Business Assistance Center
RCRA	Resource Conservation and Recovery Act
RECs	Renewable Energy Credits
REG	Renewable Energy Group
REPS	Renewable Energy and Energy Efficiency Portfolio Standard
RFS	Renewable Fuel Standards
RHV	Reid-Hillview Airport
RINs	Renewable Identification Numbers
RNG	Renewable Natural Gas
RAP	Reclaimed Asphalt Pavement

Term	Definition
RTI	Research Triangle Institute
SAF	Sustainable Aviation Fuel
SAN	San Diego International Airport
SBIR	Small Business Innovation Research
SDF	Louisville Muhammad Ali International Airport
SEA	Seattle-Tacoma International Airport
SFO	San Francisco International Airport
SFPUC	San Francisco Public Utilities Commission
SLC	Salt Lake City International Airport
SLCGP	State and Local Cybersecurity Grant Program
SMR	Steam Methane Reforming
SNA	John Wayne Airport
STIP	State Transportation Improvement Program
STL	Lambert-St. Louis International Airport
STTR	Small Business Technology Transfer
TEB	Teterboro Airport
TFK	Truckee Tahoe Airport
TNC	Transportation Network Companies
TPA	Tampa International Airport
TTA	Raliegh Executive Airport
TSA	Transportation Security Administration
TUS	Tuscana International Airport
UL	Underwriters Laboratories
USDA	United States Department of Agriculture
U.S. DOE	United States Department of Energy
U.S. DOT	United States Department of Transportation
U.S. EPA	United States Environmental Protection Agency
U.S. FAA	United States Federal Aviation Administration
U.S. GOA	United States Government Accountability Office
V2G	Vehicle-to-Grid
VALE	Voluntary Airport Low Emission
VCT	Victoria Regional Airport
VNY	Van Nuys Airport
VOC	Volatile Organic Compounds
WMA	Warm Mix Asphalt
WVI	Watsonville Municipal Airport
ZEV	Zero Emission Vehicle

Executive Summary

The North Carolina Department of Transportation (NCDOT) General Aviation (GA) Airport Energy Security Toolkit is a comprehensive guide aimed at enhancing energy security at GA airports. It provides high-level strategies and resources to help GA airports improve their energy security and safety. Energy security, in this context, is the assurance that the airport has continuous access to the energy resources it needs, such as electricity, fuel, and backup power systems to maintain safe, efficient, and uninterrupted operations, even during grid outages, network outages, or supply chain disruptions. This ensures measures and systems are put in place to protect people, property, and information from any threats. The toolkit covers actionable steps for a GA airport to create an energy security strategy by implementing efforts tailored to their unique needs, such as integrating battery energy storage to improve the resiliency of the airport during emergencies and natural disasters. It also includes evaluations of various energy security efforts, assessing their potential use cases, feasibility, impact, cost, and risk to guide strategic decision-making for airport energy management.

By implementing the recommendations and best practices outlined in this toolkit, GA airports are able to reduce their reliance on imported fossil fuels, improve emergency operational resilience, decrease emissions, enhance safety, and contribute to a more energy-independent future. The toolkit emphasizes collaboration between various departments, including maintenance and operations, marketing, information technology (IT), and customer service, while providing a structured approach to identifying and implementing energy security measures that are both cost-effective and beneficial to airport operations and users. To begin implementing these strategies, GA airports can use the Energy Security Action Plan Recommendations as a practical starting point.

Energy Security Action Plan Recommendations:

1. **Conduct Feasibility Studies and Benefit Cost Analyses**: Evaluate the technical and economic viability of proposed energy security initiatives. Prioritize projects with strong return on investment and long-term resilience benefits.
2. **Prioritize Quick Wins** Identify and implement low-cost, high-impact solutions that can be deployed rapidly to enhance the protection of energy infrastructure, personnel, and data.
3. **Leverage Funding Opportunities**: Actively pursue federal, state, and local grants to reduce the financial burden of energy security investments. Explore creative financing strategies to maximize available resources.
4. **Educate and Train Staff**: Provide comprehensive training for staff on the operation, maintenance, and security of new energy technologies and systems.
5. **Collaborate with Stakeholders**: Engage with local governments, utilities, industry experts, and community partners to align efforts, share best practices, and strengthen collective energy resilience.

This NCDOT GA Airport Energy Security Toolkit has been designed for the reader to use the toolkit in its entirety or to use sections independently as reference sheets to provide the greatest overall success in energy security. The following summarizes the energy security efforts by prioritization levels.

Prioritized Energy Security Efforts

To help GA airports get started, the toolkit categorizes energy security efforts by ease of implementation:

Easy Wins (Near-Term, Low Cost, Low Risk)

These efforts are highly feasible and can be implemented quickly with minimal disruption:

- **Renewable Energy Credits (RECs)** and **Utility Green Tariff Programs** - Support domestic energy production without infrastructure changes.
- **Light Emitting Diodes (LED) Lighting Upgrades** - Reduce energy use and maintenance costs.
- **Recycling Programs** and **Waste Analysis** - Improve sustainability with low-cost operational changes.
- **Water Use Optimization** - Reduce utility costs through efficient fixtures and practices.
- **Physical and Cybersecurity Enhancements** - Protect infrastructure with scalable, low-risk improvements.

Moderate Effort (Mid-Term, Medium Cost/Risk)

These efforts require more planning and coordination but offer strong returns:

- **Battery Energy Storage** - Improve resilience during outages.
- **Energy Management Systems (EMS)** and **Smart Building Systems** - Optimize energy use through automation.
- **Electrification of Ground Support Equipment (eGSE)** and **Fleet Vehicles** - Reduce emissions and fuel costs.
- **Unleaded Aviation Fuel** and **Biofuels** - Transition to cleaner fuels with compatible infrastructure.

Strategic Investments (Long-Term, High Cost/Risk)

These efforts are transformative but require significant investment and planning:

- **On-Site Solar, Wind, and Geothermal Systems** – Generate clean, renewable energy to reduce dependency on external energy sources, long-term operational costs, and emissions.
- **Microgrids** – Enhance energy independence and reliability by integrating distributed energy resources.
- **Hydrogen Fuel Infrastructure** – Support the future of zero-emission aviation and ground operations.
- **Electric Aircraft Charging Stations and Vertiports** – Prepare for the next generation of electric and vertical takeoff aircraft with advanced charging and mobility hubs.

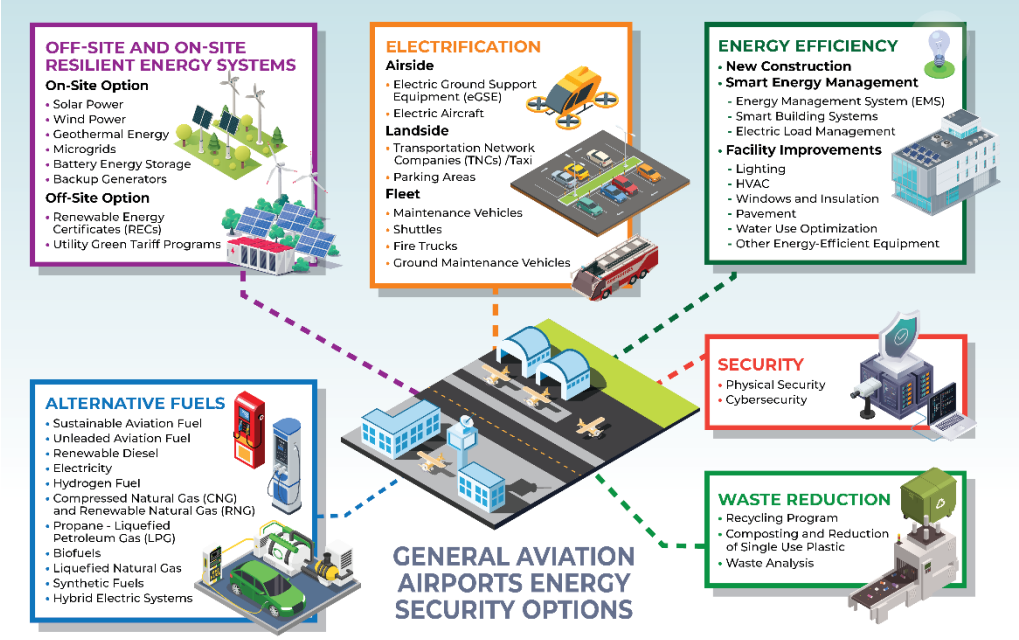
These categories help GA airports prioritize based on their current capacity, budget, and strategic goals. The toolkit supports phased implementation, allowing airports to build momentum with easy wins while planning for more complex initiatives. Ultimately, this resource empowers GA airports to strengthen their energy security and operational resilience through the thoughtful adoption of off-site and on-site resilient energy, energy efficiency technologies, waste reduction strategies, alternative fuels, electrification, and security efforts.

Introduction

Airports are grappling with both longstanding and emerging issues, including aging infrastructure, grid vulnerabilities, increasing energy demand, and cybersecurity threats. As challenges about energy reliability and availability grow, the need for energy security and independence becomes more critical for airports to protect people, property, and information from any threats. For example, "In 2017, a half-day power outage at Hartsfield-Jackson Atlanta International Airport (ATL) cost Delta Airlines up to $125 million. More recently, power outages at Los Angeles International Airport (LAX), Dallas-Fort Worth International Airport (DFW), and smaller airports such as Buffalo Niagara International Airport (BUF) have disrupted thousands of flights."[1] To best prepare GA airports for future expected growing energy needs, NCDOT has developed a comprehensive GA Airport Energy Security Toolkit. This toolkit provides GA airports with strategies and resources to ensure that the airports have continuous access to the energy resources it needs such as electricity, fuel, and backup power systems so they can maintain safe, efficient, and uninterrupted operations, even in the event of a grid outage, network failure, or supply disruption.

Investing in energy security today protects your airport's mission tomorrow.

Figure 1: Energy Security Options



It addresses a wide range of actionable energy security efforts including off-site and on-site resilient energy systems, energy efficiency improvements, waste reduction, the adoption of alternative fuels, physical security and cybersecurity. Included in the toolkit are detailed evaluations of various energy security efforts, assessing their feasibility, impact, cost, and risk to guide strategic decision-making for airport energy management activities and efforts. By implementing the recommendations and best practices outlined in this toolkit, GA airports can reduce their reliance on imported fossil fuels, improve emergency operational resilience, decrease emissions, enhance public safety, and contribute to a more energy independent future.

[1] Airport Consortium on Transformation (ACT). (2023). *Resiliency and Sustainability*

How to Use the Toolkit

GA airports should use this toolkit to identify, plan, and implement energy security measures that are both cost-effective and beneficial to their operations and users. It offers a wide range of options for GA airports to develop a customized energy security strategy. This toolkit has been designed for the reader to use the toolkit in its entirety and pull out, print, or use sections independently as reference sheets to provide the greatest overall success to energy security.

There are 3 key steps in developing an organization's Energy Security Plan. With use of this toolkit, GA airports will be able to complete each of the 3 steps and successfully develop their plans. Below is a high-level description of the steps and instructions on where to find the information needed:

Step 1: Defining Your Organization's Energy Security Strategic Framework

- **Define Goals**: Clearly articulate the goals of the GA airport, including specific targets for energy security, resiliency, and sustainability.
- **Leadership Support**: Assess and secure commitment from organizational leadership to ensure strategic alignment and the allocation of necessary resources.
- **Budget Allocation**: Estimate the budget available to achieve the energy security goals, including identifying funding sources and financial projections.
- **Airport User Demand**: Conduct surveys or focus groups with users of the GA airport to understand their demand for energy security measures. Analyze the survey data to identify key trends and user preferences.

Step 2: Determine Overall Energy Security Strategy

- **Strategy Development**: Develop a comprehensive strategy that outlines the approach to achieving energy security goals. This would include selecting energy security efforts that match the GA airport's goals.

Step 3: Prioritize Efforts, Build Timeline, and Implement Energy Security Efforts

- **Prioritization and Timeline Development**: Evaluate and prioritize efforts based on near term (0-3 years), medium term (3-7 years), and long term (7+ years) goals. Consider factors such as cost-effectiveness, impact, ease of implementation, and alignment with goals.
- **Execution**: Implement the prioritized efforts according to the timeline.
- **Monitoring and Evaluation**: Continuously monitor progress, evaluate outcomes, and make adjustments as necessary to stay on track with goals.

In the Methodology section below, additional information, guidance and tools are provided to support each of the three energy security planning steps.

Methodology

GA airports should follow these three steps to use the toolkit effectively. By systematically gathering and analyzing relevant information, they can identify the most appropriate energy security efforts to implement. This structured approach supports informed decision-making, prioritizes initiatives aligned with strategic goals, and ensures comprehensive coverage of critical energy security aspects.

Step 1: Defining Your Organization's Energy Security Strategic Framework

The GA airport should start by gathering information about their energy security goals, leadership support, budget, and airport user demand following the questions in Table 1 below. This foundational data will guide the development and implementation of energy security initiatives tailored to the airport's specific needs and circumstances. User interviews and surveys can be utilized to gather this information. Using Table 1: GA Airport Energy Security Strategic Framework Elements, input the information gathered:

Table 1: GA Airport Energy Security Strategic Framework Elements

Type	*Description*
GA Airport Energy Security Goals	*How extensive are the energy security goals at the GA airport? Would you categorize them as low, medium, or high? (Circle one)* **Low** **Medium** **High** *What are the GA Airport Energy Security Goals?*
Leadership Support	*To what extent does GA airport leadership support the energy security goals? Would you categorize their support as low, medium, or high? (Circle one)* **Low** **Medium** **High** *Does leadership support the GA airport's energy security goals?*
Budget Level	*What is the budget level allocated by the GA airport for their energy security goals? Would you categorize the budget as low, medium, or high? (Circle one)* **Low** **Medium** **High** *What is the budget allocated for the GA airport's energy security goals?*
Airport User Demand	*To what extent do GA airport users desire changes relate to energy security? Would you categorize their demand as low, medium, or high? (Circle one)* **Low** **Medium** **High** *From the survey results, what specific updates do GA airport users want to see in relation to energy security efforts?*

Step 2: Determine Overall Energy Security Strategy

Using the information in Step 1: Defining Your Organization's Energy Security Strategic Framework, the GA airport is now better equipped to select the specific energy security efforts that are aligned to their goals and objectives. Table 2 below helps identify suitable energy security efforts, categorized as easy wins, moderate effort, and strategic investments. By evaluating these factors, GA airports can develop realistic and achievable energy security strategies that align with their unique needs and goals.

To determine which opportunities best align with your airport's strategies, review the Categorization of Energy Security Efforts section to get more detail on each effort listed in Table 2. This section provides detailed descriptions of notable energy security efforts. Then in Table 2, highlight or circle those efforts most relevant to your airport.

Table 2: Energy Security Efforts Organized by Ease of Implementation Recommendations

	Easy Wins	*Moderate Effort*	*Strategic Investments*
Off-Site and On-Site Resilient Energy	**RECs** **Utility Green Tariff**	**Solar Energy** **Backup Generators** **Wind Power**	**Battery Energy Storage** **Microgrids** **Geothermal Energy**
Energy Efficiency	**Lighting** **EMS** **Electric Load Management** **Water Use Optimization**	**Windows & Insulation** **Other Energy Efficient Equipment**	**Pavement** **HVAC** **New Construction**
Waste Reduction	**Recycling Program** **Single-Use Plastics**	**Waste Analysis**	

	Easy Wins	*Moderate Effort*	*Strategic Investments*
Electrification	**Parking Areas** **TNC/Taxi**	**Maintenance Vehicle** **Ground Maintenance Equipment** **Shuttles**	**eGSE** **Electric Aircraft** **Fire Trucks**
Alternative Fuels	**Hybrid Electric** **Electricity**	**Unleaded Aviation Fuel** **CNG and RNG** **LNG** **Propane (LPG)** **Biofuels** **Renewable Diesel**	**SAF** **Hydrogen Fuel** **Synthetic Fuels**
Security	**Cybersecurity**	**Physical Security**	

Step 3: Prioritize Efforts, Build Timeline, and Implement Energy Security Efforts

To develop an effective energy security strategy, GA airports should prioritize efforts based on short term (0–3 years), medium term (3–7 years), and long term (7+ years) goals, considering factors like cost-effectiveness, impact, ease of implementation, and alignment with strategic objectives.

To complete this step, place the energy security efforts of interest that were selected in Step 2 above on to the timeline in Table 3 below. Once the efforts are organized the energy security plan has been developed and is ready for review and any approvals that are necessary. Once full approval is achieved, implementation of the efforts can start following this established timeline. Throughout the project, ongoing monitoring and evaluation help track progress, assess outcomes, and support timely adjustments.

Table 3: Energy Security Efforts Timeline

	Near Term (0-3 Years)	*Medium Term (3-7 years)*	*Long Term (7+ years)*
Energy Security Efforts	*Input your GA airport's near-term energy security efforts here.*	*Input your GA airport's medium term energy security efforts here.*	*Input your GA airport's long term energy security efforts here.*

Each of the sections below provides additional guidance and a detailed overview of key energy security efforts to support GA airports in making informed decisions.

Energy Security Efforts

This section of the toolkit outlines a range of actionable energy security efforts designed to enhance the energy security of GA airports. These efforts span multiple categories, including on-site and off-site resilient energy, energy efficiency, waste reduction, alternative fuels, electrification, and security. GA airports should use this toolkit to evaluate and select the most suitable initiatives based on their unique operational needs, resources, and long-term goals.

The section is organized to provide:

- an overview of the structure and purpose of energy security efforts,
- a summary of the energy security efforts, use cases, and ratings, as well as,
- a detailed description of each effort to support informed decision-making and implementation.

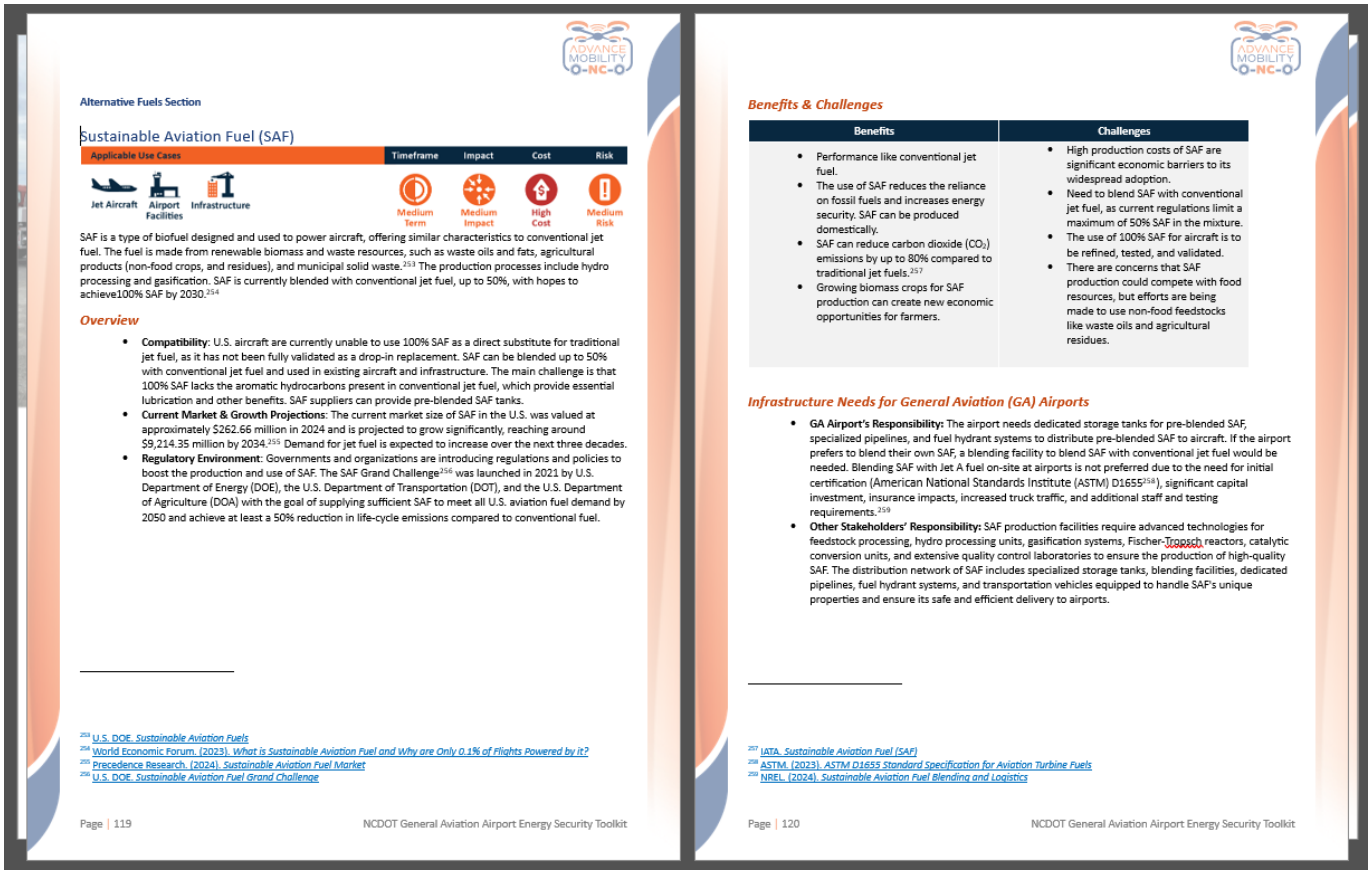
Energy Security Efforts Structure Overview

The efforts provided in this toolkit have their own sections where applicable use cases for GA airports and overall ratings for implementation are highlighted upfront. Each notable energy security effort is broken down by category and presented in a 2-page format. The overview of the effort highlights the applicable use cases and ratings at the top of the first page. These use cases demonstrate how energy security measures can be practically implemented at GA airports. The ratings provide a high-level summary of the implementation timeframe, impact, cost, and risk, allowing GA airports to quickly assess the feasibility and potential benefits of each effort. For reference, definition of all the applicable use cases and ratings are further defined in detail in this section below.

In addition, each 2-page information sheet includes a comprehensive overview of the energy security effort covering key information such as compatibility, current market conditions, growth projections, regulatory environment, benefits, challenges, infrastructure needs specific to GA airports, case studies, grant funding opportunities, and recommendations.

This format allows users to pull out, print or use these individual 2-pages as reference sheets:

Figure 2: Energy Security Efforts Template Example



Alternative Fuels Section

Sustainable Aviation Fuel (SAF)

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Jet Aircraft, Airport Facilities, Infrastructure	Medium Term	Medium Impact	High Cost	Medium Risk

SAF is a type of biofuel designed and used to power aircraft, offering similar characteristics to conventional jet fuel. The fuel is made from renewable biomass and waste resources, such as waste oils and fats, agricultural products (non-food crops, and residues), and municipal solid waste.[253] The production processes include hydro processing and gasification. SAF is currently blended with conventional jet fuel, up to 50%, with hopes to achieve100% SAF by 2030.[254]

Overview

- **Compatibility**: U.S. aircraft are currently unable to use 100% SAF as a direct substitute for traditional jet fuel, as it has not been fully validated as a drop-in replacement. SAF can be blended up to 50% with conventional jet fuel and used in existing aircraft and infrastructure. The main challenge is that 100% SAF lacks the aromatic hydrocarbons present in conventional jet fuel, which provide essential lubrication and other benefits. SAF suppliers can provide pre-blended SAF tanks.
- **Current Market & Growth Projections**: The current market size of SAF in the U.S. was valued at approximately $262.66 million in 2024 and is projected to grow significantly, reaching around $9,214.35 million by 2034.[255] Demand for jet fuel is expected to increase over the next three decades.
- **Regulatory Environment**: Governments and organizations are introducing regulations and policies to boost the production and use of SAF. The SAF Grand Challenge[256] was launched in 2021 by U.S. Department of Energy (DOE), the U.S. Department of Transportation (DOT), and the U.S. Department of Agriculture (DOA) with the goal of supplying sufficient SAF to meet all U.S. aviation fuel demand by 2050 and achieve at least a 50% reduction in life-cycle emissions compared to conventional fuel.

[253] U.S. DOE. *Sustainable Aviation Fuels*
[254] World Economic Forum. (2023). *What is Sustainable Aviation Fuel and Why are Only 0.1% of Flights Powered by it?*
[255] Precedence Research. (2024). *Sustainable Aviation Fuel Market*
[256] U.S. DOE. *Sustainable Aviation Fuel Grand Challenge*

Page | 119 NCDOT General Aviation Airport Energy Security Toolkit

Benefits & Challenges

Benefits	Challenges
• Performance like conventional jet fuel. • The use of SAF reduces the reliance on fossil fuels and increases energy security. SAF can be produced domestically. • SAF can reduce carbon dioxide (CO_2) emissions by up to 80% compared to traditional jet fuels.[257] • Growing biomass crops for SAF production can create new economic opportunities for farmers.	• High production costs of SAF are significant economic barriers to its widespread adoption. • Need to blend SAF with conventional jet fuel, as current regulations limit a maximum of 50% SAF in the mixture. • The use of 100% SAF for aircraft is to be refined, tested, and validated. • There are concerns that SAF production could compete with food resources, but efforts are being made to use non-food feedstocks like waste oils and agricultural residues.

Infrastructure Needs for General Aviation (GA) Airports

- **GA Airport's Responsibility:** The airport needs dedicated storage tanks for pre-blended SAF, specialized pipelines, and fuel hydrant systems to distribute pre-blended SAF to aircraft. If the airport prefers to blend their own SAF, a blending facility to blend SAF with conventional jet fuel would be needed. Blending SAF with Jet A fuel on-site at airports is not preferred due to the need for initial certification (American National Standards Institute (ASTM) D1655[258]), significant capital investment, insurance impacts, increased truck traffic, and additional staff and testing requirements.[259]
- **Other Stakeholders' Responsibility:** SAF production facilities require advanced technologies for feedstock processing, hydro processing units, gasification systems, Fischer-Tropsch reactors, catalytic conversion units, and extensive quality control laboratories to ensure the production of high-quality SAF. The distribution network of SAF includes specialized storage tanks, blending facilities, dedicated pipelines, fuel hydrant systems, and transportation vehicles equipped to handle SAF's unique properties and ensure its safe and efficient delivery to airports.

[257] IATA. *Sustainable Aviation Fuel (SAF)*
[258] ASTM. (2023). *ASTM D1655 Standard Specification for Aviation Turbine Fuels*
[259] NREL. (2024). *Sustainable Aviation Fuel Blending and Logistics*

Page | 120 NCDOT General Aviation Airport Energy Security Toolkit

Energy Security Efforts Use Cases Definitions

Each of the energy security efforts can be utilized for specific applications at GA airports, such as jet aircraft, small piston-engine aircraft, ground support equipment (GSE), fleet vehicles, and airport facilities. Jet aircraft, small piston-engine aircraft, and GSE are located on the airside at the airport. Fleet vehicles and airport facilities may be situated either landside or airside. Airside areas are secure zones beyond security checkpoints and passport control, while landside areas are accessible to the general public. The definitions of these use cases are as follows:

- **Jet Aircraft:** Airplanes powered by jet engines, designed for high-speed travel and capable of flying at high altitudes.
- **Small Piston-Engine Aircraft:** Airplanes powered by internal combustion engines (ICEs) with pistons, typically used for GA and short-distance flights.
- **Ground Support Equipment (GSE):** The machinery and vehicles used at airports to service aircraft between flights, including baggage carts, tugs, and refueling trucks.
- **Fleet Vehicles:** A group of vehicles and equipment owned or leased, used for transportation, logistics, maintenance, or operational purposes.
- **Airport Facilities:** The buildings and structures at an airport, including passenger terminals, cargo terminals, hangars, and maintenance areas, designed to support air travel operations.

Infrastructure	Policies/ Practices	Management Systems	Utilities
The fundamental physical structures and facilities needed for the operation of the GA airport	The governance framework that directs the implementation and operations, along with the practical application of energy security measures.	The actual digital systems that facilitate the automation, monitoring, and continuous improvement of operations, covering aspects such as quality control, regulatory compliance, resource management, and performance measurement.	The core services essential for facility operation, including electricity, gas, water, and sewer systems. This category also encompasses any facility upgrades or improvements that directly interface with or enhance these utility systems.

Use Cases Alignment to the Energy Security Effort

To support effective implementation, it is helpful to identify where each energy security effort can be applied across GA airports. These efforts may target specific use cases such as jet aircraft, small piston-engine aircraft, GSE, fleet vehicles, or airport facilities or span multiple areas. **Error! Reference source not found.** outlines how each initiative in this toolkit aligns with the relevant use cases. Reference the Energy Security Efforts Use Cases Definitions for the meaning of each use case icon.

Table 4: Use Case Alignment to Energy Security Effort

Energy Security Efforts									
RECs					x		x		
Utility Green Tariff Programs					x		x		
Solar Energy					x	x		x	x
Wind Power					x	x		x	x
Geothermal Energy					x	x		x	x
Battery Energy Storage					x	x		x	x
Microgrids					x	x		x	x
Backup Generators					x	x		x	x
Lighting					x	x		x	x
Heating, Ventilation, and Air Conditioning (HVAC)					x	x		x	x
Windows and Insulation					x	x			
Pavement					x	x			
Water Use Optimization					x	x	x	x	x
Other Energy-Efficient Equipment					x	x			x
New Construction					x	x			
Energy Management System (EMS)					x			x	
Smart Building Systems					x			x	
Electric Load Management					x			x	
Waste Analysis					x		x		
Recycling Program					x	x	x		x
Composting and Reduction of Single-Use Plastics					x	x	x		x
Sustainable Aviation Fuel (SAF)	x				x	x			
Unleaded Aviation Fuel		x			x	x			

Energy Security Efforts									
Renewable Diesel			x	x	x	x			
Electricity		x	x	x	x	x			x
Hydrogen Fuel	x	x	x	x	x	x			
Compressed Natural Gas (CNG) and Renewable Natural Gas (RNG)			x	x	x	x			
Propane (LPG - Liquefied Petroleum Gas)			x	x	x	x			
Biofuels for Diesel and Gasoline Engines			x	x	x	x			
Liquefied Natural Gas (LNG)			x	x	x	x			
Synthetic Fuels for Diesel and Gasoline Engines			x	x	x	x			
Hybrid Electric System			x	x	x	x			x
Parking Areas					x	x			x
TNC/Taxi				x	x	x			x
eGSE			x		x	x			x
Electric Aircraft					x	x			x
Maintenance Vehicles				x	x	x			x
Shuttles				x	x	x			x
Fire Trucks				x	x	x			x
Ground Maintenance Equipment				x	x	x			x
Physical Security					x	x	x	x	
Cybersecurity					x		x	x	

Energy Security Efforts Rating Definition

Each energy security effort has been rated on implementation timeframe, impact, cost, and risk. This information is displayed with the use cases on the first page of each energy security effort. These definitions help guide strategic decision-making by categorizing the efforts based on their implementation timeframe, impact on energy security and public health, financial cost, and associated risks. They are designed to be qualitative, reflecting the numerous evolving factors that influence the implementation of these technologies.

Near Term	Significant Impact	Low Cost	Low Risk
(0-3 years) Efforts that are already fully commercialized and can be adopted and integrated into airport operations within a short period.	Efforts bring significant enhancements to energy security and substantial public health and environmental benefits.	Efforts with minimal financial investment required for implementation.	Efforts with proven reliability and safety, posing minimal risk to airport financial investments and operations.
Medium Term	**Medium Impact**	**Medium Cost**	**Medium Risk**
(3-7 Years) Efforts that require further advancements in technology, economic feasibility, and regulatory approval, resulting in a longer implementation period.	Efforts contributing moderately to energy security, and noticeable improvements in public health and environmental benefits.	Moderately priced efforts that require reasonable financial investment.	Efforts with some uncertainties or challenges, requiring careful benefit/cost analysis and management to consider implementation and mitigate risks.
Long Term	**Insignificant Impact**	**High Cost**	**High Risk**
(7+ Years) Efforts involving substantial technological advancements, extensive modifications to infrastructure and operations, development of economic feasibility, and regulatory approval, resulting in a lengthy adoption period.	Efforts with limited influence on overall energy security, and minimal public health and environmental benefits.	Expensive efforts that necessitate substantial financial investment for adoption and integration.	Efforts with significant uncertainties or potential challenges, necessitating thorough risk assessment and management.

Categorization of Energy Security Efforts

This section provides a detailed overview of various strategies and initiatives aimed at enhancing energy security at GA airports. This section categorizes the efforts into key categories including resilient energy systems, energy efficiency improvements, waste reduction, electrification, and alternative fuels. Each category is designed to address specific aspects of energy security, offering practical solutions and best practices that GA airports can implement to reduce their reliance on traditional fossil fuels, improve operational resilience, and energy security. By exploring these categories, GA airports can develop customized energy security strategies that align with their unique needs and goals.

The major categories include:

- **Off-Site & On-Site Resilient Energy Systems:** Works to ensure reliable energy supply by utilizing both external renewable sources and on-site generation/storage to withstand and recover quickly from disruptions.
- **Energy Efficiency:** Focuses on optimizing energy use to reduce consumption and costs.
- **Waste Reduction:** Aims to minimize waste through efficient and responsible practices.
- **Alternative Fuels:** Covers the use of sustainable fuels for aircraft, vehicles, GSE, and facilities.
- **Electrification:** Promotes the use of electric power for various applications (landside, airside, and fleet).
- **Security:** Safeguards energy infrastructure against physical threats and cyber-attacks, ensuring the resilience and reliability of both physical and digital systems.

For each category, there are specific energy security efforts that GA airports can evaluate for their energy security plan based on their budget, energy security goals, and the needs of airport users. The following sections give a high-level overview of the energy security efforts by category.

Off-Site and On-Site Resilient Energy

Off-site and on-site resilient energy refers to energy systems designed to maintain reliable power during disruptions, either generated at the location of use (on-site) or sourced from external, secure locations (off-site). On-site systems often include solar panels with battery storage or microgrids, while off-site solutions may involve purchasing power from renewable energy plants. Both on- and off-site energy systems should have built-in redundancies to ensure continuous supply. This category of energy security efforts explores different off-site and on-site resilient energy portfolio and generation options the GA airport can select from.

Off-Site Resilient Energy Options

Off-Site Options utilizes external entities and systems to produce energy off the airport premises, as an option to effectively offset on-site energy consumption.

ID	Energy Security Effort	Implementation Timeframe	Impact	Cost	Risk
1	Error! Reference source not found.: These credits enable airports to offset their emissions by purchasing certificates that represent the generation of renewable energy, supporting sustainable energy production. Link to Section	Near Term	Insignificant Impact	Low Cost	Low Risk
2	**Utility Green Tariff Program:** allows airports to purchase renewable energy directly from their utility provider, supporting domestic energy production and reducing reliance on fossil fuels. Link to Section	Near Term	Insignificant Impact	Low Cost	Low Risk

On-Site Generation and Storage

On-Site Generation and Storage refers to the systems that produce and store energy directly on the airport premises, supplying a reliable and sustainable power supply.

ID	Energy Security Effort	Implementation Timeframe	Impact	Cost	Risk
3	**Solar Energy:** The conversion of sunlight into electricity using photovoltaic (PV) cells. Link to Section	Near Term	Medium Impact	High Cost	Medium Risk
4	**Wind Power:** Harnesses the energy of wind through turbines to generate electricity. Link to Section	Near Term	Significant Impact	High Cost	Medium Risk
5	**Geothermal Energy:** Utilizes heat from the Earth's interior to produce electricity or provide direct heating. Link to Section	Near Term	Medium Impact	Medium Cost	High Risk

ID	Energy Security Effort	Implementation Timeframe	Impact	Cost	Risk
6	**Microgrids:** Localized energy systems that can operate independently or in conjunction with the main power grid, providing reliable and efficient energy. Link to Section	**Near Term**	**Medium Impact**	**High Cost**	**Low Risk**
7	**Battery Energy Storage:** Involves capturing and storing energy for later use, typically using batteries or other technologies to balance supply and demand. Link to Section	**Near Term**	**Significant Impact**	**High Cost**	**Medium Risk**
8	**Backup Generators:** Provide emergency power during outages, ensuring continuous operation of critical systems. Link to Section	**Near Term**	**Medium Impact**	**Low Cost**	**Medium Risk**

Energy Efficiency

Energy efficiency categorized efforts are strategies, technologies, or practices that reduce the amount of energy required to perform the same task or produce the same outcome. These solutions help lower energy consumption, cut costs, and reduce environmental impact by optimizing systems like lighting, heating, cooling, and equipment operations. The energy efficiency category includes various energy security efforts to improve the energy usage of the GA airport facility and operations.

Facility Improvements

Facility Improvements are enhancements in lighting, heating, ventilation, and air conditioning (HVAC), windows, insulation, pavement, and other energy-efficient equipment to reduce energy consumption.

ID	Energy Security Effort	Implementation Timeframe	Impact	Cost	Risk
9	**Lighting:** Illumination technologies such as LEDs and Compact Fluorescent Lamps (CFLs) that consume less energy, produce less heat, and have a longer lifespan compared to traditional incandescent bulbs. Link to Section	**Near Term**	**Medium Impact**	**Medium Cost**	**Medium Risk**

ID	Energy Security Effort	Implementation Timeframe	Impact	Cost	Risk
10	**HVAC:** Heating, Ventilation, and Air Conditioning (HVAC) involves technologies used to control the temperature, humidity, and air quality in enclosed spaces. Link to Section	**Near Term**	**Significant Impact**	**Medium Cost**	**Medium Risk**
11	**Windows & Insulation:** Involve design features and technologies that enhance energy efficiency, durability, and functionality by improving thermal resistance and reducing heat transfer. Link to Section	**Near Term**	**Medium Impact**	**Medium Cost**	**Medium Risk**
12	**Pavement:** Paving materials and methods that have a lower environmental footprint, often incorporating recycled materials and sustainable resources, and designed to reduce stormwater runoff and pollution. Link to Section	**Near Term**	**Medium Impact**	**Medium Cost**	**Medium Risk**
13	**Water Use Optimization:** the strategic management and implementation of practices, technologies, and policies to reduce water consumption, improve efficiency, and maximize the sustainable use of water resources. Link to Section	**Near Term**	**Insignificant Impact**	**Low Cost**	**Medium Risk**
14	**Other Energy-Efficient Equipment:** Appliances and building-related equipment designed to operate with minimal energy consumption. Link to Section	**Near Term**	**Medium Impact**	**Medium Cost**	**Medium Risk**

New Construction

New Construction are structures designed and constructed to be environmentally responsible and resource-efficient throughout their lifecycle, from planning and design to construction, operation, maintenance, renovation, and demolition.

ID	Energy Security Effort	Implementation Timeframe	Impact	Cost	Risk
15	**New Construction:** Involves using sustainable materials, energy-efficient designs, and innovative techniques to minimize environmental impact and enhance resource efficiency throughout a building's lifecycle. These practices also focus on improving indoor air quality, conserving water, and integrating renewable energy sources to create healthier and more sustainable buildings. Link to Section	**Near Term**	**Medium Impact**	**High Cost**	**Medium Risk**

Smart Energy Management

Smart Energy Management are Innovative software solutions to optimize energy use in existing infrastructure, including energy management systems (EMS), smart building systems, and electric load management.

ID	Energy Security Effort	Implementation Timeframe	Impact	Cost	Risk
16	**EMS:** A set of computer-aided tools used to monitor, control, and optimize the performance of electric utility grids or other energy systems. Link to Section	**Near Term**	**Medium Impact**	**Medium Cost**	**Low Risk**
17	**Smart Building Systems:** Integrate various building-wide systems like HVAC, lighting, and security into a single IT-managed network infrastructure to enhance efficiency and responsiveness. Link to Section	**Near Term**	**Medium Impact**	**Medium Cost**	**Medium Risk**
18	**Electric Load Management:** The process of balancing electricity supply with demand by adjusting or controlling the electrical load rather than the power station output Link to Section	**Near Term**	**Medium Impact**	**Medium Cost**	**Low Risk**

Waste Reduction

Waste reduction is the process of minimizing the amount of waste generated by using resources more efficiently, reusing materials, and preventing unnecessary consumption. It aims to conserve natural resources, reduce environmental impact, and promote sustainability by avoiding the creation of waste at its source. GA airports can use the energy security efforts in this category to minimize the airport's waste production and carbon footprint.

ID	*Energy Security Effort*	*Implementation Timeframe*	*Impact*	*Cost*	*Risk*
19	**Waste Analysis:** An evaluation of the airport's waste to recommend ways to reuse, reduce, or eliminate different types of waste. Link to Section	**Near Term**	**Insignificant Impact**	**Low Cost**	**Low Risk**
20	**Recycling Programs:** Internal programs for airport users and employees to collect and encourage recycling. Link to Section	**Near Term**	**Insignificant Impact**	**Low Cost**	**Low Risk**
21	**Composting:** The process of collecting food scraps and landscaping waste to naturally break down organic materials, reducing the amount of waste sent to landfills and enriching soil in the process. Link to Section	**Near Term**	**Insignificant Impact**	**Low Cost**	**Low Risk**
22	**Reduction of Single-Use Plastics:** The effort to minimize or eliminate the use of plastic products that are designed to be used once and then discarded, such as plastic bags, straws, utensils, and packaging. Link to Section	**Near Term**	**Insignificant Impact**	**Low Cost**	**Low Risk**

Alternative Fuels

Alternative Fuels are energy sources that serve as substitutes for conventional fossil fuels like gasoline and diesel. They include options such as electricity, biodiesel, hydrogen, and natural gas, and are often cleaner and more sustainable, helping to reduce greenhouse gas emissions and dependence on petroleum. This section will detail the different energy security efforts or fuel types that can be used to power aircraft, vehicles, equipment, and facilities.

ID	*Energy Security Effort*	*Implementation Timeframe*	*Impact*	*Cost*	*Risk*
23	**Sustainable Aviation Fuel (SAF):** A type of biofuel designed to power aircraft, made from renewable biomass and waste resources, offering similar characteristics to conventional jet fuel. Link to Section	**Medium Term**	**Medium Impact**	**High Cost**	**Medium Risk**
24	**Unleaded Aviation Fuel:** A type of aviation gasoline (avgas) that does not contain lead, formulated to meet the performance requirements of piston-engine aircraft. Link to Section	**Near Term**	**Insignificant Impact**	**Medium Cost**	**Medium Risk**
25	**Renewable Diesel:** A biofuel made from renewable resources like vegetable oils, animal fats, and waste cooking oils, chemically similar to petroleum diesel and produced through hydrotreating. Link to Section	**Medium Term**	**Significant Impact**	**Medium Cost**	**Medium Risk**
26	**Electricity:** Typically stored in batteries or supplied through a grid—to power vehicles and equipment instead of traditional fossil fuels like gasoline or diesel. It is considered a cleaner and more sustainable option, especially when generated from renewable sources such as solar, wind, or hydroelectric power. Link to Section	**Near Term**	**Significant Impact**	**High Cost**	**Low Risk**

ID	Energy Security Effort	Implementation Timeframe	Impact	Cost	Risk
27	**Hydrogen Fuel:** A clean energy source produced using low-carbon methods such as electrolysis powered by solar or wind energy, used in fuel cells to generate electricity through a chemical reaction. It offers high efficiency, emits only water vapor as a byproduct. Link to Section	**Medium Term**	**Significant Impact**	**High Cost**	**High Risk**
28	**Compressed Natural Gas (CNG) and Renewable Natural Gas:** CNG is natural gas compressed to high pressure for use as a fuel, while renewable natural gas is produced from organic waste and can be used similarly. Link to Section	**Near Term**	**Medium Impact**	**Medium Cost**	**Low Risk**
29	**Propane (LPG – Liquefied Petroleum Gas):** A hydrocarbon gas liquefied through pressurization, used as a fuel for heating, cooking, and vehicles. Link to Section	**Near Term**	**Insignificant Impact**	**High Cost**	**High Risk**
30	**Biofuels for Diesel and Gasoline Engines:** Renewable fuels made from biological materials such as vegetable oils, animal fats, and agricultural waste. Link to Section	**Near Term**	**Medium Impact**	**Medium Cost**	**Medium Risk**
31	**Liquefied Natural Gas (LNG):** Natural gas that has been cooled to a liquid state for storage and transportation. Link to Section	**Near Term**	**Insignificant Impact**	**High Cost**	**Medium Risk**
32	**Synthetic Fuels for Diesel and Gasoline Engines:** Artificially produced hydrocarbons designed to replace conventional diesel and gasoline, offering cleaner combustion and reduced emissions. Link to Section	**Long Term**	**Medium Impact**	**Medium Cost**	**High Risk**

ID	Energy Security Effort	Implementation Timeframe	Impact	Cost	Risk
33	**Hybrid Electric Systems:** These systems combine a traditional internal combustion engine with an electric propulsion system. By seamlessly switching between or simultaneously using both power sources, hybrid vehicles optimize performance, lower fuel consumption, and offer a cleaner alternative to conventional engines—especially in stop-and-go driving conditions. Link to Section	**Near Term**	**Medium Impact**	**Medium Cost**	**Low Risk**

Electrification

Electrification is the process of replacing technologies that use fossil fuels with those that use electricity as a power source. It plays a key role in reducing reliance on imported fuels and improving energy efficiency, especially when paired with renewable energy sources. The category includes energy security efforts or electrification options on the landside, airside, and fleet side of GA airports.

Landside

Landside refers to the areas of an airport that are accessible to the general public. These areas are outside the security checkpoints, where airport users can access various airport services and facilities. Electrification opportunities for parking areas and Transportation Network Companies (TNC)/Taxi are described in this section.

ID	Energy Security Effort	Implementation Timeframe	Impact	Cost	Risk
34	**Parking Areas:** Electrification of parking areas involves installing electric vehicle (EV) charging stations to support the growing number of EVs. Link to Section	**Near Term**	**Insignificant Impact**	**High Cost**	**Medium Risk**
35	**TNC/Taxi:** Incorporate electrification incentive programs by the GA airport to support the transition of TNCs and taxis to EVs. Link to Section	**Medium Term**	**Insignificant Impact**	**Low Cost**	**Low Risk**

Airside

Airside refers to the secure areas of an airport beyond security checkpoints and passport control. Access is restricted to authorized personnel and cleared airport users. For this toolkit, Electric Ground Support Equipment (eGSE) and electric aircraft is discussed.

ID	Energy Security Effort	Implementation Timeframe	Impact	Cost	Risk
36	**eGSE:** Includes converting airport ground vehicles and machinery, such as baggage tractors and belt loaders, from diesel to electric power. Link to Section	**Near Term**	**Medium Impact**	**Medium Cost**	**Medium Risk**
37	**Electric Aircraft:** With the rise in electric aircraft, the GA airport is exploring ways to support their electrification, including the potential installation of charging infrastructure and other necessary facilities. Link to Section	**Medium Term**	**Significant Impact**	**Medium Cost**	**Medium Risk**

Fleet

Fleet refers to the collection of vehicles operated at an airport to support daily operations, including maintenance trucks, shuttle buses, and fire trucks.

ID	Energy Security Effort	Implementation Timeframe	Impact	Cost	Risk
38	**Maintenance Vehicles:** Specialized automobiles used to support the upkeep of airport facilities and infrastructure. Link to Section	**Near Term**	**Significant Impact**	**High Cost**	**Low Risk**
39	**Shuttles:** Vehicles that transport airport users, crew, or staff between GA airport facilities. Link to Section	**Near Term**	**Significant Impact**	**High Cost**	**Low Risk**
40	**Fire Trucks:** Specialized emergency response vehicles designed to respond quickly to airport incidents and fires. Link to Section	**Near Term**	**Significant Impact**	**High Cost**	**Low Risk**

ID	Energy Security Effort	Implementation Timeframe	Impact	Cost	Risk
41	**Ground Maintenance Equipment:** Specialized automobiles used to maintain the airport's outdoor infrastructure. These vehicles include lawn mowers, sweepers, snow removal equipment, and pavement repair trucks. Link to Section	**Near Term**	**Significant Impact**	**High Cost**	**Low Risk**

Security

Security refers to the measures and systems put in place to protect people, property, and information from threats such as theft, vandalism, or unauthorized access. At an airport, security ensures safe operations through surveillance, access control, and emergency response protocols. The security section gives general information on physical and cyber security efforts that can be used by GA airports.

ID	Energy Security Effort	Implementation Timeframe	Impact	Cost	Risk
42	**Physical Security:** Measures designed to protect personnel, facilities, and assets from physical threats such as unauthorized access, theft, vandalism, and natural disasters. Link to Section	**Near Term**	**Significant Impact**	**Medium Cost**	**Low Risk**
43	**Cybersecurity:** Practice of protecting networks, devices, and data from unauthorized access, cyberattacks, and criminal use, ensuring the confidentiality, integrity, and availability of information. Link to Section	**Near Term**	**Significant Impact**	**Medium Cost**	**Low Risk**

Off-Site and On-Site Resilient Energy Systems

This section focuses on off-site or on-site resilient energy system options for GA airport operations. It explores various strategies to support domestic energy production and enhance airport energy security through RECs, utility green tariffs, and on-site resilient energy solutions. These solutions include renewable energy generation (solar, wind, and geothermal), battery energy storage, microgrids, and backup generators. By implementing off-site and on-site resilient energy systems, GA airports can achieve significant cost savings, enhance sustainability, and ensure reliable operations during emergencies and grid outages. These solutions reduce reliance on external stakeholders, thereby increasing energy independence and security. This section provides valuable insights and practical recommendations to help GA airports build a diverse domestic energy portfolio and robust on-site energy infrastructure.

Off-Site Options

The off-site options section explores various strategies for enhancing energy security by utilizing resources and technologies located outside the airport premises. This section delves into the benefits and challenges of implementing RECs and utility green tariff programs. By leveraging these off-site options, GA airports can support domestic energy production and contribute to a more resilient aviation sector. The insights provided in this section aim to guide GA airports in making informed decisions about integrating off-site energy solutions into their overall energy security strategy.

Renewable Energy Credits (RECs)

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Airport Facilities, Policies/ Practices	Near Term	Insignificant Impact	Low Cost	Low Risk

RECs are generated and offered by off-site energy generation companies. GA airports can purchase RECs to claim the domestic energy and environmental benefits of renewable energy generation, even if their on-site energy is not from domestic (fossil fuels and nuclear) and renewable energy sources. RECs represent the generation of renewable energy, such as wind, solar, and geothermal. Each REC corresponds to one megawatt-hour (MWh) of electricity from renewable sources.

RECs play a crucial role in reducing market-based Scope 2 emissions, which are emissions from purchased energy from utilities. They support the development of renewable energy projects, demonstrating a commitment to domestic energy production.[2] General Aviation (GA) airports can acquire RECs through various avenues, including Power Purchase Agreements (PPAs), green pricing programs, community solar programs, green tariffs, direct purchases from brokers, and other mechanisms.

Overview

- **Compatibility:** RECs are universally compatible with all airports, as they do not require any changes to infrastructure, operations, or maintenance. Any electricity consumer can purchase RECs to claim the domestic energy benefits without needing to modify existing systems.
- **Current Market & Growth Projections:** The U.S. REC market is growing rapidly. Valued at $13 billion in 2022, it is expected to reach $40 billion by 2033, driven by tax credits, state clean energy targets, and high prices for solar and wind credits. REC generation is forecast to rise from 950 million MWh in 2024 to nearly 2.7 billion MWh by 2033.[3]
- **Regulatory Environment:** In North Carolina, RECs are regulated by the North Carolina Utilities Commission (NCUC). The NCUC oversees the implementation of the state's Renewable Energy and Energy Efficiency Portfolio Standard (REPS), which includes the management and regulation of RECs.[4]

[2] EPA. (2018). *Offsets and RECs: What's the Difference?*
[3] S&P Global. (2024). *U.S. Renewable Energy Credit Market Size Forecast to Approach $40B by 2033*
[4] General Assembly of North Carolina. (2007). *Session Law 2007-397 Senate Bill 3*

Benefits & Challenges

Benefits	Challenges
• RECs allow airports to support the development of domestic renewable energy infrastructure. • RECs can provide a cost-effective way to achieve energy security goals without the need for significant infrastructure changes or on-site renewable energy generation.	• GA airports that continue to rely solely on fossil fuels risk remaining dependent on utility providers for all energy generation needs. • In emergencies, RECs do not provide the immediate, on-site power needed to maintain critical functions during grid outages or high demand periods.

Infrastructure Needs

- **GA Airport's Responsibility:** GA airports are responsible for purchasing and managing RECs. This involves budgeting for REC purchases and evaluating the cost-effectiveness of renewable energy investments. Additionally, the airport must ensure the credibility of REC providers by checking certifications and standards compliance.
- **Other Stakeholders' Responsibility:** The renewable energy suppliers (utilities and renewable energy companies) are responsible for consistently producing renewable energy that meets the standards required for RECs. Additionally, they are responsible for obtaining proper certification and verification to ensure the energy generated qualifies for RECs. These suppliers may sell the RECs either to customers or on the open market. Brokers or aggregators are responsible for purchasing RECs from renewable energy generators and then selling them to customers. The North Carolina Utilities Commission (NCUC) uses the North Carolina Renewable Energy Tracking System (NC-RETS)[5] to track and regulate RECs.

Additional Resources

- **Case Studies:**
  - **San Francisco International Airport (SFO)** mentioned in the 2020 Zero Net Energy Plan, SFO plans to purchase 1.9 billion kBtu of off-site renewable energy (combination of San Francisco Public Utilities Commission (SFPUC)'s "green tariffs" and RECs) in the first year for all airport and tenant-occupied buildings. By 2050, this will decrease to 910 million kBtu/year as overall energy use declines. The total cost over the plan's duration is estimated at $139 million.[6]
  - **John F. Kennedy International Air Terminal (JFK)** has invested in RECs to reduce Scope 2 emissions to net zero at Terminal 4.[7]
  - **Chicago O'Hare International Airport (ORD)** transitioned to 100% renewable energy on January 1, 2025, with 30% of their current energy sources coming from RECs.[8]

[5] NCUC. *NC-RETS*
[6] SFO. (2020). *Zero Net Energy at SFO 2020 Executive Summary Report*
[7] T4 JFK International Air Terminal. (2024). *JFKIAT Reduces Scope 2 Emissions to Net Zero with the Purchase of Green-E® Renewable Energy Certificates (RECs)*
[8] Islands Media. (2025). *One of the World's Busiest Airports Has Gone 100% Carbon-Free*

- **Potential Funding and Incentives:**
  - Currently, there are no specific funding opportunities available for purchasing RECs.
  - Visit the NC State University DSIRE database (Database of State Incentives for Renewables & Efficiency) for the most comprehensive source of information on incentives and policies that support renewables and energy efficiency in the United States.[9]

Summary Ratings

- **Near Term**, RECs are readily available in North Carolina and can be utilized by airports now. Airports can purchase RECs without the need to deploy any renewable energy infrastructure, making it a convenient and cost-effective option.
- **Insignificant Impact**, while REC investment supports domestic renewable energy generation, they cannot provide on-site power required for energy security to sustain critical operations during grid outages or periods of high demand. In order to support continued operations, GA airports will need to use a variety of energy sources and cannot rely solely on REC. RECs can provide benefits in terms of achieving net zero goals.
- **Low Cost**, RECs tend to be less expensive than on-site energy generation. The GA airport has the flexibility to purchase as many RECs as needed to meet their energy security goals. Also, the cost of RECs in North Carolina can vary based on market conditions, the type of renewable energy, and the volume purchased.[10]
- **Low Risk**, Since RECs require no infrastructure investment, they carry low implementation risk. RECs can be easily purchased and sold.

Recommendations

RECs are ideal for airports aiming to support domestic energy production without the need for on-site energy infrastructure. They can also be used in conjunction with some on-site energy production to enhance energy security efforts. If GA airports would like to consider purchasing RECs, the GA airport staff can follow these next steps. First, airports would assess their energy consumption and determine the number of RECs equivalent (~1REC = 1 MWh) to their emissions or a part of their emissions. Next, airports can purchase RECs from certified providers, ensuring that the credits are sourced from reputable renewable energy projects. Finally, airports can integrate RECs into their sustainability reporting and marketing efforts, showcasing their commitment to promoting domestic energy production and reducing emissions.

[9] NC Clean Energy Technology Center. *DSIRE database*
[10] EPA. (2025). *Green Power Pricing*

Utility Green Tariff Programs

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Airport Facilities, Policies/ Practices	Near Term	Insignificant Impact	Low Cost	High Risk

Utility green tariff programs allow eligible customers to source up to 100% of their electricity from renewable resources.[11] These programs provide a structured rate for purchasing bundled renewable energy, enabling larger commercial and industrial customers to meet their energy security goals, reduce long-term energy risks, and support the development of new domestic and renewable energy projects. By participating in utility green tariffs, organizations can demonstrate their commitment to energy security and contribute to the growth of the renewable energy market.

Overview

- **Compatibility:** Utility green tariff programs are compatible with existing General Aviation (GA) airport systems, as they can be easily integrated into the utility's energy portfolio.
- **Current Market & Growth Projections:** U.S. Corporate customers announced more than 3,000 megawatts (MW) of green tariff deals in 2022 alone, highlighting the rapid growth of these programs.[12] The current market value of utility green tariff programs in the U.S. growing, with over 50 active programs offered by more than 40 utilities (either pending or approved, as of January 2023). [13]
- **Regulatory Environment:** The regulatory environment for utility green tariff programs in North Carolina is overseen by the North Carolina Utilities Commission (NCUC). The NCUC is responsible for regulating the rates and services of public utilities in the state, ensuring that these programs align with modern goals and innovations.[14] Recently, North Carolina regulators approved Duke Energy's Green Source Advantage Choice program, allowing large electric customers to contribute extra for renewable energy projects that Duke Energy is already mandated to build.[15] Also, another green tariff provider in North Carolina is from Tennessee Valley Authority with their Green Invest program.[16]

[11] EPA. (2025). *Utility Green Tariffs*
[12] Id.
[13] Clean Energy Buyers Association. (2023). *U.S. Utility Green Tariff Report: January 2023 Update*
[14] North Carolina Utilities Commission. (2025).
[15] Duke Energy. (2024). *Duke Energy expands North Carolina program that helps businesses become more renewable and carbon-free*
[16] Clean Energy Buyers Association. (2023). *Industry Stakeholder Collaboration*

Benefits & Challenges

Benefits	Challenges
• Support domestic and renewable energy generation without needing to invest in the infrastructure. • Allow larger customers to buy bundled renewable electricity through a special utility tariff rate. • Utility green tariffs help reduce long-term energy risks by providing price stability and enhancing energy security through local renewable energy investments.	• Utility green tariff programs also encounter challenges such as ensuring that the renewable energy supplied is genuinely additional and not just repurposed from existing projects. • In emergencies, utility green tariffs cannot provide the immediate power required to sustain critical operations during grid outages or peak demand periods. • Utility green tariff programs are designed to support large-scale renewable energy projects, which often involve long-term agreements to ensure the financial viability and stability of the projects.

Infrastructure Needs

- **GA Airport's Responsibility:** When participating in a utility green tariffs program, GA airports can evaluate their energy consumption and energy security goals to determine the appropriate amount of renewable energy needed. They must allocate funds for the purchase, ensuring cost-effectiveness and alignment with financial plans and sustainability goals. Additionally, airports should verify the credibility of green tariff providers by checking certifications and compliance with standards. Integrating the green tariffs into their overall energy portfolio and proper reporting is crucial to showcase their commitment to energy security. Regular monitoring and auditing of the performance and impact of the green tariffs are also necessary to ensure they meet the airport's energy objectives.
- **Other Stakeholders' Responsibility:** Utilities must provide transparent information about green tariff options, including pricing, availability, and renewable energy sources, and ensure seamless integration into the airport's energy portfolio while offering technical support. Regulators, such as state public utility commissions, are responsible for approving and overseeing green tariff programs to ensure they meet regulatory standards and provide fair access to renewable energy. Renewable energy providers must supply high-quality, certified renewable energy that meets program standards and maintain transparency and reliability in their production. Additionally, energy consultants and advisors can assist the airport in evaluating green tariff options, conducting cost-benefit analyses, and ensuring alignment with the airport's energy security goals.

Additional Resources

- **Case Studies:**
  - In **San Francisco International Airport (SFO)** Zero Net Energy 2020 Executive Summary Report, SFO mentions the strategy of procuring "any remaining energy use via San Francisco Public Utilities Commission (SFPUC) Green Tariff, power purchase agreements, or Renewable Energy Credits (RECs)", totaling a capital cost of $139 million.[17]
  - **Duke Energy's Green Source Advantage (GSA) Program** has been popular among large businesses in North Carolina. It allows companies to offset their power purchases with renewable energy from new projects connected to Duke Energy's grid.[18]
  - **The Green Invest Program offered by the Tennessee Valley Authority** connects customers with renewable energy projects by using a competitive selection process.[19]
- **Potential Funding and Incentives:** Currently, there are no specific funding opportunities available for opt-in utility green tariffs. Visit the NC State University DSIRE database (Database of State Incentives for Renewables & Efficiency) for the most comprehensive source of information on incentives and policies that support renewables and energy efficiency in the United States.[20]

Summary Ratings

- **Near Term**, green tariff programs in North Carolina are readily available and can be implemented within a short time frame.
- **Insignificant Impact**, green tariff programs contribute to domestic energy adoption and emissions reduction. However, their reach is limited to off-site energy generation. While these programs support domestic energy goals, integrating on-site energy generation is essential for achieving a more substantial impact on energy security goals for the airport. Green tariff programs can help GA airports meet net zero emissions targets.
- **Low Cost**, the average cost of green tariffs varies depending on the utility and region. This cost is typically considered moderate, as it is higher than conventional electricity rates but lower than upfront on-site energy generation infrastructure costs. However, green tariffs do not necessitate infrastructure investment, workforce training, maintenance, or other internal costs. GA airports can flexibly purchase green tariffs based on their energy security goals, choosing as little or as much as needed.
- **High Risk**, purchasing green tariffs for GA airports is generally considered high risk. The inherent risks are because of the long-term contractual commitments required by some green tariff programs.

Recommendations

GA airports should consider utility green tariff programs to enhance their domestic energy investment efforts. By participating in these programs, GA airports can source up to 100% of their electricity from domestic renewable

[17] SFO. (2020). *Zero Net Energy at SFO 2020 Executive Summary Report*
[18] Duke Energy. (2024). *Duke Energy expands North Carolina program that helps businesses become more renewable and carbon-free*
[19] Tennessee Valley Authority. (2025). *Green Invest*
[20] NC Clean Energy Technology Center. *DSIRE database*

energy projects, thereby reducing their emissions and aligning with their energy security goals. Additionally, these programs often offer stable and potentially lower energy costs over time, providing financial benefits.

On-Site Generation and Storage

This section examines the systems that produce and store energy directly on airport premises. It will cover various technologies, including solar energy, wind power, geothermal energy, microgrids, battery energy storage, and backup generators. Implementing these on-site generation and storage solutions entails upfront, operational, maintenance, battery replacement, decommissioning, infrastructure, grid integration, insurance, and permitting costs. Nevertheless, by adopting these technologies, GA airports can significantly enhance their operational resilience, reduce dependency on external energy sources, and improve their capacity to respond effectively to emergencies and natural disasters.

Solar Energy

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Airport Facilities, Infrastructure, Management Systems, Utilities	Near Term	Significant Impact	High Cost	Medium Risk

Solar energy converts sunlight into electricity using photovoltaic (PV) cells. North Carolina ranks 5th in the nation for installed solar capacity, with approximately 9,668 megawatts (MW) and solar energy accounting for about 9.65% of the state's electricity.[21] General Aviation (GA) airports can install solar panels on rooftops, parking structures, and open land to generate electricity on-site. Solar energy can also be used to heat water via solar thermal systems, which can then be used for various purposes such as hot water and space heating.

Overview

- **Compatibility:** Solar energy systems are compatible with airports.
- **Current Market & Growth Projections:** As of 2025, the U.S. solar energy market value is at approximately $51.2 billion with a Compound Annual Growth Rate (CAGR) of 5.58% through 2030.[22] In 2024, the U.S. solar industry installed nearly 50 gigawatt (GW) direct current (DC) of capacity, a 21% increase from 2023, accounting for 66% of new electricity-generating capacity added to the grid. The industry is projected to triple its cumulative capacity from 236 GW DC at year-end 2024 to 739 GW DC by 2035.[23]
- **Regulatory Environment:** North Carolina's solar industry thrives due to strong state policies like the Renewable Energy and Energy Efficiency Portfolio Standard (REPS), which promote solar energy. The state supports solar-plus-storage systems as cost-effective alternatives.[24] The North Carolina Energy Regulatory Process (NERP) updates utility regulations to align with modern goals and innovations.[25] The Federal Aviation Administration (FAA) requires airports to assess and mitigate the hazardous glare impact of solar projects on federally obligated airports with control towers to ensure aviation safety.[26]

Benefits & Challenges

Benefits	Challenges
• On-site solar energy generation coupled with energy storage can provide a reliable power source during emergencies or grid outages.	• Installing solar panels and related infrastructure can be expensive. • Solar panels need significant space, which might be limited at some airports. Solar

[21] Solar Energy Industries Association. (2024). *North Carolina*
[22] Statista. (2025). *Solar Energy - United States*
[23] Solar Energy Industries Association. (2025). *Q4 2024 Solar Market Insight Report*
[24] Solar Energy Industries Association. (2024). *North Carolina*
[25] NCDEQ. (2020). *North Carolina Energy Regulatory Process*
[26] Federal Register. (2021). *FAA Policy: Review of Solar Energy System Projects on Federally-Obligated Airports*

Benefits	Challenges
• Using solar energy can reduce utility expenses and the lifetime of the panels can be decades. • Once installed, solar thermal systems can significantly reduce heating costs, especially for water heating and space heating.	panel installations can interfere with airport expansion. • Solar panel glare can pose a safety hazard by affecting pilots' and air traffic controllers' visibility. • Solar energy generation is affected by weather conditions, leading to variability in power supply.

Infrastructure Needs

- **GA Airport's Responsibility:** When a GA airport installs solar energy on-site, its responsibilities include overseeing the project to ensure compliance with all relevant regulations and standards. The airport must coordinate with the FAA to review and approve the project. Additionally, the airport is responsible for obtaining necessary permits from local government agencies, facilitating grid integration with utility companies, and managing the design, installation, and maintenance of the solar energy systems through contractors and engineers. The airport must also secure appropriate funding and investment. To implement solar energy at a GA airport, the necessary infrastructure includes solar panels, energy storage systems, backup generators, and possible microgrids
- **Other Stakeholders' Responsibility:** The FAA reviews and approves the project to prevent hazardous solar glare. Local government agencies handle permitting and zoning, while utility companies facilitate grid integration. Contractors and engineers design, install, and maintain the systems, and financial institutions provide funding. To produce solar panels, manufacturers need access to high-purity silicon, specialized machinery for cutting and assembling silicon wafers, and advanced testing equipment for quality control.

Additional Resources

- **Case Studies:**
  - **The Washington-Warren Field Airport (OCW)** has a 39-acre solar farm that began operating in 2013. The 23,000 panels generate 5 MW of power, and the airport collects $1,200 per acre per year leasing to the solar company.[27] [28]
  - **Midland, Bay City, Saginaw International Airport (MBS)** is planning to build a solar canopy and smaller solar arrays. [29]
  - **Tuscana International Airport (TUS)** air traffic control tower is powered by a 1,600-panel solar farm.[30]
  - At the **Penn Yan Airport (PEO)**, the FAA has installed solar panels and battery systems to power 23 lighting safety systems, including runway and taxiway edge lights, obstruction lights, elevated runway guard lights, windsocks, and signs.[31]

[27] Washington Daily News. (2014). *Added bonus: Larger solar farm means more revenue*
[28] Washington-Warren Airport. (2022). *Airport Strategic Business Plan*
[29] Midland Daily News. (2025). *Midland City Council Approves MBS Airport Bonds for Solar Project*
[30] FAA. (2023). *FAA Facts: FAA Harnesses the Sun to Save Energy and Lower Expenses*
[31] Id.

- **Denver International Airport (DEN)** has over 42,600 solar panels across 56 acres, expanding capacity.[3233]
- **San Francisco International Airport (SFO)** installed solar PV systems generating 4.9 million kilowatt-hour (kWh) annually: new projects to save 94 million kilo British Thermal Unit (kBtu)/year at a cost of $194 million. [34]
- **Indianapolis International Airport (IND)** has the largest airport-based solar farm, generating 17.5 MW alternating current (AC), enough to power 3,210 homes annually, spanning 183 acres with 87,478 panels. [35]
- **Honolulu's Daniel K. Inouye International Airport (HNL)** has 1,278 kilowatts (kW) of DC power from 4,236 PV panels.

- **Potential Funding and Incentives:**
  - NCDOT Division of Aviation manages both state-funded and federal grant programs for airports, including the State Aid to Airports program, which allocates funds based on the Airport System Plan and applications.[36]
  - The FAA awards grants for airport development as part of the Airport Improvement Program (AIP) Supplemental Grant Program.[37]
  - The 2024 NCDOT North Carolina Airports Program Guidance Handbook has state and federal funding sources and program details.[38]
  - The U.S. Department of Agriculture (USDA) Rural Utilities Service offers funding specific to eligible rural communities (including state and local government entities) with annual average household energy cost exceeding 275 percent of the national average under benchmarks published in the 2025 High Energy Cost Grant Funding Opportunity Announcement.[39]
  - The Inflation Reduction Act allows commercial solar customers to take 30% of their solar investment as a credit against federal tax liability and the Modified Accelerated Cost-Recovery Systems (MACRS) is an additional tax credit that allows businesses to write off the cost of solar assets over a shorter period of time allowing businesses to depreciate 87% of the cost of their solar investment.[40]
  - The North Carolina General Statute § 105-275(45) mandates that 80% of the appraised value of a solar energy electric system is exempt from property taxation, meaning that only 20% of the system's value is subject to property taxes.[41]

---

[32] PV Magazine. (2024). *Vertical Solar Power at U.S. Airports*
[33] Solar Tribune. (2021). *Solar Power Takes Off at U.S. Airports*
[34] SFO. (2020). *Zero Net Energy at SFO 2020 Executive Summary Report*
[35] Indianapolis International Airport. (2025). *Sustainability*
[36] Connect NCDOT. (2025). *Airport Grant Programs*
[37] *FAA. (2025). AIP*
[38] NCDOT Division of Aviation. (2024). *North Carolina Airports Program Guidance Handbook*
[39] USDA Rural Development. *High Energy Cost Grants*
[40] Commercial Solar. (2024). *Key North Carolina Commercial Solar Incentives & Rebates Available in 2024*
[41] North Carolina Department of Revenue. Solar Energy Electric Systems Memorandum (2011)

- Visit the NC State University DSIRE database (Database of State Incentives for Renewables & Efficiency) for the most comprehensive source of information on incentives and policies that support renewables and energy efficiency in the United States.[42]

Summary Ratings

- **Near Term**, solar energy technology is commercially available and can be rapidly deployed, contingent upon supply chain availability.
- **Significant Impact**, a GA airport solar energy system in North Carolina can produce a substantial amount of electricity. For example, a solar array of around 87.5 kW in Arlington, Washington can generate approximately 145,000 kWh of renewable energy annually.[43] This amount can considerably offset the airport's annual electric consumption, providing savings against rising utility costs.
- **High Cost**, the cost of a solar energy system varies based on its size. Key expenses include the initial investment, operational and maintenance costs, battery replacement, decommissioning, infrastructure upgrades, grid integration, and insurance and permitting fees.
- **Medium Risk**, the primary risks of installing a solar energy system at the airport are financial and contractor related. Given the maturity of technology and North Carolina's high solar energy potential, these risks are manageable and can be mitigated through careful planning and selection of experienced contractors.

Recommendations

GA airports should conduct a feasibility study on implementing on-site solar generation to enhance energy security and operational efficiency. This study will assess the technical, economic, and environmental viability of solar energy solutions, including site assessment, system design, and cost analysis. Engaging with solar energy consultants and stakeholders will provide valuable insights and ensure compliance with regulations, enabling informed decision-making.

[42] NC Clean Energy Technology Center. *DSIRE database*
[43] General Aviation. (2024). *Largest Solar Array at a Washington GA Airport in the Works*

Wind Power

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Airport Facilities, Infrastructure, Management Systems, Utilities	Near Term	Significant Impact	High Cost	High Risk

Wind power is power generated from wind turbines that convert the wind's kinetic energy into electrical energy via a generator. General Aviation (GA) airports can set up wind turbines in open areas to harness wind energy, providing a sustainable power source. The size of a wind turbine can range from small rooftop turbines to land-based wind turbines. This can be particularly effective in regions with consistent wind patterns. On average, North Carolina experiences moderate wind speeds, with coastal areas generally having stronger winds compared to inland regions.

Overview

- **Compatibility:** Wind turbines can be installed on GA airport land and be seamlessly integrated into the airport's electricity system. Wind turbines can be installed at GA airports in perimeter areas, non-aeronautical zones, and buffer zones, ensuring they do not interfere with aircraft operations.
- **Current Market & Growth Projections:** The current U.S. market value for wind power is substantial, with over $12 billion in capital investment in 2022. Wind power accounted for 22% of new electricity capacity installed in the U.S. in 2022. Growth projections are strong, with forecasts indicating nearly 18,000 megawatts (MW) of land-based wind energy installed by 2026, a 60% increase from previous estimates.[44]
- **Regulatory Environment:** North Carolina's regulatory environment for wind power includes restrictions like the Ridge Law and coastal development rules, which can limit potential sites for wind energy projects near GA airports. GA airports must check with Federal Aviation Administration (FAA) for any vertical construction on airfield and ensure that wind energy projects comply with these regulations and do not interfere with aviation safety and operations.

Benefits & Challenges

Benefits	Challenges
• Can lower energy costs for airport operations. • Provides a reliable and renewable source of energy, enhancing energy security and reducing dependence on fossil fuels.	• Wind turbines can interfere with radar systems and pose visual obstructions, impacting flight safety. • Regulations often mandate minimum distances between wind turbines and airports to minimize risks.

[44] U.S. DOE. (2023). *U.S. Department of Energy Projects Strong Growth in U.S. Wind Power Sector*

Benefits	Challenges
	• Airports may have limited space for installing wind turbines without affecting aviation operations. • Airports attract large flocks of birds, increasing the risk of bird strikes on turbine blades, which can cause significant damage. • Regular maintenance is required to ensure turbines operate efficiently and safely, which can be resource intensive. • Wind energy generation is variable and dependent on weather conditions, leading to inconsistent power supply.

Infrastructure Needs

- **GA Airport's Responsibility:** To implement wind power at a GA airport, the airport will need wind turbines, site assessments for suitable turbine locations that ensure safety compliance with FAA regulations, and to establish grid connections. Additionally, airports must set up maintenance facilities and mitigate environmental impacts like bird strikes and noise pollution.
- **Other Stakeholders' Responsibility:** Other stakeholders need to provide robust electrical grid connections to integrate wind power generated at GA airports. Additionally, efficient transportation infrastructure is needed to deliver and install large wind turbine components, along with clear regulatory frameworks and support for permitting processes.

Additional Resources

- **Case Studies:**
  - **Boston Logan International Airport (BOS)** offices are equipped with 20 AeroVironment AVX 1000 wind turbines, each standing 12 feet tall, to enhance their energy efficiency and sustainability.[45]
  - **The Hawaii Department of Transportation, Airports Division (HDOT-A)** has installed 16 building-mounted wind turbines, each with a capacity of 1 kilowatt (kW), on **Honolulu's Daniel K. Inouye International Airport (HNL)** owned structure. These turbines help meet the electrical demand of the new airfield and support smaller loads within the building.[46]
  - **Dallas Love Field (DAL)** is acquiring energy-capturing pods to harness wind generated by aircraft and convert it into sustainable energy. After a two-year testing phase from 2021 to 2024, the first batch of market-ready pods was manufactured in August 2024.[47]

[45] City of Boston. (2016). *Using Wind Energy to Power the City*
[46] State of Hawai'i Department of Transportation - Airports Division. (2014). *sustainableHNL 2014 Elements Baseline Update Year 5 Sustainability Categories Update: Energy, Carbon, Water, & Waste*
[47] Dallas Love Field. (2024). *JetWind Adds to DAL Terminal Amenities*

- **Potential Funding and Incentives:**
  - NCDOT Division of Aviation manages both state-funded and federal grant programs for airports, including the State Aid to Airports program, which allocates funds based on the Airport System Plan and applications.[48]
  - The FAA awards grants for airport development as part of the Airport Improvement Program (AIP) Supplemental Grant Program.[49]
  - The 2024 NCDOT North Carolina Airports Program Guidance Handbook has state and federal funding sources and program details.[50]
  - The United States Department of Agriculture (USDA) Rural Utilities Service offers funding specific to eligible rural communities (including state and local government entities) with annual average household energy cost exceeding 275 percent of the national average under benchmarks published in the 2025 High Energy Cost Grant Funding Opportunity Announcement.[51]
  - Visit the NC State University DSIRE database (Database of State Incentives for Renewables & Efficiency) for the most comprehensive source of information on incentives and policies that support renewables and energy efficiency in the United States.[52]

Summary Ratings

- **Near Term**, wind power technology is both commercially available and mature. A GA airport can feasibly deploy wind power within 0-3 years.
- **Significant Impact**, wind power can generate sufficient electricity to supplement the energy needs of GA airports, particularly when combined with energy storage systems. By producing energy on-site, wind power can significantly reduce the airport's reliance on imported fuels.
- **High Cost**, the cost of wind turbines can vary significantly based on factors such as size, location, and specific project requirements.
- **High Risk**, installing wind power at a GA airport can interfere with radar systems and disrupt air traffic patterns, posing safety risks. Additionally, they can create obstacle hazards, increase climb gradients, and impact local wildlife. These factors necessitate careful planning, thorough feasibility studies, and strict adherence to regulatory compliance to mitigate risks and ensure safe operations.

Recommendations

GA airports can complete a comprehensive feasibility study to determine whether wind power installations offer significant benefits and are a cost-effective solution. If the study yields positive results, the GA airport can move forward with implementation to achieve long-term energy savings and environmental advantages.

---

[48] Connect NCDOT. (2025). *Airport Grant Programs*
[49] *FAA. (2025). AIP*
[50] NCDOT Division of Aviation. (2024). *North Carolina Airports Program Guidance Handbook*
[51] USDA Rural Development. *High Energy Cost Grants*
[52] NC Clean Energy Technology Center. *DSIRE database*

Geothermal Energy

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Airport Facilities, Infrastructure, Management Systems, Utilities	Near Term	Medium Impact	High Cost	Low Risk

Geothermal energy harnesses heat, in the form of hot water or steam, from the Earth's interior for heating and cooling. In North Carolina, geothermal energy is primarily harnessed through geothermal heat pump systems, which utilize the stable ground temperature. This reduces the need for imported energy sources and enhances domestic energy potential.[53] General Aviation (GA) airports can use geothermal systems to efficiently manage their heating and cooling needs, reducing operational costs and negative public health impact.

Overview

- **Compatibility:** Integrating a geothermal heat pump system with the existing infrastructure of a GA airport can be challenging but feasible with proper planning. Key considerations include space constraints for drilling boreholes, potential disruptions during installation, and ensuring compatibility with existing heating and cooling systems.
- **Current Market & Growth Projections:** As of 2025, the U.S. geothermal energy market is valued at approximately $6.66 billion, with a Compound Annual Growth Rate (CAGR) of 7.7% from 2024 to 2025.[54]
- **Regulatory Environment:** The regulatory environment for geothermal energy in North Carolina involves permitting by the North Carolina Department of Environmental Quality (NCDEQ), compliance with environmental regulations, and adherence to local ordinances. The Inflation Reduction Act of 2022 expanded the Investment Tax Credit (ITC) to include geothermal heat pumps, allowing airports to claim a credit for a percentage of the installation costs.[55]

[53] U.S. DOE. (2025). *Geothermal Energy*
[54] The Business Research Company. (2025). *Global Geothermal Energy Major Players 2025, Forecast to 2034*
[55] plante moran. (2024). *Inflation Reduction Act: Tax Credits and Incentives for Airports*

Benefits & Challenges

Benefits	Challenges
• Geothermal systems provide efficient heating and cooling, reducing operational costs. • On-site geothermal systems reduce reliance on imported fuels, enhancing energy security.	• The installation of geothermal systems requires significant upfront investment. • Airports may face limitations in available space for drilling and installing geothermal systems. • The permitting process for geothermal energy involves site assessment, obtaining permits from the NCDEQ, environmental review, adherence to local ordinances, and careful installation planning.

Infrastructure Needs

- **GA Airport's Responsibility:** The infrastructure needed for a geothermal energy system at a GA airport includes geothermal heat pumps, ground loops, boreholes, heat exchangers, and mechanical vaults. GA airports are responsible for managing the construction, maintenance, operation, and ownership of the geothermal energy system, while also coordinating with regulatory authorities to ensure compliance.
- **Other Stakeholders' Responsibility:** Regulatory authorities need robust frameworks for permitting and compliance to ensure environmental and safety standards are met. Utility companies require integration capabilities to connect geothermal systems to the grid and manage energy distribution. Construction firms need specialized equipment and expertise for drilling boreholes and installing geothermal systems, while local governments need zoning and land use regulations that accommodate geothermal installations.

Additional Resources

- **Case Studies:**
  - **Outagamie County Regional Airport (ATW)** in Appleton, Wisconsin, uses geothermal heating and cooling in its Platinum Flight Center GA Terminal.[56]
  - **Louisville Muhammad Ali International Airport (SDF)** in Kentucky has the largest geothermal wellfield of any U.S. airport, providing heating and cooling for the terminal. The project is estimated to save $400,000 annually on utility costs and reduce carbon emissions by 80%.[57]
- **Potential Funding and Incentives:**
  - U.S. Department of Energy (DOE) Geothermal Technologies Office offer various funding opportunities for geothermal projects, including competitive solicitations and Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs.[58]

[56] Appleton Flight Center. (2025). *Sustainability*
[57] Louisville Muhammad Ali International Airport. (2023). *Geothermal Technology Now Live at Louisville Muhammad Ali International Airport*
[58] U.S. Department of Energy. (2025). *Geothermal Technologies Office Open Funding Opportunities*

- The Federal Aviation Administration (FAA) awards grants for airport development as part of the Airport Improvement Program (AIP) Supplemental Grant Program.[59]
- The 2024 NCDOT North Carolina Airports Program Guidance Handbook has state and federal funding sources and program details.[60]
- There are also a variety of clean energy tax incentives for businesses that GA airports can take advantage of.[61]
- Visit the NC State University DSIRE database (Database of State Incentives for Renewables & Efficiency) for the most comprehensive source of information on incentives and policies that support renewables and energy efficiency in the United States.[62]

Summary Ratings

- **Near Term**, deploying a geothermal energy system at a GA airport typically takes 1 to 3 years, depending on project size, site conditions, and regulatory approvals. This timeline covers feasibility studies, securing funding, system design, drilling and installation of geothermal wells, and integration with existing infrastructure. For example, the geothermal project at Louisville Muhammad Ali International Airport took over two years from groundbreaking to completion.[63]
- **Medium Impact**, geothermal energy systems offer a reliable and stable source of heating and cooling, reducing dependency on external energy suppliers and mitigating risks associated with energy price volatility.
- **High Cost**, geothermal systems generally have higher upfront costs compared to other on-site generation options like solar panels or wind turbines. However, they can significantly lower operational and utility costs by providing consistent energy savings and reducing maintenance expenses. The geothermal project at Louisville International Airport is expected to save approximately $400,000 annually on heating and cooling costs.[64]
- **High Risk**, deploying a geothermal energy system at a GA airport involves geological, technical, economic, regulatory, and operational risks. These include uncertainties in subsurface conditions, high upfront costs, compliance challenges, and the need for ongoing maintenance.

Recommendations

To adopt geothermal energy systems, GA airports can begin with a feasibility study to assess site potential and energy needs. If the system is deemed technically, operationally, and economically feasible, the next step is to create a detailed project plan. Engaging stakeholders for support, selecting qualified contractors, and implementing the project according to the plan are essential steps. Post-installation, continuous monitoring and optimization of the system's performance are necessary, along with documenting and promoting the project's success to encourage further adoption of energy security practices.

---

[59] *FAA. (2025). AIP*
[60] NCDOT Division of Aviation. (2024). *North Carolina Airports Program Guidance Handbook*
[61] IRS. (2024). *Clean Energy Tax Incentives for Businesses Publication 5886 (Rev. 3-2024)*
[62] NC Clean Energy Technology Center. *DSIRE database*
[63] Louisville Muhammad Ali International Airport. (2023). *Geothermal Technology Now Live at Louisville Muhammad Ali International Airport*
[64] CMTA. *Louisville Muhammad Ali Intl. Airport Project at a Glance*

Battery Energy Storage

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Airport Facilities, Infrastructure, Management Systems, Utilities	Near Term	Medium Impact	High Cost	Medium Risk

Battery energy storage systems, such as batteries, store excess energy for later use, ensuring a more stable and reliable power supply. These systems can also help manage energy costs by storing energy during off-peak hours for use during peak demand periods. Battery energy storage systems can provide a reliable backup power source during grid outages, ensuring that critical airport operations, like air traffic control and lighting, remain uninterrupted. Battery energy storage can also be integrated with on-site energy generation (solar, wind, and geothermal) to increase the resiliency and energy security of airport operations.

Overview

- **Compatibility:** Battery energy storage systems are compatible with the existing infrastructure at General Aviation (GA) airports. These systems can be integrated as additional components, leveraging the airport's current electrical and structural frameworks.
- **Current Market & Growth Projections:** As of 2024, the battery energy storage market was valued at approximately $106.7 billion. Looking ahead, it is projected to reach $1.49 trillion by 2034, growing at a Compound Annual Growth Rate (CAGR) of 29.1% from 2025 to 2034. This growth is driven by increased integration of renewable energy sources and efforts to modernize the grid.[65]
- **Regulatory Environment:** When installing battery energy storage at a GA airport in North Carolina, environmental permits from the North Carolina Department of Environmental Quality (NCDEQ) and building and electrical permits from local authorities are required. Establishing interconnection agreements with utility companies ensures seamless integration with the existing grid. Compliance with Federal Aviation Administration (FAA) regulations is essential, especially if the installation affects navigational aids or flight operations. Additionally, adherence to local zoning laws and land use regulations, which may require additional permits or approvals, is necessary.

Benefits & Challenges

Benefits	Challenges
• System integrity by providing backup power during outages. • Decreases energy costs by leveraging energy management software to optimize	• Existing electrical and structural frameworks may require upgrades to support battery energy storage systems.

[65] Global Market Insights. (2025). *U.S. Energy Storage Market Size – By Technology, By Application, Analysis, Share, Growth Forecast, 2025 – 2034*

Benefits	Challenges
peak shaving and load shifting with storage systems. • Reduces reliance on imported fuel if coupled with on-site energy generation.	• High upfront costs for purchasing and installing battery energy storage systems can be a barrier. • Ongoing maintenance and management of battery energy storage systems require specialized skills and resources. • Batteries have a finite lifespan, requiring periodic replacement and maintenance, which adds to long-term costs. • Over time, batteries can experience efficiency losses, reducing their ability to store and deliver energy effectively.

Infrastructure Needs

- **GA Airport's Responsibility:** To install a battery energy storage system at a GA airport, the airport is responsible for ensuring adequate electrical infrastructure, including transformers and inverters for grid interconnection. The airport must provide sufficient physical space to house the battery units and associated equipment. Compliance with fire safety regulations, such as installing fire suppression systems and safety signage, is essential. Environmental protections, including stormwater management and measures against extreme weather conditions, must be addressed. Additionally, the airport must ensure easy access for construction, maintenance, and transportation of large equipment.
- **Other Stakeholders' Responsibility:** Utility companies ensure grid interconnection and provide necessary upgrades, while regulatory agencies oversee compliance and issue permits. Technology providers supply the battery units and offer technical support. Contractors and engineers design, construct, and install the system, ensuring technical specifications are met.

Additional Resources

- **Case Studies:** With the installation of on-site generation systems such as solar, wind, and geothermal, battery energy storage is often integrated. Here are some examples of commercial airports utilizing battery energy storage.
    - **Kalaeloa Airport (JRF)** in Hawaii has installed a three-phase battery energy storage and solar microgrid to power eight hangar bays. The system includes 144 solar modules, inverters, charge controllers, and batteries. By installing a microgrid, the airport eliminated the need for trenching through the concrete airfield to install new power lines.[66]
    - **San Diego International Airport (SAN)** has installed 5.5 megawatts (MW) of solar Photovoltaic (PV) and a 2 MW/4 megawatt-hour (MWh) lithium-ion battery storage system. The storage system helps reduce energy charges during peak demand, which accounts for around 40% of the airport's monthly electricity costs.[67]
- **Potential Funding and Incentives:**
    - U.S. Department of Energy (DOE) Energy Storage Grand Challenge and the Office of Electricity's (OE) awards will continue to provide grants and prizes for innovative projects and allocate grants to accelerate next-generation energy storage technologies beyond 2025.[68]
    - There are various federal grants available for battery energy storage [69], including FAA grants for airport development through the Airport Improvement Program (AIP) Supplemental Grant Program.[70]
    - The 2024 NCDOT North Carolina Airports Program Guidance Handbook outlines state and federal funding sources and program details.[71]
    - Commercial Property Assessed Clean Energy (C-PACE) funding allows commercial property owners to obtain low-cost, long-term financing for energy efficiency and renewable energy projects, repaid through property tax assessments.[72]
    - Visit the NC State University DSIRE database (Database of State Incentives for Renewables & Efficiency) for the most comprehensive source of information on incentives and policies that support renewables and energy efficiency in the United States.[73]

[66] Briggs & Stratton Energy Solutions. *Case Study: Microgrid Powers Eight Hangar Bays at Kalaeloa Airport*
[67] Airport Cooperative Research Program. (2020). *Airport Renewable Energy Projects Inventory and Case examples*
[68] U.S. DOE. *Funding Opportunities*
[69] U.S. Grants. (2025). *Energy Storage Services Grants 2025/2026*
[70] *FAA. (2025). AIP*
[71] NCDOT Division of Aviation. (2024). *North Carolina Airports Program Guidance Handbook*
[72] C-PACE Alliance
[73] NC Clean Energy Technology Center. *DSIRE database*

Summary Ratings

- **Near Term**, battery energy storage solutions are readily available in the market and can be deployed quickly, allowing for immediate benefits and enhanced energy resilience.
- **Medium Impact**, battery energy storage systems can store energy from the grid or other external sources and provide reliable backup power during outages, ensuring critical operations remain uninterrupted. Although, having battery energy storage without on-site energy generation still relies on the electric grid, which includes imported fuels in its energy mix.
- **High Cost**, battery energy storage systems involve high costs. The investment includes expenses for battery units, inverters, installation, and balance of system (BoS) components. Additionally, operational and maintenance costs, along with end-of-life management, contribute to the overall cost.
- **Medium Risk**, energy storage batteries typically have a lifespan of 10 to 15 years.[74] Towards the end of this lifespan, the batteries will need to be replaced. The risk involves continuous maintenance and operational costs, including routine inspections, component replacements, and software upgrades. Ensuring the system is kept up to date and continues to provide benefits requires careful management and planning. Also, there are federal funding uncertainties that may impact the financial feasibility of energy battery storage for GA airports.

Recommendations

Review the GA airport's energy security strategy and determine if battery energy storage aligns with its goals and allocated budget. Then, if battery energy storage aligns, proceed with a battery energy storage feasibility study to evaluate technical and economic viability. If a battery energy storage project is feasible, secure funding and permits to begin battery energy storage implementation.

[74] NREL. (2025). *Battery Lifespan*

Microgrids

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Airport Facilities, Infrastructure, Management Systems, Utilities	Near Term	Significant Impact	High Cost	Medium Risk

Microgrids are localized energy systems capable of operating independently or alongside the main power grid to efficiently manage and distribute energy. These systems can seamlessly integrate various energy sources such as solar panels and wind turbines. By adopting microgrids, General Aviation (GA) airports can significantly enhance their resilience and reliability, ensuring uninterrupted operations during power outages. Furthermore, microgrids can help reduce operational costs by optimizing energy usage and incorporating on-site energy generation.

Some resources related to microgrid development are the U.S. Government Accountability Office (GOA) Airport Infrastructure Selected Airports' Efforts to Enhance Electrical Resilience[75] and the Airport Cooperative Research Program (ACRP) Airport Microgrid Implementation Toolkit.[76]

Overview

- **Compatibility:** Microgrids are highly compatible with existing GA airport infrastructure due to their modular and scalable nature. They can be seamlessly integrated into current energy systems without requiring extensive modifications. Additionally, microgrids can be tailored to meet the specific energy demands of different airport operations, from lighting and Heating, Ventilation, and Air Conditioning (HVAC) systems to electric vehicle (EV) charging stations and hangars.
- **Current Market & Growth Projections:** As of 2023, the U.S. microgrid market is valued at approximately $21.15 million and is projected to grow at a Compound Annual Growth Rate (CAGR) of 15.6%, reaching $58.49 million by 2030.[77]
- **Regulatory Environment:** Federal regulations, such as the Public Utility Regulatory Policies Act (PURPA), enable microgrids to qualify as Qualifying Facilities (QFs). This status allows microgrid owners to sell energy or capacity to utilities, purchase certain services from utilities, and receive relief from specific regulatory burdens.[78] Additionally, Executive Order 80, signed by Governor Roy Cooper, directs state agencies to support clean energy initiatives, including microgrids, to enhance energy resilience and reduce greenhouse gas emissions.[79] The North Carolina Utilities Commission (NCUC) regulates the rates and services of public utilities, including policies related to interconnection standards and net metering, which are crucial for microgrid development.[80]

[75] United States Government Accountability Office. (2023). *Airport Infrastructure Selected Airports' Efforts to Enhance Electrical Resilience*
[76] ACRP. (2021). *Airport Microgrid Implementation Toolkit (ACRP Research Report 228)*
[77] Horizon Grand View Research. (2024). *U.S. Microgrid Market Size & Outlook, 2023-2030*
[78] FERC. (2023). *Public Utility Regulatory Policies Act of 1978 (PURPA) Qualifying Facilities*
[79] North Carolina Department of Environmental Quality (DEQ) State Energy Office. (2019). *North Carolina Clean Energy Plan*
[80] National Association of Regulatory Utility Commissioners. *State Microgrid Policy, Programmatic, and Regulatory Framework*

Benefits & Challenges

Benefits	Challenges
• Microgrids ensure a reliable power supply, allowing airport operations to continue smoothly during outages or emergencies. • Microgrids optimize energy use and decrease reliance on costly imported fuels, resulting in substantial long-term savings. • If coupled with renewable energy sources, microgrids reduce greenhouse gases and support sustainability goals. • If designated as a QF, sale of energy can offset installation costs. • Microgrids can lower energy costs by optimizing local energy resources and reducing transmission losses. • Microgrids can be tailored to fit the needs of GA airports.	• Designing, installing, and maintaining a microgrid involves significant upfront costs, which can be a considerable financial challenge for airports. • Integrating a microgrid is complex and requires advanced technical expertise. • Navigating regulatory compliance challenges as policies and incentives vary widely.

Infrastructure Needs

- **GA Airport's Responsibility:** Deploying a microgrid at a GA airport requires some kind of energy source, energy storage, and control system. Maintaining the microgrid involves advanced control systems for real-time monitoring and optimization, as well as regular technical support. The airport must oversee the project, ensuring it aligns with operations and strategic goals, while integrating the microgrid with existing infrastructure and managing disruptions. Financial management involves securing funding and budgeting. Engaging with the local community to address concerns and promote awareness is also important.
- **Other Stakeholders' Responsibility:** Utility companies collaborate on grid integration and provide technical support, and engineering and construction firms design and build the infrastructure. Environmental agencies assess the project's impact and monitor sustainability standards, while financial institutions manage funding and evaluate economic feasibility. Community stakeholders engage with the local community to address concerns and promote awareness. Additionally, hardware manufacturers need to supply reliable and efficient components, such as inverters and battery systems, to support the microgrid's functionality.

Additional Resources

- **Case Studies:**
  - **Pittsburgh International Airport (PIT)** operates a microgrid that includes five natural gas generators and close to 10,000 solar panels, collectively generating over 20 megawatts (MW) of electricity.[81]
  - **Kalaeloa Airport (JRF)** implemented a microgrid system to supply power to eight hangar bays, thereby eliminating the need for costly and disruptive trenching through the concrete airfield to install new power lines.[82]
  - **Los Angeles International Airport (LAX) and John F. Kennedy International Airport (JFK)** are developing microgrid systems to improve energy resilience and reduce dependency on the main grid.[83]
  - **Hartsfield-Jackson Atlanta International Airport (ATL)** has conducted feasibility studies for microgrid implementation to enhance electrical resilience.[84]
- **Potential Funding and Incentives:**
  - The Federal Aviation Administration (FAA) awards grants for airport development as part of the Airport Improvement Program (AIP) Supplemental Grant Program.[85]
  - The 2024 NCDOT North Carolina Airports Program Guidance Handbook has state and federal funding sources and program details.[86]
  - Visit the NC State University DSIRE database (Database of State Incentives for Renewables & Efficiency) for the most comprehensive source of information on incentives and policies that support renewables and energy efficiency in the United States.[87]

[81] Allegheny County Airport Authority. *Energy*
[82] Briggs & Stratton Energy Solutions. *Case Study: Microgrid Powers Eight Hangar Bays at Kalaeloa Airport*
[83] Facilities Dive. (2024). *JFK International Airport's New Terminal One to Host Largest Airport Microgrid in US*
[84] Burns Engineering, Inc. *Hartsfield-Jackson Atlanta International Airport Preliminary Microgrid Feasibility Study*
[85] *FAA. (2025). AIP*
[86] NCDOT Division of Aviation. (2024). *North Carolina Airports Program Guidance Handbook*
[87] NC Clean Energy Technology Center. *DSIRE database*

Summary Ratings

- **Near Term**, microgrid technology is commercially available and can be deployed within 0-3 years. There are numerous successful microgrid projects in aviation and other industries that demonstrate proven viability and benefits.
- **Significant Impact**, microgrid technology can convert an airport into a self-sufficient entity, operating entirely on on-site energy generation and storage without relying on external energy sources. Microgrids significantly enhance energy security and improve the public health environment at GA airports by providing reliable, resilient power and reducing emissions.
- **High Cost**, implementing a microgrid at a GA airport can be expensive, with costs varying significantly based on factors such as airport size, system complexity, and types of energy sources used. Given that microgrids include energy generation and storage systems, expenses tend to be on the higher side. Costs encompass design and feasibility studies, infrastructure and equipment, construction and installation, regulatory compliance, integration and testing, operations and maintenance, financial management, and community engagement.
- **Medium Risk**, while microgrids are a mature technology, financing a microgrid can be challenging for a GA airport due to the substantial investment required for such projects. Securing funding and managing financial constraints are key considerations that need to be addressed to mitigate risks. Other risks can include supply chain delays, staffing insufficiencies, poor design, and regulatory uncertainty.

Recommendations

GA airports in North Carolina considering microgrids can start with a feasibility study to assess technical and economic viability, including current energy usage, potential renewable sources, and cost estimates. If the study shows the microgrid is cost-effective and aligns with the airport's energy security objectives, airports can proceed with planning and design, defining the project scope, selecting technologies, and engaging stakeholders. They can explore grant opportunities, and form partnerships with energy companies and research institutions. Implementation involves installing and commissioning the microgrid, ensuring regulatory compliance, and monitoring performance for continuous improvement.

Backup Generators

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Airport Facilities, Infrastructure, Management Systems, Utilities	Near Term	Medium Impact	Low Cost	Medium Risk

Backup generators provide emergency power during outages, typically powered by diesel, natural gas or propane, and can also use renewable alternatives like hydrogen and biofuels. Installing generators ensures that General Aviation (GA) airports have a reliable power source during emergencies, allowing them to maintain continuous operations, ensure safety, and minimize disruptions. Backup generators support critical systems such as air traffic control, lighting, and communication networks, enhancing overall airport resilience and reliability. By providing a dependable power source, these generators significantly increase energy security, reducing dependence on external power supplies and improving the airport's ability to respond effectively to unexpected power outages.

Overview

- **Compatibility:** Backup generators are highly compatible with GA airports. These generators can be integrated into the airport's existing electrical infrastructure, ensuring continuous operation of critical systems such as air traffic control, security, lighting, and communication.
- **Current Market & Growth Projections:** As of 2024, the market was valued at $6.6 billion and is projected to reach $12.9 billion by 2034, growing at a Compound Annual Growth Rate (CAGR) of 6.8%.[88]
- **Regulatory Environment:** Facilities with emergency generators or emergency use internal combustion engines (ICE) must comply with permitting requirements if their emissions exceed certain thresholds. For example, facilities consuming less than 322,000 gallons per year of diesel fuel or 62,500,000 cubic feet per year of natural gas are exempt from certain permit requirements.[89] Emergency generators must meet emission standards set forth in regulations.[90]

Benefits & Challenges

Benefits	Challenges
• Ensures uninterrupted operation of critical systems during power outages during extreme weather events and other emergencies. • Enhances passenger and staff safety by maintaining essential services like heating, cooling, and emergency lighting.	• The upfront costs for purchasing and installing backup generators can be substantial. • Backup generators require dedicated on-site space with proper ventilation and easy accessibility for the generator, fuel tanks, and associated equipment.

[88] Global Market Insights. (2024). *U.S. Standby Generator Sets Market Size – By Power Rating, By Fuel, By Application, Analysis, Share, Growth Forecast, 2025 – 2034*

[89] North Carolina Environmental Quality. (2018). *15A NCAC 02Q .0807 Emergency Generators*

[90] North Carolina Environmental Quality. (2016). *15A NCAC 02Q .0903 Emergency Generators and Stationary Reciprocating*

Benefits	Challenges
• Reduces the risk of flight interruptions, preserving the airport's reliability and reputation. • If powered with renewable fuels can reduce airports overall carbon footprint and greenhouse gas emissions.	• Emissions from the use of gas or diesel backup generators can negatively impact the air quality in the area. • Backup generators require regular testing and maintenance.

Infrastructure Needs

- **GA Airport's Responsibility:** Installing a backup generator at a GA airport involves conducting a site assessment to determine the optimal location, ensuring safety and accessibility. The existing electrical infrastructure must support the generator integration, including transformers and wiring. Obtaining necessary permits and ensuring regulatory compliance is crucial. The airport must allocate space for the generator, fuel tanks, and associated equipment, ensuring proper ventilation and accessibility. Coordination with contractors for installation and developing a maintenance plan for routine inspections, fuel management, and component replacements are also essential responsibilities.
- **Other Stakeholders' Responsibility:** Utility companies ensure grid interconnection and provide necessary upgrades, while regulatory agencies oversee compliance with safety, environmental, and building regulations, issuing necessary permits. Contractors and engineers design and construct the backup generator system, ensuring it meets technical specifications and integrates seamlessly with existing infrastructure. Technology providers supply generator units, fuel systems, and associated equipment, offering ongoing technical support.

Additional Resources

- **Case Studies:** Numerous commercial airports have backup generators to ensure operational continuity during power outages. Notable examples include
  - **Hartsfield-Jackson Atlanta International Airport (ATL)** received a $100 million investment from Georgia Power and Atlanta Airlines Terminal Company (AATC) for backup power generation for all terminals and concourses.[91]
  - **John F. Kennedy International Airport (JFK)'s New Terminal One (NTO)** has a microgrid, battery energy storage systems, fuel cells, and solar power.[92]
  - **Chicago O'Hare International Airport (ORD)** has an emergency and standby power system.[93]
  - **Honolulu Daniel K. Inouye International Airport (HNL)** has a fully operational Emergency Power Facility (EPF).[94] The power plant is engineered to endure a Category 5 hurricane and an earthquake with a 2,500-year recurrence interval. Additionally, it has the capability to operate on jet fuel during extended emergencies.

[91] Airport Technology. (2021). *Hartsfield-Jackson Airport to receive $100m infrastructure investment*
[92] Metropolitan Airport News. (2023). *E-J Is the EPC for JFK's New Terminal One (NTO) Microgrid Project*
[93] Epstein. (2020). *O'Hare International Airport Emergency & Standby Power Systems*
[94] State of Hawaii. (2018). *Daniel K. Inouye International Airport Emergency Power Facility in Full Operation*

- **Potential Funding and Incentives:**
  - The Hazard Mitigation Grant Program (HMGP)[95] and Pre-Disaster Mitigation Program (PDM)[96] provide funding for projects that mitigate the effects of natural disasters, including backup generators for critical facilities.
  - The NCDOT Division of Aviation administers state-funded Airport Grant Programs.[97]
  - The Federal Aviation Administration (FAA) offers grants for airport improvement projects, including backup power systems.[98]
  - Commercial Property Assessed Clean Energy (C-PACE) funding allows commercial property owners to obtain low-cost, long-term financing for energy efficiency and renewable energy projects, repaid through property tax assessments.[99]
  - Visit the NC State University DSIRE database (Database of State Incentives for Renewables & Efficiency) for the most comprehensive source of information on incentives and policies that support renewables and energy efficiency in the United States.[100]

Summary Ratings

- **Near Term**, backup generators powered by diesel, natural gas, propane, and renewable diesel are commercially available. These generators can be deployed quickly.
- **Medium Impact**, backup generators notably enhance energy security for GA airports during emergencies. While traditionally powered by fossil fuels like diesel, natural gas, and propane, these generators can also run on renewable diesel, supporting the use of more sustainable and domestically produced fuel options. Dual-fuel backup generators, typically powered by diesel and natural gas, offer flexibility in switching between fuel types. Additionally, some models can run on both renewable diesel and traditional diesel.
- **Low Cost**, backup generators for GA airports are relatively affordable, making them accessible for many facilities. The initial investment is manageable, and ongoing maintenance and operational costs are reasonable, ensuring long-term efficiency. This low cost allows GA airports to enhance their energy security without imposing an excessive financial burden.
- **Medium Risk**, key risks include ensuring proper installation to avoid electrical hazards, managing ongoing maintenance to prevent operational failures, and complying with regulatory requirements. These factors require careful planning and professional oversight to mitigate potential issues.

Recommendations

Considering the FAA's order (Joint Order 6030.20G)[101] that underscores the importance of both primary and backup power systems to fulfill functional and operational needs, it is strongly advised that GA airports also implement backup generators. These generators are vital for emergency situations, ensuring continuous operation of critical systems like air traffic control, security, lighting, and communication during power outages.

---

[95] North Carolina Department of Public Safety. *Hazard Mitigation*
[96] FEMA. (2025). *Pre-Disaster Mitigation (PDM) Grant Program*
[97] Connect NCDOT. (2025). Airport Grant Programs
[98] *FAA. (2025). AIP*
[99] C-PACE Alliance
[100] NC Clean Energy Technology Center. *DSIRE database*
[101] FAA. (2019). Air Traffic Organization Policy: Electrical Power Policy

Energy Efficiency

Optimizing energy usage is one of the most accessible and cost-effective measures in this toolkit. By enhancing energy efficiency, GA airports can reduce their energy consumption and operational costs while boosting overall resiliency. This section highlights various strategies and technologies to improve energy efficiency, including facility upgrades, new construction, and advanced smart technologies. Most of these options, aside from new construction, can be integrated with existing infrastructure. By adopting these measures, GA airports can achieve substantial energy savings and contribute to a more resilient and energy efficient airport.

Facility Improvements

Facility improvements involve upgrading lighting, HVAC systems, windows, insulation, pavement, water use optimization, and other energy-efficient equipment. GA airports can reduce their energy consumption and operational costs with these facility improvements. Some of these updates can be cost-effective options, for example upgrading to light emitting diode (LED) light bulbs in facility can reduce energy use.

Lighting

Applicable Use Cases				Timeframe	Impact	Cost	Risk
 Airport Facilities	 Infrastructure	 Management Systems	 Utilities	 Near Term	 Medium Impact	 Medium Cost	 Medium Risk

Upgrading to energy-efficient light emitting diode (LED) lighting can significantly reduce energy consumption and maintenance costs at General Aviation (GA) airports. Airports can implement these improvements by replacing existing lighting fixtures with LED alternatives and installing motion sensors and timers to optimize usage. Airports can upgrade to LED lighting both inside facilities and outside on aprons, taxiways, runways, and approach lighting. LED bulbs consume much less energy, provide better illumination, more consistent light distribution, and emit less heat than traditional incandescent or fluorescent bulbs. Additionally, LED bulbs do not contain mercury, unlike most fluorescent lighting, which requires special handling and disposal. Furthermore, LED systems often come with advanced controls that allow for automation or dimming, enhancing energy conservation.

Overview

- **Compatibility:** Upgrading to energy efficient LED lighting is highly compatible with GA airports and is easy to implement. LED bulbs have much longer operational usage which reduces the frequency of replacement as well as maintenance costs.
- **Current Market & Growth Projections:** While it is difficult to get information solely for GA airports, the global airport lighting market was valued at $661.1 million in 2024 with the expectation of Compound Annual Growth Rate (CAGR) of 6.9% to 2031.[102] This growth is driven by increased travel demand, technological advancements, modernization efforts, and a push for sustainable solutions which are repeatedly driving the industry toward LED lights.
- **Regulatory Environment:** North Carolina issued an Energy Efficient Lighting Guidance Document in 2016 for use by designers of both new construction and retrofit public projects. The document serves as a general guideline and compiles both information and best practices that should be considered during design, construction and retrofit.[103] Any changes to lighting will need to comply with Federal Aviation Administration (FAA) Advisory Circular (AC) 150/5370-10H (125-2.1 Installation of Airport Lighting Systems) updated most recently in 2020 and AC 150/5340-30 from 2018.[104] [105]

[102] Cognitive Market Research. (2025). *Airport Lighting Market Report 2025*
[103] North Carolina Department of Environmental Quality. (2016). *Energy Efficient Lighting Guidance Document for New Construction and Retrofits: The State of North Carolina*
[104] FAA. (2018). *Advisory Circular: Standard Specifications for Construction of Airports*
[105] FAA. (2018). *Advisory Circular: Design and Installation Details for Airport Visual Aids*

Benefits & Challenges

Benefits	Challenges
• LED energy efficient lighting consumes less energy than incandescent or fluorescent bulbs yielding significant energy savings. • LED bulbs have a significantly longer lifespan which reduces frequency of replacement/maintenance which translates to long-term cost savings. • LED bulbs provide environmental benefits by producing less waste due to longevity and do not contain hazardous materials. • LED bulbs emit less heat which can lower cooling costs. • LED bulbs often have advanced controls allowing for automation or dimming for reduced energy consumption.	• Initial upfront costs of LED lighting can be higher than legacy lighting options. • There are compatibility issues, as aircraft using Enhanced Flight Vision Systems (EFVS) may have difficulty detecting LED lights due to a lack of infrared radiation. EFVS is used to improve visibility and safety during flight operations and is equipped on some high-end business jets, helicopters, and various military aircraft. • LED lights can cause glare or visibility issues when they are too bright, poorly distributed, improperly aimed, or used in environments with reflective surfaces.

Infrastructure Needs

- **GA Airport's Responsibility:** GA airports have several responsibilities when installing LED lighting including compliance with local building codes/regulations, adherence to FAA lighting standards and ensuring all lighting equipment is certified under the Airport Lighting Equipment Certification Program (ALECP). The GA airport should notify the FAA of airport approach lighting LED usage to be included in a list of such airports used to notify pilots using EFVS of potentially decreased sensor performance that may require a go-around.[106] [107] In the future this information will most likely be included in the FAA's Chart Supplement. Airfield management will be responsible for budgeting, planning, installation, and maintenance of the lighting. GA airports will need to ensure the construction, and any airfield operational impacts, are properly communicated by Notice to Airmen (NOTAM) in applicable systems. As GA airports shift to LED lighting, they will need to ensure proper disposal of legacy lighting, especially those containing hazardous materials. GA airports should explore federal and state grants or incentives for energy efficient upgrades and based on those results, plan and budget for the initial installation and cost of ongoing maintenance.

[106] FAA. (2025). *LED Approach Lighting System Installations*
[107] National Business Aviation Association (NBAA). (2025). *LED Airport Lights Can Be Invisible to Enhanced Vision Systems*

- **Other Stakeholders' Responsibility:** Lighting manufacturers and suppliers need to ensure products meet FAA specifications and obtain certification for airfield use. Pilots should provide feedback on the performance of LED lighting (especially regarding compatibility and visibility with EFVS) and report any issues. Airfield installation crews and crews installing past security checkpoints may require additional security screening. Tenants should maintain open lines of communication with airfield management, so they are aware of project timeline and any potential disruptions to operations.

Additional Resources

- **Case Studies:**
  - **Teterboro Airport (TEB)** installed LED lighting on Runway 1/19.[108]
  - **Van Nuys Airport (VNY)** integrated LED lighting for taxiways and aprons a part of a rehabilitation project of Taxiway A.[109]
  - **McAlester Regional Airport (MLC)** installed Medium-intensity Approach Lighting System (MALS) for Runway 02.[110]
  - **King County International Airport-Boeing Field (BFI)** is upgrading with new runway guard lights and a new lighting control system.[111]
- **Potential Funding and Incentives:**
  - FAA's Airport Improvement Program (AIP) provides grants for various development projects including projects focused on sustainability and energy efficiency and are awarded based on passenger volume.[112]
  - Davidson County Executive Airport (EXX) and Hickory Regional Airport (HKY) are both recent recipients of the FAA AIP Supplemental Discretional Grants that were used to upgrade airfield lighting to LED.[113]
  - As part of the Infrastructure Investment and Jobs Act (IIJA), the Airport Infrastructure Grant (AIG) allocates funding over five years starting in FY 2022 to improve airfield lighting systems and specifically includes the installation of new lighting for runways and taxiways to enhance safety and efficiency.[114]
  - The state-funded Airport Grant Program and FAA State Block Grant Program is administered by the NCDOT Division of Aviation and can be used for a variety of airport improvement programs to include updating lighting to LED. The State Aid to Airports Program is a basic airport aid program and can provide funding for airfield lighting and capital improvement projects.[115]

[108] FAA. (2023). *Teterboro Airport (TEB) Pilot Information*
[109] Aviation Property Network. (2021). *Taxiway Rehabilitation Completed at Van Nuys Airport*
[110] AirNav. (2025). *McAlester Regional Airport FAA Information*
[111] King County. (2024). *Airfield Electrical Project - Phase 3*
[112] FAA. *(2025). AIP*
[113] NCDOT. (2024). *Federal Grants Awarded to N.C. Airports for Sustainability and Resiliency Upgrades*
[114] FAA. (2023). *$201M in Bipartisan Infrastructure Law Lights the Way to Improve Runway Safety*
[115] NCDOT Division of Aviation. (2024). *State Aid to Airports Program: General Legislative Funds*

- The North Carolina Airport Economic Development Fund, most recently revised in 2017, can be used for airside projects such lighting systems that can increase the capacity of an airport and support economic development.[116]
- GA airports should check with their utility providers for any rebates or incentives of energy-efficient lighting that could offset the upfront cost of installation. For example, GA airports located in EnergyUnited territory may be eligible for "per unit" rebates to upgrade their light bulbs to LEDs.[117]
- The Internal Revenue Service (IRS) offers energy efficient commercial building deductions for eligible commercial buildings.[118]
- Visit the NC State University DSIRE database (Database of State Incentives for Renewables & Efficiency) for the most comprehensive source of information on incentives and policies that support renewables and energy efficiency in the United States.[119]

Summary Ratings

- **Near Term**, LED lighting is both commercially available and FAA certified for use in both infrastructure and airfield lighting. GA airports should determine if the upfront costs of transitioning are worth the overall energy usage benefits and long-term cost savings.
- **Medium Impact**, LED lighting can significantly reduce energy consumption, ultimately reducing costs and maintenance requirements due to longer operational life and has environmental benefits due to the production of less waste and lack of hazardous materials.
- **Medium Cost**, while LED lighting will produce a long-term cost savings for a GA airport, it will require an upfront investment to replace legacy lighting and require conscious disposal of old materials.
- **Medium Risk**, installing LED lighting at GA airports can provide long-term cost savings after the initial upfront investment. GA airports should install LED approach lighting last after the FAA has had an opportunity to determine how their use can degrade EFVS capabilities and provide follow-on recommendations or procedures.

Recommendations

GA airports can conduct studies to plan, identify, and budget for opportunities to incorporate LED lighting into landside and airside operations. While an initial wholesale replacement of legacy lighting may not be feasible, GA airports can seek to implement overtime to take advantage of long-term energy usage impacts and cost savings.

[116] NCDOT Division of Aviation. (2021). *North Carolina Airport Economic Development Fund*
[117] EnergyUnited. *LED Lighting Rebate Program*
[118] IRS. *Energy efficient commercial buildings deduction*
[119] NC Clean Energy Technology Center. *DSIRE database*

Heating Ventilation and Air Conditioning (HVAC)

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Airport Facilities, Infrastructure, Management Systems, Utilities	Near Term	Significant Impact	Medium Cost	Medium Risk

Enhancing HVAC systems with energy-efficient models and smart thermostats can improve energy efficiency and comfort at General Aviation (GA) airports. Airports can implement these improvements by upgrading or retrofitting existing HVAC systems and integrating smart controls for better temperature management. Benefits include reduced energy consumption, lower operational costs, and improved indoor air quality.

Overview

- **Compatibility:** Upgrading to energy-efficient HVAC systems with smart thermostats is generally compatible with GA airports. Newer HVAC systems could also incorporate smart thermostats into existing systems, but older HVAC systems may not be compatible with add-on smart thermostats.
- **Current Market & Growth Projections:** While it is difficult to obtain data solely for GA airports, the global HVAC systems market in the U.S. is predicted to grow from $22.35 billion in 2024 to $32.35 billion in 2029 with growth being fueled by desire for energy-efficient systems and the reduction of carbon emissions in various sectors, especially aviation.[120] Additionally, significant investments in airport infrastructure specifically targeting modernization and sustainability are expected to spur demand for energy-efficient HVAC systems.
- **Regulatory Environment:** The North Carolina State Building Code: Energy Conservation Code, Chapter 5 for Existing Buildings, Section R503 Alterations applies to facility improvements such as HVAC.[121] Federal Aviation Administration (FAA) AC 150/5370-10 outlines standards for construction at airports including HVAC systems.[122]

Benefits & Challenges

Benefits	Challenges
• Energy-efficient HVAC systems can significantly reduce energy emissions and reduce operational costs.	• Initial upfront costs of energy-efficient HVAC systems can be significant. • Existing HVAC systems may not be compatible with smart thermostats and

[120] PR Newswire. (2025). *United States (USA) HVAC System Market worth $32.35 billion by 2029 - Exclusive Report by MarketsandMarkets™*

[121] International Code Council (ICC) Digital Codes. (2018). *2018 North Carolina State Building Code: Energy Conservation Code*

[122] FAA. (2018). *Advisory Circular: Standard Specifications for Construction of Airports*

Benefits	Challenges
• Smart thermostats allow optimization of heating and cooling based on real-time data and usage. • Reducing energy consumption reduces overall imported energy use which enhancing energy security efforts. • Smart thermostats maintain optimal indoor temperatures and allow proactive temperature planning. • Smart technology can proactively predict maintenance needs, reducing downtime and costly repairs.	may require additional modifications or upgrades. • Integrating smart technology can be complex and require training for staff and maintenance personnel. • Smart technology depends on a stable internet connection and disruptions can affect functionality. • There can be potential privacy concerns regarding data collection and usage patterns.

Infrastructure Needs

- **GA Airport's Responsibility:** The GA airport must ensure that upgrades to the HVAC system comply with all relevant local, state and federal regulations and building standards. The installation of new HVAC units may require local permits. Removal of existing units and any materials must be completed thoroughly and properly. As with any construction or improvements at an airport, safety and security of existing airport operations must occur and airports will need to implement new safety measures to protect passengers and workers during the installation. The airport will need to ensure that new systems are properly integrated with older electrical and mechanical systems. The use of new HVAC systems with smart thermostats may require additional training to airport staff on operations and maintenance as well as the establishment of a preventative maintenance program to ensure the new system remains efficient and reliable. Airports must actively communicate project scope, timelines, and any potential disruptions to airport tenants and customers.
- **Other Stakeholders' Responsibility:** Airport tenants should obtain detailed schedules of the upgrade project and seek ways to mitigate any potential disruptions to their operations. Contractors and vendors may require additional security screening to access sensitive areas of airport maintenance systems. Additionally, any equipment staging area will need to be properly secured and established in a convenient area for project efficiency but also somewhere that does not interfere with existing operations. Local governments and building code inspectors will need to ensure the proper permits and installation of new HVAC systems.

Additional Resources

- **Case Studies:** As one of the largest energy consumers at airports, HVAC units are often one of the first targets to reduce carbon emissions, improve energy efficiency, and optimize air quality. The following are just a few examples where airports have upgraded HVAC systems. Airports that have upgraded their HVAC system in some capacity are:

- **Waterbury-Oxford Airport (OXC)** was awarded $950,000 for replacing the HVAC system, replacing ATCT roof, windows, and shades.[123]
- **Acadiana Regional Airport (ARA)** received $500,000 from FAA to modernize HVAC system to optimize energy efficiency and to replace tower communications equipment.[124]
- **Marquette Sawyer Regional Airport (MQT)** is working on upgrading their existing HVAC system.[125]
- **Henderson Executive Airport (HND)** was awarded around $900,000 for technology upgrades, including HVAC system improvements.[126]
- **Victoria Regional Airport (VCT)** received $1.7 million for the rehabilitation of the tower, including new energy-efficient systems such as HVAC.[127]
- **King County International Airport (BFI)** upgraded its HVAC system as part of a deep energy retrofit project.[128]

- **Potential Funding and Incentives:**
  - The Bipartisan Infrastructure Law (BIL) provides funding to "improve safety and support critical aviation operations" and has been used at the airports listed in the case studies mentioned previously in this section to replace or upgrade HVAC systems.[129] While funding remains, it was allocated solely for use between 2024 and 2026 and remains uncertain while current federal policies are under review.
  - FAA's Airport Improvement Program (AIP) provides grants for various development projects including projects focused on sustainability and energy efficiency, including HVAC upgrades, and are awarded based on passenger volume.[130]
  - The Inflation Reduction Act of 2022 provides incentives for the installation of energy-efficient HVAC systems. In development in North Carolina, Commercial Property Assessed Clean Energy (C-PACE) Financing allows commercial property owners to obtain low-cost, long-term financing for energy-related deferred maintenance upgrades in existing buildings.[131]
  - NCDOT Division of Aviation Grants offers state-funded grant programs for capital improvement projects including energy-efficient upgrades.[132]
  - Local North Carolina programs, such as Duke Energy's Smart $aver Business Heating & Cooling Program, offer rebates for the installation of energy efficient HVAC systems into commercial properties.[133]

---

[123] FAA. (2024). *FY2025 FAA Contract Tower Program Selections*
[124] Global Air. (2024). *FAA investing $20M to modernize airport-owned ATC towers*
[125] Michigan Government. (2025). *Advertisement for Bids Marquette Sawyer Regional Airport, Gwinn, Michigan*
[126] Global Air. (2024). *FAA investing $20M to modernize airport-owned ATC towers*
[127] Id.
[128] Seattle City Light. *Case Study Innovative HVAC Approach Helps Airport's Energy Savings Take Off*
[129] General Aviation News. (2024). *$20 Million Approved to Modernize Airport-Owned ATC Towers*
[130] *FAA. (2025). AIP*
[131] C-PACE Alliance
[132] NCDOT. (2025). *Doing Business*
[133] Duke Energy. *HVAC*

- The Internal Revenue Service (IRS) offers energy efficient commercial building deductions for eligible commercial buildings.[134]
- Visit the NC State University DSIRE database (Database of State Incentives for Renewables & Efficiency) for the most comprehensive source of information on incentives and policies that support renewables and energy efficiency in the United States.[135]

Summary Ratings

- **Near Term**, HVAC systems with smart thermostats are highly compatible and available for use in commercial spaces to improve energy efficiency, reduce carbon emissions and optimize temperature and air quality in airport facilities.
- **Significant Impact**, HVAC units are one of the largest energy consumers at GA airports, replacing them with energy-efficient HVAC units with smart thermostats can significantly reduce energy consumption. By continually regulating and optimizing temperature based on real-time conditions, smart thermostats allow the most energy efficient power usage with least waste.
- **Medium Cost**, while the replacement of HVAC units will allow for long-term energy efficiency and cost savings, it will require an upfront investment. GA airports should take advantage of any grants, rebates, or incentives available for installing energy-efficient systems to offset the upfront costs of replacement.
- **Medium Risk**, GA airports will need to weigh the benefits of HVAC upgrade/replacement against initial upfront costs, complex installation requirements, potential compatibility issues, and additional training requirements for maintenance personnel to see if the replacement aligns with longer term goals for energy security and efficiency.

Recommendations

Replacing outdated and inefficient HVAC systems to upgraded systems with smart thermostats can be one of the most powerful steps a GA airport can take to increase energy efficiency, reduce carbon emissions, and optimize air quality in their facilities. Airports should seek grants and long-term financing (when needed) to offset replacement costs.

[134] IRS. *Energy efficient commercial buildings deduction*
[135] NC Clean Energy Technology Center. *DSIRE database*

Windows & Insulation

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Airport Facilities, Infrastructure	Near Term	Medium Impact	Medium Cost	Medium Risk

Upgrading windows to double or triple-pane models and improving insulation can enhance energy efficiency by reducing heat loss and stabilizing interior temperatures. General Aviation (GA) airports can implement these improvements by replacing old windows and adding insulation to walls, roofs, and floors. Airports may also elect to further upgrade by installing electrochromic glass, also known as smart glass, where the glass tints in response to an electric current to respond to outside conditions. GA airports can start upgrading any areas already showing signs of degradation to existing windows (broken glass or window seals) and where replacement will add the largest value. Insulation can be added to areas where staff work, or aircraft maintenance occurs to enhance the working environment. Benefits include lower energy bills, improved thermal comfort, and reduced noise pollution.

Overview

- **Compatibility:** Upgrading windows and adding insulation to buildings to increase energy efficiency is compatible with GA airports.
- **Current Market & Growth Projections:** Driven by rising demand in construction, refurbishment of older buildings, and a focus on the energy efficiency, the U.S. window and door market was valued at $27.71 billion in 2023 and expected to grow at a CAGR of 3.4% to 2030.[136] The global thermal insulation market was valued at $26.86 billion in 2024 and expected to grow at a Compound Annual Growth Rate (CAGR) of 5.9% from 2025 to 2030 driven by environmental awareness and favorable regulations that focus on reduction in energy conservation.[137]
- **Regulatory Environment:** Recent legislative changes in North Carolina demonstrate the State's commitment to energy efficiency and stability. The Energy Conservation Code has increased R-value requirements and improved air seal measures to encourage a reduction in energy consumption. That combined with the North Carolina Insulation Code (subset of North Carolina Building Code) sets standards for commercial structures, seeks to maximize insulation effectiveness, and is enforced through the permit and inspection process.[138] Local governments may also have additional permitting and inspection processes. While Federal Aviation Administration (FAA) AC 150/5370-10H governs Standard Specification for Construction of Airports, it does not specifically address windows or insulation other than used to

[136] Grand View Research. (2024). *U.S. Windows and Doors Market Size, Industry Report, 2030*
[137] Grand View Research. (2025). *Building Thermal Insulation Market, Industry Report, 2030*
[138] Legal Clarity. (2025). *North Carolina Insulation Code: Requirements and Compliance Guide*

cover electrical components. FAA AC 150/5000-9B addresses windows and insulation in terms of sound insulation for structures exposed to noise and advises on ways to mitigate impact.[139]

Benefits & Challenges

Benefits	Challenges
• Replacing windows and adding insulation will reduce energy consumption and costs, keeping the airport cooler in summer and warmer in the winter. • Better insulation will lead to more stable indoor temperatures which will improve comfort. • Better insulation and upgraded windows will reduce aircraft and other outside noise and provide a quieter inside environment. • New windows can improve the overall appearance of a facility and add to the customer experience. • Adding insulation to hangars improves maintenance experience for mechanics by providing more stable temperatures for work.	• The cost of replacement windows can be high, especially for larger buildings with larger windows. • Replacing windows and adding insulation can have operational impacts on airports and can disrupt operations. • Installation of insulation to existing structures can be complex and may require significant modification.

Infrastructure Needs

- **GA Airport's Responsibility:** GA airports have several responsibilities when undergoing window replacement and insulation installation projects. Airports will ensure that windows and insulation comply with North Carolina State Building codes and that appropriate permits and resulting inspections are applied for and satisfactorily passed. GA airports are also responsible for implementing safety protocols that protect construction workers, employees, and tenants during construction. The NCDOT Division of Aviation, North Carolina Airports Program Guidance Handbook, published in October 2024, is a compilation of resources and steps to optimize airport program management and discuss the construction process.[140]
- **Other Stakeholders' Responsibility:** Airport tenants should obtain detailed schedules of the upgrade project and seek ways to mitigate any potential disruptions to their operations. Additionally, any equipment or product staging area will need to be properly secured and established in a convenient area

[139] FAA. (2022). *Advisory Circular: Guidelines for Sound Insulation of Structures Exposed to Aircraft Noise*
[140] NCDOT Division of Aviation. (2024). *North Carolina Airports Program Guidance Handbook*

for project efficiency but also somewhere that does not interfere with existing operations. Local governments and building code inspectors will need to ensure the proper permits and installation of new windows and insulation installation.

Additional Resources

- **Case Studies:** Many commercial airports have enhanced their facilities with smart glass installations. The airports that have done window upgrades are:
  - **Minneapolis-St. Paul International Airport (MSP)** with smart glass installations at their Charles Lindbergh Terminal (smart glass installation).
  - **Nashville International Airport (BNA)** with window replacement at D Concourse, BNA Marketplace, T-Gates, and International Arrivals Facility (smart glass installation).
  - **The King County International Airport (BFI)** performed a deep energy retrofit with numerous interior improvements, including weatherization and upgrades of the insulation to modern standards. As a result, the historic airport was able to achieve 60% energy savings and $31,000 in annual cost savings, while improving comfort and reducing maintenance.[141]
- **Potential Funding and Incentives:**
  - The Bipartisan Infrastructure Law (BIL) provides funding to "improve safety and support critical aviation operations."[142] NCDOT Division of Aviation will apply on behalf of N.C.'s Non-Primary airports for Federal Airport Infrastructure Grants as airports are ready to collect.[143] While funding remains, it was allocated solely for use between 2024 and 2026 and is uncertain while current federal policies are under review.
  - The FAA's Airport Improvement Program (AIP) provides grants for various development projects including projects focused on sustainability and energy efficiency, including window replacement and insulation installation, and are awarded based on passenger volume.[144]
  - The North Carolina State Transportation Improvement Program (STIP) can provide funding to GA airports through the "Division Needs" eligibility category and can provide funds for capital improvement projects, modernization projects and projects that increase airport capacity.[145]
  - State Aid to Airports, the state funding program of NCDOT Division of Aviation, provides funding to airports in the North Carolina Aviation System Plan (NCASP) to meet goals and objectives. Additionally, the 20 "Green" airports in North Carolina as designated by the NCASP Airport Grouping Methodology are eligible for the Safety Enhancement Match program and can accelerate project funding by reducing implementation barriers.[146]
  - The IRS offers energy efficient commercial building deductions for eligible commercial buildings.[147]

[141] retrofit magazine. (2019). *Historic Airport Terminal Realizes Massive Savings from Deep Energy Retrofit*
[142] General Aviation News. (2024). *$20 Million Approved to Modernize Airport-Owned ATC Towers*
[143] NCDOT Division of Aviation. (2024). *North Carolina Airports Program Guidance Handbook*
[144] *FAA. (2025). AIP*
[145] Understanding STIP (2024). *NCDOT Div. of Aviation*
[146] North Carolina Airports System Plan (NCASP). (2015). *North Carolina Airports System Plan*
[147] IRS. *Energy efficient commercial buildings deduction*

Summary Ratings

- **Near Term**, GA airports can install new, more energy-efficient windows and install insulation to meet long-term airport energy consumption goals and vision. GA airports can choose to upgrade to windows with smart glass to provide temperature stability optimization aligning with conditions.
- **Medium Impact**, replacing inefficient windows with upgraded replacement windows and adding or upgrading insulation will reduce energy consumption. These changes will immediately impact the overall power usage and lower operating costs.
- **Medium Cost**, depending on the size of the project window replacement and insulation installment, can require significant initial upfront investment that is gradually returned over time through energy savings. GA airports should seek to offset their costs by obtaining grants, utilizing incentives and seeking utility rebates when available.
- **Medium Risk**, when making decisions about upgrading windows and installing insulation, GA airports must weigh upfront construction costs and disruption to airport operations against added energy efficiency benefits, improved thermal comfort and sustainability efforts.

Recommendations

As GA airports seek to invest in infrastructure improvements and energy efficiency, the replacement of existing windows and additional insulation can lower overall energy consumption and operating costs. While buildings or airports do not necessarily need to address these projects across all facilities at the same time, there can be significant cost savings and overall timeline efficiencies from several areas of the facilities being upgraded simultaneously. Streamlining projects can also minimize disruptions to operations.

Pavement

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Airport Facilities, Infrastructure	Near Term	Insignificant Impact	Medium Cost	Medium Risk

The Federal Aviation Administration (FAA) has focused on identifying material and additives that increase lifespan and performance of pavements, including recycled materials and innovative technologies, to enhance durability and reduce environmental impacts. The FAA uses FAARFIELD 2.0 software for pavement design and incorporates sustainable practices and materials into guidelines. General Aviation (GA) airports can implement these improvements by resurfacing runways, taxiways, and aprons with energy-efficient materials such as Warm Mix Asphalt (WMA) and Reclaimed Asphalt Pavement (RAP). Benefits include extended pavement life, reduced energy usage during production, improved water drainage, reduced runway surface temperatures, and extended pavement life, ultimately leading to long-term cost savings. Implementing other energy-efficient pavement solutions, such as reflective coatings and permeable materials, can reduce heat island effects and improve stormwater management. GA airports will need to weigh the initial costs, durability, and lifecycle against their overall long term energy efficiency and sustainability goals to discover if the added benefits align with the long-term vision of the airfield. Challenges may involve initial investment and potential disruptions to airport operations. The costs will depend on the size of the airport and the extent of the resurfacing.

Overview

- **Compatibility:** Energy-efficient pavement materials and reflective coatings are currently available for use at all airports.
- **Current Market & Growth Projections:** While it is difficult to determine market and growth predictions for solely airport pavement, the global asphalt market, which includes energy-efficient pavements, is projected to grow from $119.4 million tons in 2020 to $183 million tons by 2027 due to the growing emphasis on sustainable construction practices.[148] The use of reflective coating at airports is growing driven by increased demand for improved safety and energy efficiency as well as advances in coating technology. The global market for traffic road marking coatings, including reflective coating and not solely restricted to airports, was valued at $5.48 billion in 2023 and is expected to grow at a Compound Annual Growth Rate (CAGR) of 6.2% from 2024 to 2030.[149]

[148] Business Wire. (2023). *Global Asphalt Markets Report 2022-2027 - Developing Countries Spearhead Current and Future Market Growth*

[149] Grand View Research. (2024). Traffic Road Marking Coatings Market Size Report, 2030

- **Regulatory Environment:** Airfield construction, to include pavement and earthwork, needs to be compliant with FAA advisory circular (AC) 150/5370-10H, FAA AC 150/5320-6G, FAA AC 150/5340-1M, and FAA AC 150/5380-7.[150] [151] FAA AC 150/5345-39E[152] provides standards and specifications for retroreflective markers. Additionally, the North Carolina Department of Environmental Quality (NCDEQ) Stormwater Design Manual governs pavement requirements to control stormwater runoff.[153] North Carolina General Statues (N.C.G.S 143-214.7[154]) and North Carolina Administrative Code (15A NCAC 02H.101[155]) regulates stormwater management at airport facilities and requires them to implement stormwater control measures to avoid promoting standing water that may attract wildlife causing a potential hazard to aviation.[156]

Benefits & Challenges

Benefits	Challenges
• WMA and RAP reduce production costs, allow for increased hauling distances, lengthen paving season, and are environmentally friendly.[157] • Lower production temperatures of WMA provide fuel savings, reduce greenhouse gas emissions, enhances workability and is easier to compact. • WMA can be laid in colder weather which extends paving season. • Use of RAP provides economic benefits by lowering production costs, conserving natural resources, and reducing waste. • Reflective coating can enhance safety and visibility of pavement markers, especially at night and during adverse weather. • Reflective coatings can reduce surface temperature which ultimately extends pavement lifecycle and reduces heat-related damage.	• WMA is more expensive than traditional hot mix asphalt. • Although authorized by the FAA for use, evaluation of long-term performance of WMA is still being studied. • RAP requires proper processing and handling to meet performance requirements and may contain contaminants that need to be addressed. • Initial cost of reflective coating application is more expensive than traditional pavement treatments. • Reflective coating may require more frequent maintenance to retain effectiveness of reflective properties. • Depending on quality of coating and long-term environmental conditions, reflective coatings might wear out faster and require reapplication.

[150] FAA. (2018). *Advisory Circular: Standard Specifications for Construction of Airports*
[151] FAA. (2021). *Advisory Circular: Airport Pavement Design and Evaluation*
[152] FAA. (2021). *AC 150/5345-39E Specification for L-853, Runway and Taxiway Retroreflective Markers*
[153] North Carolina Department of Environmental Quality. (2018). *NCDEQ Stormwater Design Manual*
[154] North Carolina General Assembly. (2023). *Stormwater Runoff Rules and Programs*
[155] North Carolina Administrative Code. (2015). *15A NCAC 02H.101 Point Source Discharges to the Surface Waters*
[156] North Carolina Department of Environmental Quality. (2018). *NCDEQ Stormwater Design Manual*
[157] FAA. (2021). *Resilience and Addressing Climate Change - Airport Pavements*

Infrastructure Needs

- **GA Airport's Responsibility:** When considering adding energy-efficient paving materials or reflective coatings to airfield pavement, GA airports must evaluate the condition of existing pavement to include thickness, strength, sub-service draining and overall lifecycle condition. All pavement projects must adhere to FAA standards and guidelines as defined by applicable ACs. The airfield management will need to consider material selection, applicable safety measures, and quality control implementation. GA airports will need to pursue the appropriate permitting process, FAA notification requirements, and environmental impacts and procedures. GA airports will need to ensure the construction, and any airfield operational impacts, are properly communicated by Notice to Airmen (NOTAM) in applicable systems. GA airports should review the project safety plan, monitor construction progress to ensure appropriate inspections are properly conducted and satisfactorily passed. GA airports will want to ensure tenants and customers understand project timelines, potential impacts, and maintain open lines of communication for any questions that may arise.
- **Other Stakeholders' Responsibility:** Engineers, designers and construction workers need to design and construct project specifications and standards according to FAA certifications, requirements, and quality control standards. Construction companies will also need to follow strict protocols and may require additional training to educate workers on airfield standards, marking, restricted areas and the dangers of foreign object debris (FOD) to aircraft and flight operations. Construction crews may also require additional security screening to receive access to sensitive airfield locations. Local governments and zoning boards will need to issue permits, ensure the project aligns with local regulations and may need to address community concerns. Additionally, pavement suppliers will be essential in providing high-quality, energy-efficient materials to ensure the durability and sustainability of the GA airport infrastructure.

Additional Resources

- **Case Studies:**
  - **Boston Logan International Airport (BOS)** was the first airport in the nation to repave their runway using energy-efficient asphalt (WMA & RAP 4R/22L).[158]
  - **Chicago O'Hare International Airport (ORD)** used RAP to repave their runway 9C/27C.[159]
  - **Dekalb-Peachtree Airport (PDK)** installed reflective coating on a section of the airport's pavement to prevent reflective cracking.[160]
  - In 2010 and 2011, **West Virginia International Yeager Airport (CRW)** transformed one of its runways into a taxiway. During this project, nearly 200 tons of concrete and asphalt were repurposed for perimeter patrol roads and access roads around the airport. This approach allowed the airport to save on construction costs by eliminating the need for the contractor to transport the materials off-site for disposal.[161]

[158] For Construction Pros. (2008). *Boston Logan's Warm Mix - a First!*
[159] City of Chicago. (2022). *Sustainable Airport Manual Green Airplane Certification*
[160] Solmax. (2025). *Reflective cracking prevention at DeKalb-Peachtree Airport with Petromat*
[161] FAA. (2013). *Recycling, Reuse and Waste Reduction at Airports - A Synthesis Document*

- **Potential Funding and Incentives:**
  - The Bipartisan Infrastructure Law (BIL) provides funding to "improve safety and support critical aviation operations."[162] NCDOT Aviation will apply on behalf of N.C.'s Non-Primary airports for Federal Airport Infrastructure Grants as airports are ready to collect.[163] While funding remains, it was allocated solely for use between 2024 and 2026 and is uncertain while current federal policies are under review.
  - The FAA's Airport Improvement Program (AIP) provides grants for various development projects including projects focused on sustainability and energy efficiency, including airfield pavement projects, and are awarded based on passenger volume.[164]
  - The North Carolina State Transportation Improvement Program (STIP) can provide funding to GA airports through the "Division Needs" eligibility category and can provide funds for capital improvement projects, modernization projects and projects that increase airport capacity such as paving.[165]
  - State Aid to Airports, the state funding program of NCDOT Division of Aviation, provides funding to airports in the North Carolina Aviation System Plan (NCASP) to meet goals and objectives. Additionally, the 20 "Green" airports in North Carolina as designated by the NCASP Airport Grouping Methodology are eligible for the Safety Enhancement Match program and can accelerate project funding by reducing implementation barriers.[166]
  - The North Carolina Airport Economic Development Fund, most recently revised in 2017, can be used for airside projects such pavement improvements that increase the capacity of an airport and support economic development.[167]

[162] General Aviation. (2024). *$20 Million Approved to Modernize Airport-Owned ATC Towers*
[163] NCDOT Division of Aviation. (2024). *North Carolina Airports Program Guidance Handbook*
[164] *FAA. (2025). AIP*
[165] Understanding STIP (2024). *NCDOT Div. of Aviation*
[166] North Carolina Airports System Plan (NCASP). (2015). *North Carolina Airports System Plan*
[167] NCDOT. (2021). *North Carolina Airport Economic Development Fund*

Summary Ratings

- **Near Term**, advancements in energy-efficient pavement materials and reflective coating for pavements are already available for use in airport paving or rehabilitation projects.
- **Insignificant Impact**, Energy-efficient material pavement overall reduces energy usage. For example, WMA reduces energy consumption during production, while RAP lowers the need for new raw material and decreases energy usage. While RAP does require additional production and inspection requirements, the reclamation greatly reduces project waste. Continued advancements in reflective coating for pavement reduce surface temperatures, aircraft tire degradation (and required runway contaminant removal, rubber) and helps with storm water runoff.
- **Medium Cost**, while energy efficient pavement and pavement reflective coatings will cost more than traditional construction materials, the added environmental benefits and extension of pavement lifecycle may be worth the upfront initial costs for GA airports.
- **Medium Risk**, installing energy-efficient pavement materials can involve higher initial costs and complex installation and maintenance. Performance may vary based on local climate and usage frequency, with concerns about durability under heavy loads. GA airports need to weigh the safety, environmental, and construction flexibility benefits of energy efficient pavement materials and reflective coating with initial costs of installation and additional maintenance requirements to maintain reflective properties.

Recommendations

GA airports can conduct a life cycle assessment to optimize materials and construction methods and reduce energy consumption and greenhouse gas emissions. The results of the assessment can determine planning, budgeting, construction, and maintenance requirements for the scope of the project. When pavement on site needs replacement, airports should identify opportunities to incorporate energy efficient pavement into construction.

Water Use Optimization

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Airport Facilities; Infrastructure; Management Systems; Utilities; Policies/ Practices	Near Term	Insignificant Impact	Low Cost	Medium Risk

General Aviation (GA) airports have an opportunity to reduce water consumption and lower utility costs through strategic water use optimization. This involves a comprehensive approach that spans infrastructure and equipment upgrades, operational practices, landscaping and ground management, and robust monitoring and data analysis. Some water use optimization examples are smart irrigation systems, rainwater harvesting, grey water reuse, permeable materials, and leak detection monitoring. As an example of a successful effort, the National Vehicle and Fuel Emissions Laboratory (Ann Arbor, Michigan) significantly reduced its water consumption by 80%, by replacing its single-pass cooling system with a recirculating chilled water loop. This upgrade resulted in annual savings of approximately 24.8 million gallons of water.[168] By implementing these strategies, GA airports can enhance sustainability, improve efficiency, and contribute to long-term environmental stewardship.

Overview

- **Compatibility:** Most water use optimization strategies are compatible for GA airports. Many of these measures can be integrated into existing water infrastructure, control systems, ground maintenance practices, and operational policies.
- **Current Market & Growth Projections:** Since the 1980s, individual water consumption in the U.S. has gradually decreased, thanks in large part to advancements in water-saving technologies, updated building regulations, and the adoption of certified efficiency standards.[169] The global smart water market is valued at $16.9 billion in 2023 with a CAGR of 13.4% from 2024 to 2030.[170]
- **Regulatory Environment:** In North Carolina, GA airports operate under a unique regulatory framework that supports water use optimization while prioritizing flight safety. State laws, such as North Carolina General Assembly (NCGS) 143-214.7(c3)[171] and 15A North Carolina Administrative Code (NCAC) 02H .1001(1)(e)[172], exempt airports from using stormwater control measures that promote standing water, which could attract wildlife and pose safety risks.[173] While airports must still comply with public water system regulations and may require National Pollutant Discharge Elimination System (NPDES) permits, they are encouraged to adopt water-efficient practices like rainwater harvesting for irrigation and aircraft washing, provided these align with operational and safety guidelines.

[168] EPA. (2024). *Water Management Plans and Best Practices at EPA*
[169] The Water Research Foundation. (2020). *Water Use & Efficiency*
[170] Grand View Research. (2024). *Smart Water Management Market, Industry Report, 2030*
[171] *North Carolina. N.C.G.S. 143-214.7*
[172] North Carolina. *15A NCAC 02H .1001*
[173] NCDEQ. (2018). *NCDEQ Stormwater Design Manual*

Benefits & Challenges

Benefits	Challenges
• Lower water consumption directly decreases water and sewer costs. • Early detection and repair of leaks minimize water loss and prevent damage to airport facilities. • Using less water means using less energy for pumping, heating, or treating water, reducing the airport's carbon footprint.	• The financial payback period may be long, especially for smaller airports with lower water usage. • Installing new fixtures, smart irrigation systems, or rainwater harvesting infrastructure can require significant initial funding.

Infrastructure Needs

- **GA Airport's Responsibility:** The GA airport is responsible for conducting a comprehensive water use assessment, either internally or by hiring a qualified consultant. The airport must also engage relevant stakeholders throughout the process, including assessment, planning, implementation, and ongoing operations and maintenance. Ultimately, the airport is accountable for overseeing the integration of water use optimization strategies into its infrastructure and daily operations, ensuring long-term sustainability and efficiency. The GA airport can conduct a benefit-cost analysis to evaluate savings from implementing water use optimization strategies.
- **Other Stakeholders' Responsibility:** Consultants support the airport by conducting water use assessments, assisting with planning and design, and performing cost-benefit analyses. Contractors are responsible for installing water-efficient infrastructure and equipment in accordance with project specifications. Water efficiency equipment manufacturers supply the necessary products upon procurement and may also provide technical support and guidance during installation and operation.

Additional Resources

- **Case Studies:**
  - **Los Angeles International Airport (LAX)** Installed purple piping to distribute reclaimed water across the airport, uses recycled water for dust control, street sweeping, and landscaping, and added over 200,000 square feet of drought-tolerant landscaping and implemented weather-based irrigation controllers.[174]
  - **San Diego International Airport (SAN)** operates a condensate recovery system that captures water from air conditioning units for reuse in cleaning operations. SAN also uses low-flow fixtures and native landscaping to reduce water consumption.[175]

[174] LAWA. *Sustainability Elements Water Management*
[175] *Cleantech San Diego Organization. (2017). San Diego International Airport Wins Environmental Excellence Award*

- **Dallas Fort Worth International Airport (DFW)** has implemented a reclaimed water system used for cooling towers, irrigation, and toilet flushing, significantly reducing potable water use. The airport also uses smart irrigation systems and drought-tolerant landscaping to conserve water.[176]

- **Potential Funding and Incentives:**
  - Bipartisan Infrastructure Law (BIL) funds are applicable for water-efficient upgrades. [177]
  - The NCDOT Division of Aviation manages the state-funded Airport Grant Programs and Federal Aviation Administration (FAA) State Block Grant programs, which can be used for water conservation and efficiency upgrades. [178]
  - The IRS (Internal Revenue Service) offers energy efficient commercial building deductions for eligible commercial buildings with hot water system installations meeting certain energy saving requirements.[179]
  - Visit the NC State University DSIRE database (Database of State Incentives for Renewables & Efficiency) for the most comprehensive source of information on incentives and policies that support renewables and energy efficiency in the United States.[180]
  - The 2024 NCDOT North Carolina Airports Program Guidance Handbook has state and federal funding sources and program details.[181]
  - Commercial Property Assessed Clean Energy (C-PACE) funding allows commercial property owners to obtain low-cost, long-term financing for energy efficiency and renewable energy projects, repaid through property tax assessments.[182]

Summary Ratings

- **Near Term,** water use optimization efforts can be implemented within 0-3 years.
- **Insignificant Impact**, the overall impact of water efficiency measures at GA airports is relatively low, as these facilities typically have minimal water usage. As a result, reductions in water consumption and water heating may offer only modest improvements to the airport's overall sustainability and resilience when compared to other initiatives.
- **Low Cost**, implementing water use optimization strategies is generally low-cost, particularly for initiatives involving non-invasive equipment upgrades, process or policy adjustments, and landscaping improvements. Costs would be higher for large-scale infrastructure upgrades or the installation of complex water efficiency systems, due to their technical requirements and construction demands.
- **Medium Risk,** more intensive water use optimization projects such as major infrastructure upgrades or complex equipment installations carry a moderate level of risk, as they may significantly alter the airport's existing water systems. In contrast, policy or process improvements and simple equipment retrofits typically involve minimal disruption and are associated with lower risk.

---

[176] DFW. (2020). *Board Approves Plan to Continue Reclaimed Water Use Agreement*
[177] General Aviation News. (2024). *$20 Million Approved to Modernize Airport-Owned ATC Towers*
[178] NCDOT Division of Aviation. (2024). *State Aid to Airports Program: General Legislative Funds*
[179] IRS. *Energy efficient commercial buildings deduction*
[180] NC Clean Energy Technology Center. *DSIRE database*
[181] NCDOT Division of Aviation. (2024). *North Carolina Airports Program Guidance Handbook*
[182] C-PACE Alliance

Recommendations

A GA airport can begin by conducting a comprehensive water use assessment to identify areas with the greatest potential for efficiency improvements. Based on the findings, the airport can prioritize and plan targeted water optimization strategies that offer the most benefit. Implementation can then proceed through a coordinated effort involving internal staff, contractors, and/or consultants to design, install, and maintain the selected solutions effectively.

Other Energy-Efficient Equipment

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Airport Facilities, Infrastructure, Utilities	Near Term	Medium Impact	Medium Cost	Medium Risk

Installing energy-efficient equipment can further reduce energy consumption at General Aviation (GA) airports. Airports can implement these improvements by upgrading or replacing existing equipment with energy-efficient alternatives. As policies and industry trends increasingly prioritize energy efficiency and resiliency, airports will have access to a growing array of energy-efficient equipment options. This shift will enable airports to enhance operational efficiency, reduce energy consumption, and contribute to a resilient aviation industry. Benefits include lower energy use, reduced maintenance costs, and improved operational efficiency.

Overview

- **Compatibility:** Overall energy efficient appliances are compatible with GA airports. Some equipment could be retrofitted and others would need to be replaced.
- **Current Market & Growth Projections:** The global energy-efficient appliance market, driven by escalating energy prices and consumer awareness of sustainability efforts, was valued at $221 billion in 2023 and is expected to reach $441 billion by 2023 with a Compound Annual Growth Rate (CAGR) of 8%.[183]
- **Regulatory Environment:** Regarding energy-efficiency, commercial buildings must comply with the most recent International Energy Conservation Code (IECC) and American National Standards Institute/ American Society of Heating, Refrigerating and Air Conditioning Engineers/ Illuminating Engineering Society of North America (ANSI/ASHRAE/IESNA) 90.1[184] standards or specific sections of the North Carolina Energy Conservation Code (NCECC).[185]

Benefits & Challenges

Benefits	Challenges
• Energy-efficient equipment can lower energy usage which leads to cost savings. • Energy-efficient equipment reduces carbon emissions by optimizing use patterns and increasing operational efficiency.	• Upgrading to energy-efficient equipment often has a significant upfront investment. • Integrating new systems with existing infrastructure can lead to technical challenges and compatibility issues that require additional modification.

[183] Zion Market Research. (2024). *Energy-Efficient Appliances Market Size, Share, Analysis, Trends, Growth, Forecasts, 2032*
[184] U.S. DOE. (2024). *ANSI/ASHRAE/IES Standard 90.1 - 2022: Energy Savings Analysis*
[185] International Code Council (ICC) Digital Codes. (2018). *2018 North Carolina State Building Code: Energy Conservation Code*

Benefits	Challenges
	• Energy-efficient systems may require specialized maintenance which can require additional training to support. • Energy-efficient systems may require additional training to optimize system capabilities.

Infrastructure Needs

- **GA Airport's Responsibility:** During the installation of energy-efficient equipment, GA airports must work with designers and engineers to create a detailed plan for the system including layout and equipment and ensure that it meets regulatory requirements. Airports will need to obtain funding for the system and coordinate with other stakeholders before and during installation to mitigate disruptions to operations. New equipment will need to be tested to ensure it is properly integrated with existing equipment. Airports may require additional security screening of the workers during the installation as they will have access to sensitive areas of the airport.
- **Other Stakeholders' Responsibility:** During the installation and integration of upgraded energy-efficient equipment and commercial-grade appliances, the tenants will need to maintain open lines of communications with airport managers and keep track of timelines. To minimize the impact of operations, contractors and vendors responsible for the installation should be pre-screened for security concerns as they will have access to sensitive areas of the airport. Appropriate permits and inspections will need to occur to ensure the project is completed to regulatory standards.

Additional Resources

- **Case Studies:**
  - **San Francisco International Airport (SFO)** has energy-efficient buildings, appliances, and construction equipment.[186]
  - **Hartsfield-Jackson Atlanta International Airport (ATL)** utilizes all-electric building systems. [187]
- **Potential Funding and Incentives:**
  - If available, Airport Improvement Program (AIP) funds can be used to finance energy-efficient equipment. [188]
  - Bipartisan Infrastructure Law (BIL) funds are applicable for energy-efficient upgrades. [189]

[186] SFO. (2015). *Sustainable Planning, Design and Construction Guidelines*
[187] Sustainability Magazine. (2023). *Top 10 Net-Zero Strategies from the World's Busiest Airports*
[188] *FAA. (2025). AIP*
[189] General Aviation News. (2024). *$20 Million Approved to Modernize Airport-Owned ATC Towers*

- The NCDOT Division of Aviation manages the state-funded Airport Grant Programs and Federal Aviation Administration (FAA) State Block Grant programs, which can be used to upgrade airport equipment. [190]
- The IRS offers energy efficient commercial building deductions for eligible commercial buildings.[191]
- Visit the NC State University DSIRE database (Database of State Incentives for Renewables & Efficiency) for the most comprehensive source of information on incentives and policies that support renewables and energy efficiency in the United States.[192]

Summary Ratings

- **Near Term**, upgraded energy-efficient commercial appliances are compatible with GA airports.
- **Medium Impact**, replacing outdated commercial appliances with energy-efficient options will reduce energy consumption and the overall carbon footprint of the facility. The impact of replacement will depend on the current system's energy usage and operational tempo of the facility.
- **Medium Cost**, the cost of upgrading commercial appliances at GA airports varies greatly. Overall costs would include the price of the new energy-efficient equipment, installation fees, potential modifications to existing infrastructure, ongoing maintenance, and any necessary training for airport staff to operate and maintain the new systems.
- **Medium Risk**, integrating energy-efficient equipment at GA airports involves higher initial costs and specialized maintenance and training for staff. Performance variability based on local conditions is another challenge.

Recommendations

If considering a transition to energy-efficient equipment, GA airports should conduct an energy scan to identify energy consumption of the current equipment to identify return on investment of new systems. When airports seek to upgrade commercial appliances they should replace with energy-efficient equipment to lower energy consumption and carbon emissions.

[190] NCDOT Division of Aviation. (2024). *State Aid to Airports Program: General Legislative Funds*
[191] IRS. *Energy efficient commercial buildings deduction*
[192] NC Clean Energy Technology Center. *DSIRE database*

New Construction

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Airport Facilities, Infrastructure	Near Term	Medium Impact	High Cost	Medium Risk

New construction projects at General Aviation (GA) airports offer a unique opportunity to incorporate energy-efficient designs and technologies from the ground up, significantly enhancing energy efficiency and security. By integrating advanced building materials, renewable energy systems, water-conserving plumbing and smart technologies, new facilities can optimize energy use and reduce operational costs. GA airports can implement these improvements by collaborating with architects, engineers, and sustainability experts to design and construct buildings that meet high energy performance standards. The benefits of new construction include lower energy bills, improved environmental impact, and increased resilience to energy disruptions. Additionally, construction that attains Leadership in Energy and Environmental Design (LEED®) certification, the world's most widely used green building rating system, are eligible for federal, state and local tax incentives and utility rebates which will reduce overall operating costs. In recent years as new construction has been required at commercial airports, many have chosen to erect green buildings that are LEED® certified. LEED® certification is awarded to buildings that are proficient in sustainable design and are highly efficient, providing cost savings and boasting environmental, social, and governance benefits.[193]

Overview

- **Compatibility:** New construction may only be compatible with existing GA airports where operational capacity dictates construction or expansion of existing facilities or where government initiatives investing in airport modernization (with a focus on sustainability) drive new construction.
- **Current Market & Growth Projections:** Overall, the market for sustainable construction at GA airports is forecasted for robust growth driven by an increasing demand for sustainable airport infrastructure and expansions to align with rising demands for air traffic. While it is difficult to isolate growth predictions to GA airports only, the overall global airport construction market (both commercial and GA) is projected to increase from $1,301.77 billion in 2025 to $2,019.83 billion by 2034 with a Compound Annual Growth Rate (CAGR) of roughly 5%.[194] Much of this construction is being driven by an increasing need for private and regional air travel, increasing awareness of the benefits of sustainable construction, and modernization needs.
- **Regulatory Environment:** NCDOT Division of Aviation provides guidance and oversight of airport construction projects to ensure projects comply with state and federal regulations. Federal Aviation Administration (FAA) AC 150/5360-13A provides regulations and guidance for airport terminal planning (if

[193] U.S. Green Building Council, Inc. (USGBC). *LEED® Rating System*
[194] Market Research Future. (2025). *Airport Construction Projects Market*

applicable) and AC 150/5370-10 provides construction standards for airports.[195] [196] North Carolina General Statues (N.C.G.S 143-214.7) and North Carolina Administrative Code (15A NCAC 02H.101) regulates stormwater management at airport facilities and requires them to implement stormwater control measures to avoid promoting standing water that may attract wildlife causing a potential hazard to aviation.[197] Additionally, the North Carolina Energy Conservation Code (NCECC), is a design document that regulates minimum energy conservation requirements for new buildings.[198]

Benefits & Challenges

Benefits	Challenges
• Environmental benefits of reduced energy consumption (lowering operational costs), reduction of airport's carbon footprint. Use of sustainable materials during construction can also minimize environmental impact. • Enhanced ventilation systems and low-emission materials improve indoor air quality. • Better air quality and natural lighting provide a healthier work environment for airport employees and can raise overall productivity levels. • Energy-Efficient Commercial Building Deductions allow building owners to claim tax credits for structures that achieve 50% reduction in energy consumption with partial deductions available for improved lighting, HVAC and green construction materials. • North Carolina's Renewable Energy Portfolio Standard offers incentives for energy efficiency and programs that support the construction of energy-efficient buildings.	• Higher upfront costs and certification fees. • Stringent and complex planning and documentation requirements. • On-going specialized maintenance required to maintain certification. • Potential disruption to existing operations during construction. • Potential security concerns due to additional personnel having access to sensitive areas of the airfield.

[195] FAA. (2018). AC 150/5360-13A - *Airport Terminal Planning*
[196] FAA. (2018). AC 150/5370-10H - *Standard Specifications for Construction of Airports*
[197] North Carolina Department of Environmental Quality. (2018). *NCDEQ Stormwater Design Manual*
[198] North Carolina Office of State Fire Marshal. (2012). *Effective Use of the North Carolina Energy Conservation Code*

Infrastructure Needs

- **GA Airport's Responsibility:** During airport construction, GA airports must continue to maintain operational safety, including managing construction activities to avoid interference with airport operations and ensuring all construction zones are clearly marked. GA airports will most likely own planning, design, construction, and maintenance of any LEED® Certifications which will require a higher level of maintenance and monitoring. GA airports will need to notify the FAA at least 45 days ahead of construction using the "Notice of Proposed Construction or Alteration" form (FAA 7460-1). GA airports will need to ensure the construction, and any airfield operational impacts, are properly communicated by Notice to Airmen (NOTAM) in applicable systems. Additionally, GA airports must adhere to FAA standards for construction including airfield pavement, marking, lighting and other visual aids and comply with environmental regulations and identify impacts.[199]
- **Other Stakeholders' Responsibility:** The local government will need to issue the necessary permits and ensure that construction complies with local building codes. The contractor will need to adhere to all regulatory requirements and standards of the FAA and other authorities and may need to provide special training to workers on the potential dangers of airfield construction and education on airfield markings and lighting to avoid potential runway incursions.

Additional Resources

- **Case Studies:** Airports with new construction with LEED® certifications include: **Denver International Airport (DEN)** Concourse D (LEED® Gold)**, San Diego International Airport (SAN)** Terminal 2 West (LEED® Platinum), **Orlando International Airport (MCO)** South Terminal C (LEED®v4)**, Chattanooga Airport (CHA)** Wilson Air Center (LEED® Platinum), and **Hayward Executive Airport (HWD)** Airport Administration Building (LEED® Silver certified).
- **Potential Funding and Incentives:**
    - The Bipartisan Infrastructure Law (BIL) provides funding to "improve safety and support critical aviation operations."[200]
    - FAA's Airport Improvement Program (AIP) provides grants for various development projects including projects focused on sustainability and energy efficiency and are awarded based on passenger volume.[201]
    - NCDOT Division of Aviation Grants offers state-funded grant programs for capital improvement projects including energy-efficient upgrades.[202]
    - The North Carolina Airport Economic Development Fund established in 2015 directs state taxes collected on aviation gasoline and jet fuel be dedicated to time-sensitive infrastructure development at publicly owned and operated GA airports.[203]

[199] FAA. (2018). AC 150/5370-10H - *Standard Specifications for Construction of Airports*
[200] General Aviation. (2024). *$20 Million Approved to Modernize Airport-Owned ATC Towers*
[201] *FAA. (2025). AIP*
[202] NCDOT. *Doing Business*
[203] NCDOT. (2021). *North Carolina Airport Economic Development Fund*

Summary Ratings

- **Near Term**, new construction at a GA airport could happen within 0-3 years depending on size, complexity, regulatory approvals, environmental considerations, and financing.
- **Medium Impact**, the use of energy-efficient construction and building materials will lower energy consumption and operational costs, and decrease the emissions of the GA airport.
- **High Cost**, new construction costs at a GA airport typically involve expenses for site preparation, materials, and labor. Additional costs include regulatory compliance, environmental assessments, and potential infrastructure modifications. The cost of new construction varies in size and complexity, but overall new construction projects cost more than other energy security efforts.
- **Medium Risk**, new construction at a GA airport involves risks such as safety hazards, operational disruptions, and environmental impacts. Navigating regulatory compliance and managing potential cost overruns are additional challenges. Adverse weather conditions can also cause delays, affecting the construction timeline and increasing costs.

Recommendations

As GA airports identify the need for new construction, they should identify opportunities to incorporate environmentally friendly and sustainability-focused efforts into construction and materials. GA airports should take advantage of all grant funding opportunities to offset costs, decrease long-term energy usage and utility costs, and ultimately lower the carbon footprint of facilities. When making decisions about the need for new construction at GA airports, operators should forecast facility usage to determine if expansion or facility upgrades align with near-term and longer operational vision for the airport and identify any risk mitigation measures that can be incorporated.

Smart Energy Management

Advanced technology plays a pivotal role in optimizing energy use at GA airports. By integrating innovative smart software solutions, airports can enhance their energy efficiency and security. This subsection explores various technologies, including energy management systems (EMS), smart building systems, and electric load management strategies. Artificial intelligence and machine learning (AI/ML) applications can be used to analyze data and make predictive adjustments. Airports can implement these technologies by integrating AI/ML algorithms into their EMS, smart building systems, and electric load management to optimize energy use and predict maintenance needs.

Implementing these technologies allows GA airports to gain real-time insights into their energy consumption, automate processes, and make data-driven decisions to reduce energy costs and improve resiliency. While the benefits are substantial, challenges such as initial investment costs and the need for specialized expertise must be considered. Overall, smart advanced technology offers a promising pathway for GA airports to achieve greater energy efficiency and resilience.

Energy Management Systems (EMS)

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Airport Facilities; Management Systems	Near Term	Medium Impact	Medium Cost	Low Risk

Implementing EMS enables General Aviation (GA) airports to track and manage their energy consumption in real-time, significantly enhancing operational efficiency. These systems can be applied to any building within the airport facilities. The system can include energy meters to measure electricity, gas, and water consumption, as well as environmental sensors to monitor temperature, humidity, light levels, and occupancy. Control systems are then linked to Heating, Ventilation, and Air Conditioning (HVAC), lighting, and electrical systems to optimize performance. The benefits of such systems include improved energy efficiency, reduced operational costs, and enhanced resiliency.

Overview

- **Compatibility:** EMS can seamlessly integrate with existing infrastructure by strategically placing sensors, meters, and controls within the current building setup.
- **Current Market & Growth Projections:** The current U.S. market value for energy monitoring and automation system was estimated at $12.70 billion in 2023. The market is projected to grow at a Compound Annual Growth Rate (CAGR) of 11.4% from 2024 to 2030.[204]
- **Regulatory Environment:** In North Carolina, the regulatory environment for EMS is shaped by state initiatives like the North Carolina Clean Energy Plan (CEP) and the North Carolina Energy Regulatory Process (NERP), which promote energy efficiency and the adoption of modern energy management practices. Local governments may also have specific requirements to reduce energy consumption and enhance sustainability.[205]

Benefits & Challenges

Benefits	Challenges
• Automation optimizes energy usage, reducing waste and ensuring efficient use of utilities. • Energy monitoring ensures systems operate correctly, preventing excessive energy waste.	• EMS require a significant initial investment, followed by ongoing annual software and system maintenance costs. • Staff training is essential to effectively manage and maintain energy monitoring

[204] Grand View Research. (2024). *U.S. Energy Management Systems Market Size, Share & Trends Analysis Report By System Type, By Component, By Development, By Vertical, and Segment Forecasts, 2024-2030*
[205] NCDEQ. 2020. North Carolina Energy Regulatory Process

Benefits	Challenges
• Identifying inefficiencies in the GA airport's energy system helps reduce energy costs.	and automation sensors, ensuring the system operates smoothly.

Infrastructure Needs

- **GA Airport's Responsibility:** The GA airport would plan, design, and procure the EMS. GA airports play a crucial role in assessing and planning the implementation of EMS. This process involves conducting feasibility studies and developing detailed plans. The managers at the airport would work with the software companies to ensure the system is set up properly. The GA airport would coordinate upgrading infrastructure, which includes installing sensors and meters, and enhancing electrical systems. Collaboration with utilities is vital, as is partnering with suppliers for equipment and coordinating installation with contractors. Additionally, staff training on system operation and maintenance is crucial, along with regular monitoring and evaluation.
- **Other Stakeholders' Responsibility:** The EMS company would supply the software, install the sensors, and train GA airport staff on how to utilize the system properly. Utilities would work with the system company and the GA airport to ensure the utilities side of the system is appropriately integrated.

Additional Resources

- **Case Studies:**
  - **Denver International Airport (DEN)** launched an $83 million Energy Performance Contract (EPC) aimed at significantly enhancing the energy efficiency of its facilities by upgrading the Energy Management Controls System. This initiative is expected to cut overall energy consumption by 20% and decrease greenhouse gas emissions by 30,000 metric tons annually.[206]
  - **San Francisco International Airport (SFO)** has implemented intelligent building energy management solutions to enhance energy efficiency in its terminals. These systems use sensors, connected devices, and data analytics to minimize energy wastage and boost operational efficiency.[207] In SFO Zero Net Energy 2020 Executive Summary Report, SFO mentions the strategy of completing "the energy management control system, including updated controls, meters, and integrated networking data", totaling a capital cost of $73 million.[208]

[206] DEN. *Renewable Energy at DEN*
[207] SFO. *Zero Net Energy: High Performance Buildings*
[208] SFO. (2020). *Zero Net Energy at SFO 2020 Executive Summary Report*

- **Potential Funding and Incentives:**
  - The Federal Aviation Administration (FAA) awards grants for airport development as part of the Airport Improvement Program (AIP) Supplemental Grant Program.[209]
  - The 2024 NCDOT North Carolina Airports Program Guidance Handbook has state and federal funding sources and program details.[210]
  - Visit the NC State University DSIRE database (Database of State Incentives for Renewables & Efficiency) for the most comprehensive source of information on incentives and policies that support renewables and energy efficiency in the United States.[211]

Summary Ratings

- **Near Term**, EMS are widely used in buildings across the U.S. and can be implemented at GA Airport within 0-3 years.
- **Medium Impact**, by managing energy usage and using less energy, airports can become more resilient and less dependent on external energy sources. This reduction in energy consumption can support airports' efforts to incorporate on-site energy generation and battery storage, ensuring they can meet their energy needs independently and sustainably.
- **Medium Cost**, the upfront costs for EMS, including sensors, meters, and software, are generally moderate. Additionally, it is important to account for monthly or annual subscription costs associated with maintaining and operating these systems.
- **Low Risk**, since the technology is well-developed and increasingly standard, installing an energy monitoring and automation system at GA airport facilities carries minimal risk.

Recommendations

GA Airports can conduct a thorough review of current energy security strategy and the potential benefits of implementing EMS. Following the initial review, GA Airports can undertake a comprehensive feasibility study. This study will assess the financial and technical viability of implementing EMS, ensuring that the proposed solutions are both cost-effective and technically sound. If an EMS is approved to move forward, then the GA airport would conduct an energy audit and go through the necessary steps to implement an EMS.

[209] *FAA. (2025). AIP*
[210] NCDOT Division of Aviation. (2024). *North Carolina Airports Program Guidance Handbook*
[211] NC Clean Energy Technology Center. *DSIRE database*

Smart Building Systems

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Airport Facilities, Management Systems	Near Term	Medium Impact	Medium Cost	Medium Risk

Smart building systems integrate various building operations, such as Heating, Ventilation, and Air Conditioning (HVAC), lighting, and security, into a single, intelligent network. By leveraging internet of things (IoT) devices, AI/ML algorithms, and robust network infrastructure, these systems automatically adjust building operations based on real-time data. In result, smart building systems aim to create more efficient, comfortable, and secure environments by optimizing resource use and automating processes. They provide a comprehensive solution for modern building management, ensuring that all aspects of the building work together seamlessly.

Smart building systems differ from Energy Management Systems (EMS), as they only focus on energy usage, where smart building systems are a holistic approach to managing every aspect of building operations.

Overview

- **Compatibility:** Smart building systems can seamlessly integrate with existing infrastructure by strategically placing sensors, meters, security measures, and controls within the current building setup.
- **Current Market & Growth Projections:** The current U.S. market value of smart building systems is part of EMS, and the EMS U.S. market value was estimated at $12.70 billion in 2023. The market is projected to grow at a Compound Annual Growth Rate (CAGR) of 11.4% from 2024 to 2030.[212]
- **Regulatory Environment:** In North Carolina, the regulatory environment for smart building systems is shaped by state initiatives like the North Carolina Clean Energy Plan (CEP) and the North Carolina Energy Regulatory Process (NERP), which promote energy efficiency and the adoption of modern energy management practices. Local governments may also have specific requirements to reduce energy consumption and enhance sustainability.[213]

Benefits & Challenges

Benefits	Challenges
• Centralized management of various building systems streamline operations, reducing maintenance and energy costs. • Integrated security measures, such as surveillance cameras and access controls,	• As more components connect to the internet, the risk of cyber-attacks increase, making cybersecurity a top concern.

[212] Grand View Research. (2024). *U.S. Energy Management Systems Market, Industry Report, 2030*
[213] NCDEQ. (2020). *North Carolina Energy Regulatory Process*

Benefits	Challenges
provide better protection for the building and its occupants. • Continuous monitoring and data collection provide valuable insights for making informed decisions and further optimizing building performance.	• Ensuring the privacy of occupants' data is crucial, as smart buildings collect and analyze large amounts of personal information. • Retrofitting existing buildings with smart technologies can be complex and costly, often requiring significant upgrades to infrastructure. • Different systems and devices need to work seamlessly together, which can be challenging due to varying standards and protocols.

Infrastructure Needs

- **GA Airport's Responsibility:** The General Aviation (GA) airport is responsible for planning, designing, and procuring the smart building system. This involves conducting feasibility studies, developing detailed plans, and collaborating with technology companies to ensure proper setup. The airport will also oversee infrastructure upgrades, including the installation of sensors, meters, and enhancements to electrical systems. Coordination with the Information Technology (IT) department, utilities, and suppliers, as well as contractor management, is essential. Additionally, training staff in system operation and maintenance, along with regular monitoring and evaluation, is crucial.
- **Other Stakeholders' Responsibility:** The technology company will provide the software, system integrators will install the sensors, and train GA airport staff on system usage. They will also offer ongoing support as needed. Utilities will collaborate with the technology company and the GA airport to ensure proper integration of the utilities side of the system.

Additional Resources

- **Case Studies:**
  - **Boston Logan International Airport (BOS)** installed a building management system that centralizes control of HVAC, lighting, and plumbing systems to optimize energy use and boost operational efficiency.[214]
  - **Phoenix Sky Harbor International Airport (PHX)** has integrated various smart technologies, including energy-efficient HVAC systems and real-time environmental monitoring.[215]
  - **LaGuardia Airport (LGA)** has incorporated smart building technologies to meet rising passenger demand and energy code requirements.[216]

[214] Facilities Dive. (2024). *US Airports Invest in Tech for Enhanced Traveler Experience, Sustainability*
[215] Id.
[216] Id.

- **Potential Funding and Incentives:**
  - The Federal Aviation Administration (FAA) awards grants for airport development as part of the Airport Improvement Program (AIP) Supplemental Grant Program.[217]
  - The 2024 NCDOT North Carolina Airports Program Guidance Handbook has state and federal funding sources and program details.[218]
  - Visit the NC State University DSIRE database (Database of State Incentives for Renewables & Efficiency) for the most comprehensive source of information on incentives and policies that support renewables and energy efficiency in the United States.[219]

Summary Ratings

- **Near Term**, smart building systems can be implemented at GA Airport within 0-3 years, provided that funding is available, as the installation process can be complex due to the need to integrate various systems.
- **Medium Impact**, smart building systems enhance energy security by optimizing energy use through real-time monitoring and automated controls, reducing overall consumption. They can integrate renewable energy sources and adjust usage during peak demand times, which stabilizes the energy grid. Additionally, predictive maintenance and improved resilience help ensure a continuous and reliable energy supply.
- **Medium Cost**, the cost of smart building systems varies widely based on factors such as building size, type, and the complexity of integrable systems like HVAC, lighting, and security. Additional expenses may include installation, system upgrades, and ongoing maintenance.
- **Medium Risk**, installing smart building systems carries moderate risk due to cybersecurity concerns, as increased connectivity can expose the building to cyber threats. The complexity of integrating smart technologies with existing infrastructure may require significant upgrades. Additionally, the initial investment and ongoing maintenance costs can be substantial, impacting budget planning.

Recommendations

GA Airport can start by carefully evaluating its existing energy security strategy and exploring the advantages of adopting a smart building system. After this initial assessment, the airport can proceed with a detailed feasibility study. This study will examine the financial and technical feasibility of implementing smart building systems, ensuring that the proposed solutions are both economical and technically viable.

[217] *FAA. (2025). AIP*
[218] NCDOT Division of Aviation. (2024). *North Carolina Airports Program Guidance Handbook*
[219] NC Clean Energy Technology Center. *DSIRE database*

Electric Load Management

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Airport Facilities, Management Systems	Near Term	Medium Impact	Medium Cost	Low Risk

Electric load management systems enable General Aviation (GA) airports to balance energy demand and supply, reducing peak energy usage and enhancing overall efficiency. Airports can implement these strategies through demand response programs, energy storage systems, and load-shifting techniques. Installing electric load management systems typically requires energy meters, environmental sensors, control systems linked to Heating, Ventilation, and Air Conditioning (HVAC) and lighting, and integration with Building Management Systems (BMS). The benefits include lower energy costs, improved grid stability, and enhanced energy security.

Overview

- **Compatibility:** Electric load management systems can seamlessly integrate with existing infrastructure by strategically placing sensors, meters, security measures, and controls within the current building setup.
- **Current Market & Growth Projections:** The global market for electric load management systems is valued at approximately $2.85 billion in 2023 and is projected to grow at a Compound Annual Growth Rate (CAGR) of 4.5% to reach $4.44 billion by 2033.[220]
- **Regulatory Environment:** In North Carolina, the regulatory environment for smart building systems is shaped by state initiatives like the North Carolina Clean Energy Plan (CEP) and the North Carolina Energy Regulatory Process (NERP), which promote energy efficiency and the adoption of modern energy management practices. Local governments may also have specific requirements to reduce energy consumption and enhance sustainability.[221]

Benefits & Challenges

Benefits	Challenges
• By reducing energy consumption during peak times and optimizing overall usage, these systems help lower electricity bills. • Balances energy demand and supply, preventing grid overloads and reducing the risk of power outages.	• The upfront investment for the necessary hardware and software can be substantial. This includes the cost of sensors, controllers, and the integration of these components into the existing infrastructure. • Integrating electric load management systems with existing infrastructure can

[220] Fact.MR. (2024). *Load Monitoring Systems Market*
[221] NCDEQ. (2020). *North Carolina Energy Regulatory Process*

Benefits	Challenges
• Automated controls and real-time monitoring improve energy use, leading to better resource management.	be complex and may require significant upgrades. • Increased connectivity can expose systems to cyber threats, necessitating robust security measures. • Ensuring seamless integration of various systems and devices can be difficult due to differing standards and protocols.

Infrastructure Needs

- **GA Airport's Responsibility:** GA airports must conduct thorough assessments of their current energy usage and infrastructure. Coordination with stakeholders such as utility companies, contractors, and airport staff is essential for smooth integration. Continuous monitoring and maintenance of the system are crucial for its effectiveness. Infrastructure needs include installing advanced metering infrastructure (AMI) with smart meters and sensors, incorporating energy storage systems like batteries, and upgrading existing electrical systems. Robust data management systems are necessary to handle the large volumes of data generated, and integrating renewable energy sources, such as solar panels, can further enhance sustainability.
- **Other Stakeholders' Responsibility:** The electric load management software company must provide reliable, user-friendly software that monitors and optimizes energy usage in real-time, ensuring compatibility with the airport's existing systems. The software company is responsible for robust data management solutions, offering analytics and reporting tools, and providing ongoing support and updates. Utility companies must provide reliable energy supply, support renewable energy integration, and collaborate on demand response programs. Contractors and engineers are responsible for installing and maintaining the system, ensuring all components function correctly. Airport staff need training to operate and monitor the system effectively.

Additional Resources

- **Case Studies:**
  - **San Francisco International Airport (SFO)** has implemented electrical load management as part of their distributed energy sources efforts.[222]
  - **Denver International Airport (DEN)** uses a comprehensive electric load management system that includes energy storage solutions and real-time data analytics to optimize energy consumption and reduce costs.[223]

[222] SFO Sustainability. *Zero Net Energy: High Performance Buildings*
[223] DEN. *Sustainability: Energy Management*

- **Potential Funding and Incentives:**
  - The Federal Aviation Administration (FAA) awards grants for airport development as part of the Airport Improvement Program (AIP) Supplemental Grant Program.[224]
  - The 2024 NCDOT North Carolina Airports Program Guidance Handbook has state and federal funding sources and program details.[225]
  - Visit the NC State University DSIRE database (Database of State Incentives for Renewables & Efficiency) for the most comprehensive source of information on incentives and policies that support renewables and energy efficiency in the United States.[226]

Summary Ratings

- **Near Term**, electric load management systems have been implemented for many facilities and Electric Vehicle (EV) charging infrastructure systems. This system can be implemented within 0-3 years.
- **Medium Impact**, electric load management is helpful in distributing energy usage during off-peak times to reduce utility costs and control energy consumption for greater efficiency. As a result, it enhances the airport's resiliency by improving the reliability of the energy supply, minimizing the risk of outages, and ensuring smooth operations.
- **Medium Cost**, implementing an electric load management system involves initial setup costs, subscription fees, consultation and design expenses, and ongoing maintenance.
- **Low Risk**, there is minimum risk on deploying electric load management systems since these systems have been on the market for a while and been deployed throughout the U.S.

Recommendations

The GA airport can initiate a benefit-cost analysis to evaluate the implementation of an electric load management system, focusing on potential cost and energy savings. If the analysis yields promising results and receives approval from airport leadership, the GA airport can either proceed with the implementation independently or collaborate with a consultant to identify and deploy the most suitable system for the airport.

[224] *FAA. (2025). AIP*
[225] NCDOT Division of Aviation. (2024). *North Carolina Airports Program Guidance Handbook*
[226] NC Clean Energy Technology Center. *DSIRE database*

Waste Reduction

Waste reduction is a valuable tool that GA airports can use to enhance the energy security of the region. While these efforts may not directly decrease the energy usage of the airport, they help mitigate the impact on waste management and product development that relies on imported fuel sources. By contributing to a circular economy, airports can encourage producers to use more recycled products.

Implementing efficient and responsible waste management practices allows airports to minimize their carbon footprint. This section explores various strategies for waste reduction, including waste analysis, recycling programs, composting, and reducing single-use plastics. GA airports can adopt these measures to reduce waste generation, promote recycling and composting, and collaborate with vendors and airport operations to decrease the use of single-use plastics.

Waste Analysis

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Airport Facilities, Policies/ Practices	Near Term	Insignificant Impact	Low Cost	Low Risk

Waste analysis is commonly known as waste stream analysis, waste characterization study, and waste assessments. Conducting a waste analysis allows General Aviation (GA) airports to identify opportunities for waste reduction and improve energy efficiency and security. At airports, there are different streams of waste, like municipal solid waste, construction and demolition debris, compostable and biodegradable waste, and hazardous and industrial waste. Airports can initiate this analysis by evaluating the types and quantities of waste generated, identifying areas for improvement, and developing targeted waste reduction strategies. Benefits include a better understanding of waste streams, reduced disposal costs, and enhanced sustainability. Challenges may involve the initial investment in waste analysis tools and the need for specialized expertise to interpret the data.

Overview

- **Compatibility:** A general waste analysis can be conducted alongside ongoing operations to evaluate the feasibility of integrating new waste management initiatives with the existing infrastructure.
- **Current Market & Growth Projections:** The U.S. waste management market, which includes waste analysis was valued at approximately $42.71 billion in 2023 and is projected to reach $63.25 billion by 2030, growing at a Compound Annual Growth Rate (CAGR) of 4.70% from 2024 to 2030.[227]
- **Regulatory Environment:** As part of receiving Airport Improvement Program (AIP) funding, the Federal Aviation Administration (FAA) requires airports to develop and implement recycling, reuse, and waste reduction plans as part of their master planning process. This includes assessing the feasibility of solid waste recycling, minimizing waste generation, and reviewing waste management contracts.

Benefits & Challenges

Benefits	Challenges
• Reduces waste disposal costs by identifying opportunities for recycling and waste reduction. • Streamlines waste management operations, leading to more efficient use of resources and personnel.	• Implementing a comprehensive waste analysis can incur costs related to labor, equipment, and consulting services. • Existing waste management infrastructure may not be equipped to handle the requirements of a detailed waste analysis. Upgrading or modifying

[227] NMSC. (2025). U.S. Waste Management Market

Benefits	Challenges
• Decreases the environmental footprint of the airport by promoting sustainable waste management practices.	infrastructure can be a significant challenge. • The success of implementing waste analysis recommendations hinges on the active participation and cooperation of both airport staff and users.

Infrastructure Needs

- **GA Airport's Responsibility:** GA airports can conduct the waste analysis either internally or through a consultant, depending on their expertise, capacity, and funding. If performed by airport staff, they must complete a comprehensive waste analysis, which includes identifying and quantifying all types of waste generated and assessing the existing waste management infrastructure. Once the results and recommendations are finalized, the airport should integrate the new waste management practices into daily operations and provide education and training to staff and users to ensure successful implementation.
- **Other Stakeholders' Responsibility:** Users can collaborate on waste reduction. Waste management contractors provide services, report on waste, and suggest innovative solutions. Regulatory agencies offer guidance, conduct inspections, and approve plans, while passengers and visitors engage in sustainable practices and stay informed.

Additional Resources

- **Case Studies:**
  - **San Francisco International Airport (SFO)** developed a Zero Solid Waste Management Plan with the goal of achieving "Zero Waste" status by 2021. This plan included comprehensive waste characterization studies and benchmarking of solid waste generation rates.[228]
  - **Philadelphia International Airport (PHL)** does waste analysis through their annual sustainability report.[229] It covers solid waste, recycling, hazardous waste, universal waste, and construction and demolition (C&D) debris.
  - **Portland International Airport (PDX)** gets regular waste audits performed by the Port of Portland Waste Management Team and Portland State University's Community Environmental Services program.[230] While the most recent environmental annual reports provide only brief overviews, the 2017 report[231] offers more detailed information on the waste audits.

[228] KSFO. (2016). *SFO Zero Solid Waste Management Plan: Task 1 - Benchmarking*
[229] PHL. (2024). *Environmental & Sustainability Resources*
[230] Port of Portland. *Environmental Annual Reports*
[231] Port of Portland. (2017). *Environmental Report 2016/17*

- **Potential Funding and Incentives:** Managed by the NCDOT Division of Aviation, FAA State Block Grant Program allocates federal funds to state-level projects, including those at GA airports. It supports various airport improvement initiatives, including waste management and sustainability efforts.[232]

Summary Ratings

- **Near Term**, a comprehensive waste analysis at a GA airport can be effectively implemented within 1 to 5 years. This period includes conducting an initial assessment, collecting and analyzing data, developing a strategy, implementing the plan, and monitoring its effectiveness.
- **Insignificant Impact**, conducting a waste analysis at a GA airport generally has a low impact by implementing recommendations to reduce the amount of waste produced. While it does not directly affect the energy security of the airport, it contributes to overall sustainability efforts by enhancing waste management practices and reducing environmental footprint.
- **Low Cost**, conducting a waste analysis is relatively low cost compared to other energy security efforts, as it does not require significant infrastructure investments. The primary expenses involve data collection, analysis, and the implementation of recommended practices, which are generally less costly than large-scale infrastructure projects.
- **Low Risk**, since the waste analysis is primarily an assessment, it carries a low risk. It involves evaluating current waste management practices and identifying areas for improvement without impacting existing infrastructure. The analysis poses minimal risk to airport operations and can be conducted without disrupting daily activities.

Recommendations

A GA airport can decide between completing the waste analysis internally or through a consultant. Then, the GA airport would take the results and recommendations of the waste analysis to implement actional items to reduce waste at the airport.

[232] Connect NCDOT. (2025). *Airport Grant Programs*

Recycling Program

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Airport Facilities, Infrastructure, Management Systems, Utilities	Near Term	Insignificant Impact	Low Cost	Low Risk

Implementing a recycling program at General Aviation (GA) airports can significantly enhance energy efficiency and security by reducing waste and promoting the reuse of materials. Recycling minimizes the need for new raw materials, which often require energy-intensive extraction and processing. By conserving resources, recycling decreases overall energy demand. Airports can strategically place recycling bins throughout the facility, educate staff and users on proper recycling practices, and collaborate with local recycling centers to ensure efficient processing. The benefits include reduced landfill waste, and a positive environmental impact. However, challenges may include initial setup costs, ongoing maintenance, and ensuring compliance with recycling guidelines.

Overview

- **Compatibility:** Recycling programs are well-suited for GA airports as they can seamlessly integrate with the airport's operations and maintenance activities. The success of recycling programs depends on behavior change, making it crucial to design the program to cater specifically to the GA airport. This ensures recycling is easy and convenient for both staff and users.
- **Current Market & Growth Projections:** As of 2023, the U.S. waste management and recycling market was valued at approximately $76.26 billion. It is projected to grow at a Compound Annual Growth Rate (CAGR) of 4.5% from 2023 to 2030, reaching nearly $98.34 billion by 2030.[233]
- **Regulatory Environment:** The regulatory environment for recycling programs in the U.S. is shaped by key policies such as the Resource Conservation and Recovery Act (RCRA), which governs the disposal of solid and hazardous waste, and the National Recycling Strategy developed by the U.S. Environmental Protection Agency (EPA) to enhance the national recycling system and increase the recycling rate to 50% by 2030. In North Carolina, local governments have the authority to enact stricter waste management standards, including mandatory separation of recyclable materials. The state also supports recycling through initiatives like the RecycleRight campaign[234] and the Recycling Business Assistance Center (RBAC)[235], which offers technical assistance, grants, and outreach programs.

[233] MMR. (2023). *U.S Waste Management and Recycling Market: Industry Analysis, Trends and Forecast (2024-2030)*
[234] NCDEQ. *RecycleRight*
[235] NCDEQ. *Recycling Business Assistance Center*

Benefits & Challenges

Benefits	Challenges
• Recycling reduces the need for new raw materials, which often require energy-intensive extraction and processing. This conservation of resources decreases overall energy demand. • Recycling helps minimize the carbon footprint of the airport by reducing greenhouse gas emissions associated with waste disposal and raw material production. • Many airports are required to have waste management plans that include recycling. Implementing a recycling program ensures compliance with federal and state regulations. • Recycling conserves natural resources by reusing materials, which is crucial for sustainability and long-term resource availability.	• Establishing a recycling program requires investment in infrastructure, such as recycling bins, signage, and collection systems. These initial costs can be a barrier, especially for smaller airports with limited budgets. • Maintaining the program involves regular collection, sorting, and processing of recyclables. This requires dedicated staff and resources, which can add to operational costs. • Ensuring that staff and users comply with recycling guidelines necessitates ongoing education and training programs. This can be time-consuming and requires continuous effort to keep everyone informed and engaged. • Incorrect disposal of non-recyclable materials in recycling bins can contaminate recyclables, making them less valuable or unusable.

Infrastructure Needs

- **GA Airport's Responsibility:** GA airports have several responsibilities when implementing a recycling program, including securing management support, forming a dedicated team, identifying waste types, developing a comprehensive plan, educating staff and users, and continuously monitoring the program. Essential infrastructure needs include strategically placed recycling bins, clear signage, efficient collection systems, designated storage facilities, partnerships with local recycling centers, and monitoring tools. By fulfilling these responsibilities and providing the necessary infrastructure, GA airports can successfully implement and maintain an effective recycling program, enhancing energy efficiency, reducing costs, and minimizing environmental impact.
- **Other Stakeholders' Responsibility:** Other stakeholders involved in recycling programs at GA airports include local governments, which set regulations and provide support; waste management companies, responsible for collecting and processing recyclables; vendors and concessionaires, who must sort waste and use recyclable materials; passengers, whose cooperation is vital; community organizations, which offer education and advocacy; and recycling centers, which process and repurpose collected materials. Engaging these stakeholders ensures a comprehensive and effective recycling program that benefits the entire community.

Additional Resources

- **Case Studies:**
  - **Chicago O'Hare International Airport (ORD)** has implemented a comprehensive recycling program that includes terminal recycling bins and waste diversion initiatives as part of the Chicago Department of Aviation's sustainability efforts.[236]
  - **John F. Kennedy International Airport (JFK)** managed by the Port Authority of New York and New Jersey, includes recycling as part of its airport-wide sustainability program, with initiatives targeting terminal waste and construction materials.[237]
  - **Los Angeles International Airport (LAX)** has a dedicated recycling division which manages in-house recycling, tenant programs, and special material collections. The program aims for high diversion rates and includes materials like paper, plastics, metals, and even coffee grounds.[238]
  - The **Yeager Airport (CRW)** works with the County Solid Waste Authority to recycle paper goods.[239]
- **Potential Funding and Incentives:** The Federal Aviation Administration (FAA) provides resources to implement airport recycling programs.[240]

Summary Ratings

- **Near Term**, a recycling program can be effectively implemented within a timeframe of 1 to 5 years. This period allows for thorough planning, infrastructure setup, staff training, and the integration of recycling processes into the airport's daily operations.
- **Insignificant Impact**, while a recycling program may not significantly enhance energy security, it greatly improves the sustainability of the airport by reducing waste and lowering its carbon footprint.
- **Low Cost**, recycling programs are low cost compared to other energy security efforts, making them an attractive option for airports. The costs involved include infrastructure, training, education, operational, and administrative expenses.
- **Low Risk**, recycling programs are low risk due to their relatively low cost and minimal impact on the everyday operations of an airport.

Recommendations

To implement a recycling program at a GA airport, start with a feasibility analysis to evaluate if the existing staff, processes, and infrastructure can support the program. Identify any gaps and assess the costs and efforts required. If the benefits, such as reduced landfill waste and improved sustainability, outweigh the costs, proceed with implementation. This involves setting up infrastructure like recycling bins and signage, training staff, and launching public awareness campaigns. Regular monitoring and evaluation will ensure the program's effectiveness and allow for continuous improvement.

---

[236] O'Hare & Midway International Airports. *Reduce, Reuse, Recycle*
[237] Port Authority New York New Jersey. (2024). *Operator Resources - Airport Solid Waste Management and Recycling Standards and Guidelines*
[238] Los Angeles World Airports. *LAWA Environmental Overview - LAX Construction & Maintenance Services, Recycling Program*
[239] FAA. (2013). *Recycling, Reuse and Waste Reduction at Airports - A Synthesis Document*
[240] FAA. (2022). *Airport Recycling, Reuse, and Waste Reduction*

Composting and Reduction of Single-Use Plastic

Applicable Use Cases				Timeframe	Impact	Cost	Risk
Airport Facilities	Infrastructure	Utilities	Policies/ Practices	Near Term	Insignificant Impact	Low Cost	Low Risk

Composting organic waste and reducing single-use plastics can help General Aviation (GA) airports minimize waste and promote sustainable practices. Airports can implement these improvements by setting up composting stations for food and landscaping waste and collaborating with vendors to reduce the use of single-use plastics. Examples of single-use plastics include plastic straws, cutlery, plates, cups, bags, and water bottles. If composting is not done on-site, the infrastructure needs are indeed lower. Airports can partner with local composting facilities to handle organic waste, reducing the need for extensive on-site facilities. Benefits include lower waste disposal costs, improved soil quality from compost, and reduced plastic pollution.

Overview

- **Compatibility:** Composting and reduction of single-use plastic efforts are compatible with existing infrastructure. These efforts can be incorporated on top of existing systems, processes, and operations of the airport.
- **Current Market & Growth Projections:** The compost market in the U.S. was valued at approximately $6.04 billion in 2024 and is expected to reach $6.27 billion in 2025. The market is projected to grow to $8.76 billion by 2033, with a Compound Annual Growth Rate (CAGR) of 3.9% from 2025 to 2033.[241]
- **Regulatory Environment:** North Carolina Environmental Quality provides guidance on composting.[242] NC Compost Rules (15A North Carolina Administrative Code (NCAC) 13B .1400) provide detailed guidelines for compost facility operations, including permit application processes for different types of compost facilities.[243] House Bill 8 (NC Managing Environmental Waste Act of 2025) has not yet passed but it focuses on managing environmental waste, specifically targeting the reduction of single-use plastics in government programs.[244]

[241] Global Growth Insights. (2025). *Compost Market*
[242] NCDEQ. *Composting*
[243] NCDEQ. (2019). *Section .1400 - Solid Waste Compost Facilities*
[244] North Carolina General Assembly. (2025). *House Bill 8*

Benefits & Challenges

Benefits	Challenges
• Reducing the volume of food and plastic waste sent to landfills can lower waste disposal costs. • Using compost on-site for landscaping can reduce expenses on soil amendments and fertilizers. • Procuring and using fewer single-use plastics will significantly reduce the consumption of fossil fuels by plastic manufacturers. This reduction occurs because the production of single-use plastics relies heavily on fossil fuels for raw materials and energy. • Demonstrating a commitment to sustainability can enhance the airport's public image, making it more attractive to environmentally conscious airport users.	• Effective segregation of compostable materials from other waste streams is crucial but can be complex and labor-intensive. • Airports must comply with local, state, and federal regulations regarding waste management and composting. • Efficient collection and transportation of compostable waste within the airport premises require well-coordinated logistics. This includes ensuring timely pickup and delivery to composting facilities. • Educating and training airport staff in composting practices is essential for successful implementation. Staff must be aware of proper waste segregation and handling procedures. • Alternatives to single-use plastics tend to be more expensive than single-use plastics. • Reducing single-use plastics at the airport would require extensive coordination among numerous stakeholders, including airport management, airlines, concessionaires, waste management companies, regulatory bodies, and users.

Infrastructure Needs

- **GA Airport's Responsibility:** Implementing composting and single-use plastic reduction programs at a GA airport involves several responsibilities and challenges. Airports must ensure proper waste segregation and collection, set up and maintain composting facilities, and comply with local, state, and federal regulations. Effective coordination among stakeholders, including airport management, airlines, concessionaires, and waste management companies, is essential.
- **Other Stakeholders' Responsibility:** Waste management companies play a crucial role in segregating, collecting, and transporting compostable materials and recyclables. Regulatory bodies must provide guidance and oversight to ensure health and safety standards are met. Producers would develop high-quality, cost-effective alternatives to single-use plastics, such as compostable or reusable items, that meet the needs of airport operations and comply with regulatory standards. Additionally, educating and

engaging passengers and staff is essential for successful implementation, requiring effective communication strategies to promote awareness and participation.

Additional Resources

- **Case Studies:**
  - **Dallas Fort Worth International Airport (DFW)** since March 2021, has composted 60 tons of food waste from 22 terminal restaurants.[245] The program aims to achieve zero waste by diverting 90% of waste from landfills and incinerators.[246]
  - **San Francisco International Airport (SFO)** has a robust composting program that collects organic waste from terminal concessions and other airport operations. Additionally, SFO has banned the sale of single-use plastic water bottles, encouraging passengers to use refillable bottles with numerous hydration stations installed throughout the terminals. The airport aims to become the world's first zero waste airport by diverting at least 90% of waste from landfills and incinerators through recycling and composting.[247]
  - **Seattle-Tacoma International Airport (SEA)** has implemented composting programs to manage organic waste generated at the airport. In 2023 alone, composting initiatives resulted in the collection of approximately 1,394 tons of waste.[248] As of July 2024, SEA requires all food service tenants to use only reusable or approved compostable food service ware and packaging. This initiative is part of SEA's goal to divert 60% of terminal waste from landfills and eliminate plastic and plastic-lined service ware.[249]
- **Potential Funding and Incentives:**
  - The North Carolina Composting Council (NCCC) offers $1,000 grants to support composting, compost use, or compost education projects in North Carolina. These grants are available for community or industry projects, including educational materials and composting units.[250]
  - United States Department of Agriculture (USDA) Office of Urban Agriculture and Innovative Production (OUAIP) provides funding for pilot projects that develop and implement strategies for food waste reduction and compost plans. Priority is given to projects that include food waste reduction strategies and involve multiple partners.[251]
  - North Carolina Department of Environmental Quality (NCDEQ) offers grants to local governments for projects that initiate, expand, or improve waste reduction and recycling programs through the Community Waste Reduction and Recycling Grant Program. Funding can be used to purchase infrastructure or equipment to divert materials from the waste stream.[252]

---

[245] *Dallas Regional Chamber (DRC). (2022). How DFW International Airport Steered 60 Tons of Food Waste Away from Landfills in 10 Months*
[246] Id.
[247] SFO Sustainability. *Zero Waste*
[248] Port of Seattle. (2024). *SEA Moves to All Reusable or Compostable Food Service Materials*
[249] Id.
[250] NC Composting Council. (2025). *Grants*
[251] USDA. Funding Opportunities
[252] NCDEQ. (2025). *2025 Community Waste Reduction and Recycling Grant Program*

Summary Ratings

- **Near Term**, composting and reduction of single-use plastics programs can be effectively implemented at a GA airport within 0-3 years. These initiatives can be quickly adopted due to their relatively low cost and straightforward integration into existing waste management systems.
- **Insignificant Impact**, while these programs aim to reduce fossil fuel use, their impact would primarily be limited to secondary sources such as single-use plastic manufacturers and landfills. Although this is a positive step, it highlights the need for broader initiatives to address primary sources of fossil fuel consumption for a more significant environmental impact.
- **Low Cost**, composting and reducing single-use plastics are cost-effective strategies compared to other energy security efforts. These initiatives involve several cost components: initial setup costs for infrastructure and alternative materials, operational costs for collection, transportation, and processing, and education and outreach expenses to raise public awareness.
- **Low Risk**, implementing, operating, and maintaining composting and single-use plastics reduction programs pose minimal risks due to their low costs, modest infrastructure requirements (especially if composting is not done on-site), and the ease with which they can be reversed if necessary.

Recommendations

Implementing composting and single-use plastic reduction programs at a GA airport involves several key steps. First, a GA airport can engage with stakeholders such as airport management, airlines, concessionaires, waste management companies, and regulatory bodies to ensure coordinated efforts and compliance with regulations. Secure funding through grants and partnerships to support the implementation and maintenance of the programs, considering the long-term cost savings from reduced waste disposal fees. Establish clear procedures for segregating compostable materials and provide designated bins and signage to guide proper disposal. Replace single-use plastic products with compostable or reusable products. Educate staff and airport users on the importance of these initiatives and provide training on proper waste segregation and handling.

Alternative Fuels

In the pursuit of energy independence and sustainability, GA airports play a crucial role. Diversifying energy sources at GA airports is essential to reduce reliance on traditional fossil fuels (aviation gas (avgas), Jet A, Jet A-1, diesel, and gasoline) and enhance operational resilience. Alternative fuels, such as biofuels, hydrogen, and electricity, offer promising solutions for GA airports by reducing dependence on imports and improving public health. These innovative fuels not only help mitigate the public health impact of aviation activities but also contribute to the overall energy security of the airport. This section explores the various types of alternative fuels, their benefits, and the challenges associated with their adoption, providing valuable insights for a more resilient and energy secure future for GA airports.

To enhance energy security and public health, GA airports can strategically adopt alternative fuels by prioritizing the most feasible and cost-effective options. These options are characterized by proven technology ready for deployment, benefits in terms of energy security and public health, and have low risk. The most recommended alternative fuels include electricity, CNG, and hybrid electric systems. These alternatives have demonstrated technological readiness and offer substantial benefits. Following these, unleaded aviation fuel, biofuels, RNG, and LNG can be considered for their potential to further reduce emissions. It is advisable to be cautious of LPG as major airports are transitioning away from it due to its lower energy density and higher emissions compared to other alternatives. In the future, SAF, renewable diesel, hydrogen fuel, and synthetic fuels could become more viable for GA airports to invest in and integrate into their operations.

Sustainable Aviation Fuel (SAF)

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Jet Aircraft, Airport Facilities, Infrastructure	Medium Term	Medium Impact	High Cost	Medium Risk

SAF is a type of biofuel designed and used to power aircraft, offering similar characteristics to conventional jet fuel. The fuel is made from renewable biomass and waste resources, such as waste oils and fats, agricultural products (non-food crops, and residues), and municipal solid waste.[253] The production processes include hydro processing and gasification. SAF is currently blended with conventional jet fuel, up to 50%, with hopes to achieve 100% SAF by 2030.[254]

Overview

- **Compatibility**: U.S. aircraft are currently unable to use 100% SAF as a direct substitute for traditional jet fuel, as it has not been fully validated as a drop-in replacement. SAF can be blended up to 50% with conventional jet fuel and used in existing aircraft and infrastructure. The main challenge is that 100% SAF lacks the aromatic hydrocarbons present in conventional jet fuel, which provide essential lubrication and other benefits. SAF suppliers can provide pre-blended SAF tanks.
- **Current Market & Growth Projections**: The current market size of SAF in the U.S. was valued at approximately $262.66 million in 2024 and is projected to grow significantly, reaching around $9,214.35 million by 2034.[255] Demand for jet fuel is expected to increase over the next three decades.
- **Regulatory Environment**: Governments and organizations are introducing regulations and policies to boost the production and use of SAF. The SAF Grand Challenge[256] was launched in 2021 by U.S. Department of Energy (DOE), the U.S. Department of Transportation (DOT), and the U.S. Department of Agriculture (DOA) with the goal of supplying sufficient SAF to meet all U.S. aviation fuel demand by 2050 and achieve at least a 50% reduction in life-cycle emissions compared to conventional fuel.

[253] U.S. DOE. *Sustainable Aviation Fuels*
[254] World Economic Forum. (2023). *What is Sustainable Aviation Fuel and Why are Only 0.1% of Flights Powered by it?*
[255] Precedence Research. (2024). *Sustainable Aviation Fuel Market*
[256] U.S. DOE. *Sustainable Aviation Fuel Grand Challenge*

Benefits & Challenges

Benefits	Challenges
• Performance like conventional jet fuel. • The use of SAF reduces the reliance on fossil fuels and increases energy security. SAF can be produced domestically. • SAF can reduce carbon dioxide (CO_2) emissions by up to 80% compared to traditional jet fuels.[257] • Growing biomass crops for SAF production can create new economic opportunities for farmers.	• High production costs of SAF are significant economic barriers to its widespread adoption. • Need to blend SAF with conventional jet fuel, as current regulations limit a maximum of 50% SAF in the mixture. • The use of 100% SAF for aircraft is to be refined, tested, and validated. • There are concerns that SAF production could compete with food resources, but efforts are being made to use non-food feedstocks like waste oils and agricultural residues.

Infrastructure Needs for General Aviation (GA) Airports

- **GA Airport's Responsibility:** The airport needs dedicated storage tanks for pre-blended SAF, specialized pipelines, and fuel hydrant systems to distribute pre-blended SAF to aircraft. If the airport prefers to blend their own SAF, a blending facility to blend SAF with conventional jet fuel would be needed. Blending SAF with Jet A fuel on-site at airports is not preferred due to the need for initial certification (American National Standards Institute (ASTM) D1655[258]), significant capital investment, insurance impacts, increased truck traffic, and additional staff and testing requirements.[259]
- **Other Stakeholders' Responsibility:** SAF production facilities require advanced technologies for feedstock processing, hydro processing units, gasification systems, Fischer-Tropsch reactors, catalytic conversion units, and extensive quality control laboratories to ensure the production of high-quality SAF. The distribution network of SAF includes specialized storage tanks, blending facilities, dedicated pipelines, fuel hydrant systems, and transportation vehicles equipped to handle SAF's unique properties and ensure its safe and efficient delivery to airports.

[257] IATA. *Sustainable Aviation Fuel (SAF)*
[258] ASTM. (2023). *ASTM D1655 Standard Specification for Aviation Turbine Fuels*
[259] NREL. (2024). *Sustainable Aviation Fuel Blending and Logistics*

Additional Resources

- **Case Studies**:
  - **San Francisco International Airport (SFO)** is leading the way with SAF by encouraging and supporting the industry. In 2018, at SFO, there was nearly 400,000 gallons of SAF delivered and used for gateway flights, avoiding approximately 100 metric tons of CO_2.[260] In 2020, SAF was delivered by existing multi-product pipeline infrastructure.[261]
  - **Los Angeles International Airport (LAX**) integrated SAF into its fuel supply starting in 2020 and has achieved an estimated 25% reduction in CO_2 emissions per flight using a 30% SAF blend.[262] Also, Neste has partnered with FedEx to supply over three million gallons (8,800 metric tons) of blended SAF at LAX, marking the largest SAF purchase by a U.S. cargo airline at the airport. This supply will cover about 20% of FedEx's annual jet fuel consumption at LAX.[263]
  - **John F. Kennedy International Airport (JFK)** is starting the first-ever regular delivery of SAF for the region, the agreement is up to five million gallons of SAF.[264]
  - **Seattle-Tacoma International Airport (SEA)** aims to power all flights with at least a 10% SAF blend by 2028.[265]
- **Potential Funding and Incentives:**
  - The North Carolina Clean Energy Technology Center (NCCETC) offers support for clean transportation projects.[266]
  - Federal grant programs are currently being evaluated and are pending approval to continue.

Summary Ratings

- **Medium Term**, a blend of up to 50% SAF and traditional jet fuel can be used in the U.S. and North Carolina now. As of 2025, the companies that can supply SAF to North Carolina are World Energy[267], Neste[268], and Gevo[269]. Lydian successfully piloted SAF production at the Research Triangle Institute (RTI) International in North Carolina and plans to start commercial production in 2027.[270]
- **Medium Impact**, SAF can reduce life cycle emissions by up to 80% compared to traditional jet fuels. SAF increases energy security by reducing the dependency on fossil fuels and diversifying fuel sources that are produced domestically. SAF can currently be blended with traditional jet fuel up to a maximum of 50%, which limits the full potential of its energy security and public health benefits.

---

[260] SFO. *Sustainable Aviation Fuel*
[261] Neste. (2020). *Neste delivers sustainable aviation fuel to San Francisco International Airport – first company to deliver it via pipeline*
[262] The Flying Engineer. (2024). *Real-World Impact: Case Studies of Sustainable Aviation Fuel Success (2025)*
[263] Neste. (2025). *Neste starts to supply sustainable aviation fuel to FedEx at Los Angeles International Airport, marking the first major U.S. SAF deployment by FedEx*
[264] jetBlue. (2025). *JetBlue Marks First Regular Supply of Sustainable Aviation Fuel (SAF) for Commercial Air Travel in New York*
[265] Port of Seattle. *Sustainable Aviation Fuels*
[266] NC Clean Energy Technology Center. *Clean Transportation*
[267] World Energy
[268] Neste
[269] Gevo
[270] Lydian

- **High Cost**, GA airports would need to account for the infrastructure costs of dedicated storage tanks, specialized pipelines, and fuel hydrant systems to support pre-blended SAF. Also, for aircraft operators and owners, SAF is priced at two to four times higher than traditional jet fuel.[271]
- **Medium Risk**, Integrating SAF at a GA airport involves significant risks due to supply chain challenges, high infrastructure costs, and instability of grant funding. Additionally, the political climate and economic viability further complicate the adoption of SAF.

Recommendations

Survey GA airport aircraft operators and owners to determine if there is a demand for SAF. Then, invest in SAF infrastructure when financially feasible since the SAF industry is maturing quickly.

[271] ICF. (2024). *The Role of Airports in Scaling Up Sustainable Aviation Fuel (SAF)*

Unleaded Aviation Fuel

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Small Piston-engine Aircraft; Airport Facilities; Infrastructure	Near Term	Medium Impact	Medium Cost	Medium Risk

Unleaded aviation fuel is a type of aviation gasoline (avgas) that does not contain lead. It is designed to replace traditional leaded avgas, which has been used for decades in piston-engine aircraft. The production process involves refining petroleum and blending it with specific additives to create fuel that meets the performance requirements of piston-engine aircraft. Unleaded avgas is formulated without tetraethyl lead, which is used in traditional avgas to boost octane levels. Instead, it uses alternative additives to achieve the necessary octane rating. Despite the public health benefits of unleaded avgas, it is still sourced from petroleum-based sources and does not qualify as Sustainable Aviation Fuel (SAF). The transition to unleaded avgas is part of a broader effort to eliminate lead emissions from aviation.[272] The FAA's Piston Aviation Fuels Initiative (PAFI) program[273] and the Eliminate Aviation Gasoline Lead Emissions (EAGLE) initiative[274] are key resources in this effort.

Overview

- **Compatibility**: Unleaded avgas is a "drop-in" replacement for leaded avgas, usable in existing piston-engine aircraft without modifications. However, not all aircraft are currently approved to use unleaded avgas. The Federal Aviation Administration (FAA) oversees the aircraft approval process for new fuels. Fuel developers must test the compatibility, safety, and performance of any new fuel on aircraft and engine models. The FAA reviews the results and issues a Supplemental Type Certificate upon approval. Additionally, under the Piston Aviation Fuels Initiative, the FAA uses a combination of testing and analysis to determine if unleaded avgas qualifies as a replacement. A regularly updated list of aircraft and engines that can use unleaded avgas is maintained.
- **Current Market & Growth Projects**: The U.S. unleaded avgas market was valued at approximately $1.01 billion in 2023 and is expected to grow at a Compound Annual Growth Rate (CAGR) of 7.27% through 2029.[275] The market for unleaded avgas is still developing, with ongoing efforts to increase production and distribution. The FAA's EAGLE initiative aims to transition the GA fleet to lead-free fuels by 2030. As regulatory pressures to eliminate leaded fuels increase, the demand for unleaded avgas is expected to grow.

[272] FAA. 2022. FAA Unleaded Fuel Development FAQs and Definitions
[273] FAA. (2022). *Piston Engine Aviation Fuels Initiative (PAFI) Background and Program Update*
[274] fly EAGLE
[275] Research and Markets. (2024). *United States Aviation Gasoline Market, By Region, Competition, Forecast & Opportunities, 2019-2029F*

- **Regulatory Environment**: The Environmental Protection Agency (EPA) and the FAA are working together to establish regulations and standards for unleaded avgas. The PAFI is a key part of this effort, evaluating and approving candidate fuels.

Benefits & Challenges

Benefits	Challenges
• Elimination of lead emissions supports broader environmental and public health goals. • Similar performance to leaded avgas ensures safe and efficient aircraft operation.	• Ensuring unleaded avgas meets performance requirements of all piston-engine aircraft. • Unleaded avgas is generally more expensive than leaded avgas. • New infrastructure cost for supplying unleaded avgas.

Infrastructure Needs for General Aviation (GA) Airports

- **GA Airport's Responsibility:** Dedicated storage tanks made of materials compatible with unleaded avgas, such as stainless steel or aluminum, to prevent corrosion and contamination. The unleaded avgas fuel dispensing system would include high-flow pumps, and mobile refueling trucks.
- **Other Stakeholders' Responsibility:** An unleaded avgas production facility requires specialized machinery, including feedstock preparation units, blending tanks, distillation columns, hydrotreating units, additive injection systems, and quality control laboratories. The distribution network for unleaded avgas must be expanded to ensure availability at airports across the country. Unleaded avgas distribution network infrastructure requires dedicated storage tanks, refueling trucks, and pipeline systems designed to prevent contamination and ensure fuel purity.

Additional Resources

- **Case Studies**:
  - **GAMI's (General Aviation Modifications Inc.)** G100UL unleaded avgas was approved by the FAA in 2022. Current estimates for the cost of G100UL avgas are 0.70¢ to $1.05 more per gallon compared to 100 Low Lead (LL) until it becomes more widely available, although GAMI claims that the higher fuel price will be offset by lower maintenance costs for the aircraft.
  - **California (Watsonville Municipal Airport (WVI) and Reid-Hillview Airport (RHV))** and **Mississippi (Tupelo Aviation Unlimited)** are examples of airports supplying G100UL avgas.[276]
  - **Colorado (Centennial Airport (APA))** offers UL94 unleaded avgas.

[276] General aviation Modifications, Inc.

- **Potential Funding and Incentives:**
  - The North Carolina Clean Energy Technology Center (NCCETC) offers support for clean transportation projects.[277]
  - Federal grant programs are currently being evaluated and are pending approval to continue.

Summary Ratings

- **Near Term**, unleaded avgas can be used in the U.S. and North Carolina now. Fuels like UL94, produced by Swift Fuels, and G100UL, developed by General Aviation Modifications Inc., are approved by the FAA for use in many piston-engine aircraft.
- **Medium Impact**, unleaded avgas enhances energy security by reducing reliance on imported lead additives and ensuring a stable, domestic fuel supply. But unleaded avgas still uses petroleum. In terms of public health benefits, it eliminates harmful lead emissions, contributing to cleaner air and healthier communities.
- **Medium Cost**, separate infrastructure for unleaded avgas adds to the implementation costs.
- **Medium Risk**, implementing unleaded avgas at a GA airport poses medium risk due to the significant investment required for new infrastructure and the potential for higher fuel costs during the transition period. Additionally, ensuring compatibility with all piston-engine aircraft and managing supply chain uncertainties further contribute to the medium risk level.

Recommendations

To determine if supplying unleaded avgas is economically and technically viable, a GA airport should conduct a cost-benefit analysis, considering factors such as infrastructure upgrades, fuel pricing, and potential public health benefits. Additionally, the airport should evaluate the compatibility of unleaded avgas with the existing aircraft fleet and consult with fuel suppliers and regulatory bodies to ensure compliance and feasibility.

[277] NC Clean Energy Technology Center. *Clean Transportation*

Renewable Diesel

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Ground Support Equipment, Fleet Vehicles, Airport Facilities, Infrastructure	Medium Term	Significant Impact	Medium Cost	Medium Risk

Renewable diesel is a biofuel made from renewable resources like vegetable oils, animal fats, and waste cooking oils. It is chemically similar to petroleum diesel and is made using a process called hydrotreating. This process involves reacting the feedstock with hydrogen under high pressure and temperature, resulting in a hydrocarbon fuel that meets the American National Standards Institute (ASTM) D975[278] specification for petroleum diesel. Renewable diesel can be used by Ground Support Equipment (GSE) and fleet vehicles at airports. Currently, renewable diesel is not approved for diesel aircrafts in the U.S.

Overview

- **Compatibility**: Renewable diesel is fully compatible with conventional diesel, allowing it to be used in existing diesel engines and infrastructure without any modifications. While renewable diesel is designed to be compatible with diesel engines, older engines may require adjustments or retrofits to optimize performance and prevent wear.
- **Current Market & Growth Projections**: The global renewable diesel market was valued at $23 billion in 2024 and is projected to grow at a compound annual growth rate of 8.1% from 2025 to 2034. The U.S. renewable diesel market is expected to surpass $23.4 billion by 2034, driven by government policies like the Renewable Fuel Standards (RFS) and Low Carbon Fuel Standard.[279]
- **Regulatory Environment**: The Environmental Protection Agency (EPA) currently sets the RFS, which mandates blending renewable fuels like renewable diesel with petroleum-based fuels. This program provides Renewable Identification Numbers (RINs) as credits to fuel blenders.

[278] ASTM. (2022). *ASTM D975 Standard Specification for Diesel Fuel*
[279] Global Market Insights. (2025). *Renewable Diesel Market*

Benefits & Challenges

Benefits	Challenges
• On average, renewable diesel lowers carbon intensity by 65% compared to petroleum diesel.[280] • Renewable diesel can offer more stable pricing compared to conventional diesel, as it is less affected by fluctuations in crude oil prices. • Renewable diesel offers similar or better performance compared to conventional diesel, including higher cetane numbers, which improve combustion efficiency.	• Renewable diesel can introduce unique corrosion risks, such as those caused by free fatty acids (FFAs) and other contaminants. This can affect the integrity of storage tanks, pipelines, and refueling equipment. • The cost of producing renewable diesel is generally higher than conventional diesel. This is due to the expenses associated with feedstock procurement, processing technologies, and facility operations. • Colder temperatures (15°F to 20°F) can make renewable diesel start to gel, which can obstruct fuel flow and impact engine performance.

Infrastructure Needs for General Aviation (GA) Airports

- **GA Airport's Responsibility:** A GA airport needs dedicated storage tanks made of materials compatible with renewable diesel, such as stainless steel or aluminum, to prevent contamination and corrosion. Additionally, the airport requires specialized dispensing systems, including high-flow pumps and filtration units, along with safety equipment like spill containment kits and fire suppression systems.
- **Other Stakeholders' Responsibility:** Renewable diesel production requires specialized facilities capable of hydrotreating, isomerization, and fractionation processes. The distribution network of renewable diesel includes specialized storage tanks, blending facilities, high-pressure pipelines, dedicated fuel dispensing systems, and transportation vehicles equipped to handle renewable diesel's unique properties.

[280] U.S DOE. *Alternative Fuels Data Center*

Additional Resources

- **Case Studies:**
  - The **Westchester County Airport (HPN)** in New York is testing renewable diesel on the airport's GSE fleet.[281]
  - **San Diego International Airport (SAN)** is using renewable diesel for its airside equipment, including baggage tugs, belt loaders, and firefighting vehicles.
- **Potential Funding and Incentives**:
  - The North Carolina Clean Energy Technology Center (NCCETC) offers support for clean transportation projects.[282]
  - Federal grant programs are currently being evaluated and are pending approval to continue.

Summary Ratings

- **Medium Term**, renewable diesel can be used in the U.S. and North Carolina now. Ther are renewable diesel suppliers in the U.S. that can supply North Carolina GA airports with renewable diesel. Some of the renewable diesel suppliers are: Neste, Diamond Green Diesel (GDG), Renewable Energy Group (REG), and Marathon Petroleum Corporation.
- **Significant Impact**, renewable diesel is primarily produced from renewable resources, which enhances energy security by diversifying energy sources. This reduces dependence on imported oil and supports the domestic agriculture and biofuel industries. Renewable diesel decreases air pollutants and utilizes waste materials.
- **Medium Cost**, investing in separate infrastructure for renewable diesel is essential to ensure compatibility and prevent contamination with traditional diesel. Retrofitting or replacing older infrastructure may be necessary to support renewable diesel use.
- **Medium Risk**, replacing traditional diesel with renewable diesel at GA airports poses risks such as potential fuel supply chain disruptions, higher costs, and compatibility issues with older infrastructure.

Recommendations

GA airports should conduct a cost-benefit analysis to evaluate economic and energy security advantages and collaborate with fuel suppliers and regulatory bodies to ensure feasibility. To integrate renewable diesel, GA airports should invest in dedicated storage tanks and dispensing systems compatible with renewable diesel.

[281] Biobased Diesel Daily. (2025). *Westchester County Airport in New York Trials Renewable Diesel*
[282] NC Clean Energy Technology Center. *Clean Transportation*

Electricity

Electricity is a versatile energy type widely used in General Aviation (GA) airports for various applications, including lighting, cooling, heating, transportation, and powering equipment. This section provides a high-level overview of the use of electricity as an alternative fuel for GSE and fleet vehicles. Many facilities and a growing number of vehicles, including Ground Support Equipment (GSE), are already powered by electricity, however electricity for use in aircraft is still under development. Another future technology for GA airports to monitor is Electric Vertical Take-Off and Landing (eVTOL) aircraft, which are expected to become commercially available soon and meet increasing demand from airport users. Since electrification encompasses numerous aspects of airport operations, the Electrification section will cover landslide, airside, and fleet electrification considerations. Electrification involves converting systems, devices, or vehicles to run on electricity instead of other energy sources like fossil fuels.

Overview

- **Compatibility**: Existing conventional gasoline- and diesel-powered vehicles, GSE, and aircraft are generally not compatible with electricity as a power source. Transitioning to electric power requires acquiring new electric vehicles (EVs), Electrification of Ground Support Equipment (eGSE), and electric aircraft that rely solely on batteries for power.
- **Current Market & Growth Projections**: As of 2024, the U.S. EV market is valued at approximately $119.8 billion. The market is projected to grow at a CAGR of 13.7% from 2025 to 2034.[283] The U.S. electric aircraft market was valued at approximately $3.69 billion in 2024 and is projected to reach around $23.58 billion by 2034, growing at a Compound Annual Growth Rate (CAGR) of 20.39% from 2025 to 2034.[284]
- **Regulatory Environment**: The regulatory environment of electricity in the U.S. is governed by both federal and state policies, with the Federal Energy Regulatory Commission (FERC) overseeing wholesale electricity markets and transmission, while state regulators manage retail electricity sales and local distribution.

[283] Global Market Insights. (2024). *U.S. Electric Vehicle Market*
[284] Precedence Research. (2025). *Electric Aircraft Market*

Benefits & Challenges

Benefits	Challenges
• Electric systems often have lower maintenance and operational costs. • Electricity generated from renewable resources improves air quality compared to fossil fuels. • Electricity provides a stable and consistent power supply for airport operations.	• Existing aircraft, vehicles, and GSE are generally not compatible with electric power. • High upfront costs for purchasing eGSE, vehicles, and charging stations. • (EVs and aircraft may have a limited range compared to traditional fuel-powered options.

Infrastructure Needs for GA Airports

- **GA Airport's Responsibility:** The GA airport would provide a reliable electricity supply by forecasting demand accurately, install charging stations that meet the needs of the fleet and GSE vehicles, and develop the necessary supporting electrical infrastructure, including transformers, wiring, and other essential components.
- **Other Stakeholders' Responsibility:** Production facilities for electricity require key infrastructure components such as power generation units, transformers, switchgear, and control systems to ensure efficient and reliable power generation. Additionally, cooling systems, fuel supply systems, and renewable energy integration are essential to support and optimize the production process. An electricity distribution network requires infrastructure such as substations, transformers, circuit breakers, and distribution lines to efficiently deliver power from generation sources to end users, in this case the airport.

Additional Resources

- **Case Studies:**
  - **Los Angeles International Airport (LAX)** aims to fully transition its sedan fleet to EVs by 2031 and prioritizes zero-emission options for other light-duty vehicles. They currently have the following EVs: Class 8 Nikola Tre battery-electric vehicle (BEV) semi-style tractor, 120 sedans, 20 articulating electric airfield buses, 26 Ford F-150 Lightning trucks, 10 Ford Mach-E Sedans, 32 Class 4-8 Trucks, and 27 electric buses.[285]
  - **Denver International Airport (DEN)** has the following EVs and are looking to expand: 2 Zenith electric shuttle vans (initial test vehicles), 5 Chevy Bolt EUVs, 2 electric mini-sweepers (added in 2023), 1 Ford e-Transit with custom stake bed (added in 2023), 2 additional custom Ford e-Transits (planned) and, 6 Chevy Silverado EVs (planned).[286]

[285] LAWA. (2022). *LAX Takes Delivery of First Heavy-Duty Electric Truck as Airport Transitions to All-Electric Fleet*
[286] Drive Electric USA. (2023). *Colorado, Fleet Stories Denver International Airport*

- **Potential Funding and Incentives**:
  - The North Carolina Clean Energy Technology Center (NCCETC) offers support for clean transportation projects.[287]
  - Federal grant programs are currently being evaluated and are pending approval to continue.

Summary Ratings

- **Near Term**, EVs and eGSE can already be used in the U.S. and North Carolina. The battery technology for these applications is mature and can be deployed efficiently. Early collaboration with utility providers on the deployment of charging stations is crucial for ensuring a smooth rollout of the necessary infrastructure. As for electric-powered aircraft, the technology is still developing and would be considered for future phases as demand increases.
- **Significant Impact**, electrification of GSE and fleet vehicles enhances energy security by reducing dependence on fossil fuel imports, leading to long-term savings on fuel and maintenance costs. Additionally, it contributes to public health improvements by lowering pollution.
- **High Cost**, electrification of GSE and vehicles incur high costs due to the need for significant investments in new equipment and charging infrastructure. Additionally, upgrading the existing electrical systems and providing staff training further contribute to the overall expense.
- **Medium Risk**, electrification of GSE and vehicles poses moderate risk for a GA airport due to the uncertainties of federal funding for electrification efforts. Electric-powered vehicles and equipment generally cost more than gasoline and diesel-powered vehicles and equipment. Despite the financial implications, the electrification of vehicles and equipment has proven reliable and safe. Additionally, electric equipment requires less maintenance and has fewer mechanical failures, ensuring consistent and dependable operation.

Recommendations

To analyze electrification capabilities for EVs and eGSE at a GA airport, conduct a feasibility study to assess infrastructure needs and compatibility, followed by a fleet transition plan which includes a cost analysis to estimate initial investments and long-term savings. Develop a phased implementation plan for integrating EVs and eGSE, including necessary infrastructure upgrades and staff training. In addition, GA airport should actively monitor the advancements in electric-powered aircraft technology and evaluate the optimal time for adoption as demand increases.

[287] NC Clean Energy Technology Center. *Clean Transportation*

Hydrogen Fuel

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Jet Aircraft, Small Piston-engine Aircraft, Ground Support Equipment, Fleet Vehicles, Airport Facilities, Infrastructure	Medium Term	Significant Impact	High Cost	High Risk

Hydrogen fuel is a clean energy source that produces only water and heat as byproducts when used in fuel cells and hydrogen internal combustion engine vehicles (HICEVs). Composed of hydrogen gas (H_2), it converts chemical energy into electrical energy within the fuel cells. Hydrogen fuel is produced through various methods, including electrolysis, steam methane reforming (SMR) with carbon capture, biomass gasification, and solar-driven processes. At General Aviation (GA) airports, hydrogen fuel could be valued for its potential to reduce dependence on fossil fuels, making it a promising option for powering Ground Support Equipment (GSE), fleet vehicles, backup power, energy generation, combined heat and power (CHP) systems, and potentially future hydrogen-powered aircraft.

Overview

- **Compatibility**: Hydrogen fuel is not directly compatible with existing GSE, vehicles, aircraft, backup power systems, energy generation systems, and CHP systems. New GSE, vehicles, aircraft, and systems would need to be purchased to utilize hydrogen fuel. There have been tests on retrofitting existing aircraft with hydrogen-electric powertrains. Additionally, it is important to note that hydrogen fuel cell vehicles, GSE, and aircraft also require batteries, making them dependent on battery technology.
- **Current Market & Growth Projections**: The U.S. hydrogen fuel cells market size was evaluated at $1.43 billion in 2024. [288] The U.S. hydrogen generation market is projected to grow at a Compound Annual Growth Rate (CAGR) of 8.7% from 2024 to 2030, reaching approximately $35.82 billion by 2030.[289]
- **Regulatory Environment**: The U.S. Department of Transportation (U.S. DOT) has established Fuel System Integrity of Hydrogen Vehicles standards (FMVSS No. 307) and Compressed Hydrogen Storage System Integrity standards (FMVSS No. 308).[290] The Federal Aviation Administration (FAA) has developed a roadmap to address the technical challenges, safety concerns, and policy gaps related to the use of hydrogen as an alternative energy source in aircrafts.[291]

[288] Precedence Research. (2025). *Hydrogen Fuel Cells Market*
[289] U.S. Energy Information Administration. (2024). *Annual Energy Outlook 2025 Fact Sheet: Hydrogen Market Module*
[290] U.S. DOT. (2025). *49 CFR Part 571 Federal Motor Vehicle Safety Standards; Fuel System Integrity of Hydrogen Vehicles; Compressed Hydrogen Storage System Integrity; Incorporation by Reference*
[291] FAA. (2024). *Hydrogen-Fueled Aircraft Safety and Certification Roadmap*

Benefits & Challenges

Benefits	Challenges
• Hydrogen fuel can be domestically and sustainably produced from renewable energy sources such as solar, wind, and hydroelectric power. • The long-term operational costs are often lower due to the high efficiency and low maintenance requirements of hydrogen fuel cells. • Hydrogen fuel cells are more efficient than diesel and gasoline engines.	• Hydrogen has a low energy density by volume, requiring it to be stored at high pressures or cryogenic temperatures. This presents challenges in terms of safety, infrastructure, and cost. • Producing hydrogen, especially green hydrogen through electrolysis, is currently more expensive than traditional fossil fuels. Reducing these costs requires advancements in electrolyzer technology and scaling up production facilities. • There are a couple companies offering hydrogen powered airport GSE. There are no hydrogen powered aircraft commercially available on the market.

Infrastructure Needs for GA Airports

- **GA Airport's Responsibility**: Hydrogen fuel would need to be stored in high-pressure storage tanks, cryogenic storage tanks, and transferred via pipelines, hydrogen transport vehicles, and refueling stations.
- **Other Stakeholders' Responsibility:** Hydrogen fuel production requires electrolysis plants, SMR plants, and biomass gasification plants. The distribution network for hydrogen fuel requires specialized infrastructure, including pipelines for transporting compressed hydrogen gas, liquefaction plants for converting hydrogen into liquid form, cryogenic storage tanks, high-pressure compressors, tube trailers and cryogenic tanker trucks for transportation, and dispensing stations equipped with advanced metering and contaminant detection systems. Like the other alternative fuels H2 is transported by truck, boat, and rail in addition to pipeline. Delivery of H2 from ports by rail is the current safest mode of transport.

Additional Resources

- **Case Studies:**
  - Several large commercial airports such as **Houston George Bush Intercontinental Airport (IAH) and Hartsfield-Jackson Atlanta International Airport (ATL)** are working with Airbus on a hydrogen hub feasibility study.[292]
  - While U.S. airports have not yet widely adopted hydrogen-powered vehicles or buses, several transit agencies are making the transition to hydrogen fuel cell buses. For instance, **the San Mateo County Transit District (SamTrans)** in California operates hydrogen fuel cell electric buses and recently placed an order for 108 additional hydrogen buses. This decision was driven by the fact that hydrogen buses can meet their full day's service range needs compared to battery-electric buses.[293] Consequently, this advancement has the potential to influence the adoption of hydrogen for fuel cell electric buses and shuttles at airports.
- **Potential Funding and Incentives**:
  - The North Carolina Clean Energy Technology Center (NCCETC) offers support for clean transportation projects.[294]
  - Federal grant programs are currently being evaluated and are pending approval to continue.

Summary Ratings

- **Medium Term**, hydrogen fuel technology is still developing. Transitioning to hydrogen fuel requires time and investment to acquire new hydrogen fueled airport assets (vehicles, GSE, etc.), refueling stations, and storage facilities. Also, if hydrogen fuel is not produced on site, GA airports would need to procure hydrogen fuel from suppliers such as Air Products, Air Liquid, and Linde.
- **Significant Impact**, hydrogen fuel does not use fossil fuels, reducing dependence on imported fuels, and increasing resilience to supply disruptions. Hydrogen fuel use also reduces air pollutants compared to fossil fuel use.
- **High Cost**, implementing hydrogen fuel at a GA airport is costly due to the significant investment required for building hydrogen refueling stations, storage facilities, and safety systems.
- **High Risk**, implementing hydrogen fuel at a GA airport involves risks such as high infrastructure costs, stringent regulatory compliance, potential safety hazards, and operational challenges in handling and storage.

Recommendations

Given the current limitations in the availability of reliable and cost-effective solutions, it is advisable to wait for the hydrogen fuel industry to mature and become more market ready. When the technology and market conditions are more favorable, start by conducting a feasibility study to evaluate the infrastructure, costs, and regulatory requirements for hydrogen fuel adoption. Collaborate with industry partners and seek government grants or incentives to offset initial investment costs.

---

[292] https://www.ainonline.com/aviation-news/futureflight/2024-05-21/airbus-launches-hydrogen-feasibility-studies-north-american

[293] SamTrans. (2025). *The Shift to Hydrogen-Powered SamTrans Buses is Underway*

[294] NC Clean Energy Technology Center. *Clean Transportation*

Compressed Natural Gas (CNG) and Renewable Natural Gas (RNG)

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Ground Support Equipment, Fleet Vehicles, Airport Facilities, Infrastructure	Near Term	Medium Impact	Medium Cost	Low Risk

CNG is obtained from conventional natural gas, which is extracted from underground reservoirs, then is treated to remove impurities (water, CO_2, and H_2S), then compressed to high pressure (around 3,000 to 3,600 psi) to store and transport. CNG is primarily composed of methane (CH_4), making up about 90-95% of its content with the rest consisting of other gases. CNG is commonly used for transportation, industrial applications, residential and commercial heating, and power generation.

RNG, also known as biomethane, is a type of biogas that has been refined to match the chemical composition of traditional natural gas. RNG is produced from organic waste sources such as municipal solid waste landfills, livestock farms, wastewater treatment plants, and food production facilities. RNG is made of 90-98% CH_4, with other gases. For RNG, organic waste is collected and processed through anaerobic digestion to produce biogas. The biogas is then treated and upgraded to increase its CH_4 content before being distributed. RNG is commonly used for power generation, heating, industrial processes, transportation, and agricultural applications.

Overview

- **Compatibility**: CNG and RNG are compatible with infrastructure designed for natural gas since their similar chemical compositions, primarily consisting of methane. CNG, RNG, and Liquefied Natural Gas (LNG) can all be integrated or blended into the same systems and used for similar purposes.
- **Current Market & Growth Projections**: The U.S. CNG market generated a revenue of approximately $22.6 million in 2023. The U.S. CNG market is projected to reach $24.9 million by 2030, growing at a CAGR of 1.4% from 2024 to 2030.[295] As of 2024, the North America RNG market is valued at approximately $2.94 billion with a Compound Annual Growth Rate (CAGR) of 44.8%.[296]
- **Regulatory Environment**: The retail sale, use, storage, and consumption of alternative fuels, including CNG and LNG, are exempt from the state retail sales and use tax in North Carolina.[297]

[295] Grand View Research. (2024). *U.S. CNG Market Size & Outlook*
[296] Business Research Insights. (2025). *Renewable Natural Gas Market*
[297] U.S. DOE. *Alternative Fuels Data Center: Natural Gas Laws and Incentives in North Carolina*

Benefits & Challenges

Benefits	Challenges
• CNG burns cleaner than gasoline or diesel, producing fewer pollutants such as nitrogen oxides (NOx) and particulate matter (PM). It also emits less carbon dioxide (CO_2), contributing to improved air quality. • RNG captures methane from organic waste sources like landfills, livestock manure, and wastewater treatment plants. • CNG is typically more affordable than gasoline and diesel on a per-unit energy basis. • RNG use can earn environmental credits and incentives for reducing emissions. • CNG engines generally provide similar performance to gasoline engines in terms of power and torque. • RNG can be used in the same engines and infrastructure as conventional natural gas, providing similar performance characteristics.	• Technicians need specialized training to handle CNG and RNG systems, which involve high-pressure fuel storage and delivery. • Establishing CNG refueling infrastructure can be costly and time-consuming, requiring significant investment. • CNG and RNG have lower energy densities compared to gasoline and diesel, which can result in reduced range and the need for more frequent refueling.

Infrastructure Needs for General Aviation (GA) Airports

- **GA Airport's Responsibility:** A GA airport would need high-pressure storage tanks and refueling stations equipped with compressors and dispensers to support CNG and RNG use. CNG is stored in high-pressure cylinders or tanks, typically at pressures around 3,000 to 3,600 psi. RNG is stored similarly to conventional natural gas, either in high-pressure cylinders or in the existing natural gas pipeline network.
- **Other Stakeholders' Responsibility:** CNG production facilities require gas processing units to remove impurities and high-pressure compressors to compress the natural gas for storage. RNG production facilities require anaerobic digesters or gasifiers to convert organic waste into biogas, followed by biogas upgrading systems to remove impurities and increase methane content. CNG and RNG need high-pressure storage tanks and pipeline infrastructure to transport the compressed gas to refueling stations.

Additional Resources

- **Case Studies:**
  - **Denver International Airport (DEN)** operates 95 natural gas vehicles consuming over 770,000 gasoline gallon equivalents annually. It has five private CNG stations on-site and is transitioning its entire fleet to RNG.[298]
  - **Dallas Fort Worth International Airport (DFW)** launched a RNG Initiative in 2017, transitioning its CNG fleet to RNG sourced from local landfill gas. As of 2020, 70% of its fleet's natural gas use was RNG, cutting emissions by over 16,800 tonnes of CO_2 and saving $1 million annually in operations and maintenance.[299]
  - **More than 40 commercial airports across the U.S.** have been using natural gas-powered vehicles for over two decades. These airports are increasingly adopting RNG as a replacement for fossil-based CNG, benefiting from the environmental and economic advantages of RNG.[300]
- **Potential Funding and Incentives:**
  - The North Carolina Clean Energy Technology Center (NCCETC) offers support for clean transportation projects.[301]
  - Federal grant programs are currently being evaluated and are pending approval to continue.

Summary Ratings

- **Near Term**, transitioning to CNG or RNG is feasible within a short period due to the drop-in nature of these fuels and minimal new infrastructure investment required. CNG and RNG suppliers include Trillium, Shell, Clean Energy, and U.S. Energy.
- **Medium Impact**, while CNG produces fewer pollutants than diesel and gasoline, it is still derived from fossil fuels. The majority of CNG used in the U.S. is domestically extracted, with only about 0.01% imported from Canada, enhancing energy security. RNG generally results in lower emissions compared to CNG, but both RNG and CNG emit NOx and PM during combustion.
- **Medium Cost**, CNG and RNG can utilize existing natural gas infrastructure, requiring minimal modifications. RNG production often uses waste materials, reducing feedstock costs and enhancing sustainability. While infrastructure costs may be low, CNG and RNG are more expensive than traditional natural gas.
- **Low Risk**, implementing CNG and RNG involves risks such as higher costs, and potential supply chain disruptions. While implementation has lower risk due to the fuels being able to utilize existing natural gas-powered infrastructure with minimal modifications.

Recommendations

To integrate CNG and/or RNG at a GA airport, initiate a detailed feasibility study to evaluate infrastructure needs, fuel compatibility, and environmental impacts. Subsequently, install CNG and/or RNG storage and fueling facilities,

[298] The Transport Project. *Airports - Denver International Airport*
[299] United Nations Climate Change. *Renewable Natural Gas Initiative (Dallas Fort Worth International Airport)*
[300] United Nations Climate Change. (2023). *Renewable Natural Gas Initiative (DFW)*
[301] NC Clean Energy Technology Center. *Clean Transportation*

ensuring adherence to National Fire Protection Association (NFPA) 52 standards for the safe storage, handling, and distribution of compressed natural gas.

Propane (LPG – Liquefied Petroleum Gas)

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Ground Support Equipment, Fleet Vehicles, Airport Facilities, Infrastructure	Near Term	Insignificant Impact	High Cost	High Risk

Liquefied Petroleum Gas (LPG) is a versatile fuel derived from natural gas processing and crude oil refining. LPG is a mixture of hydrocarbon gases, primarily composed of propane (C_3H_8), butane (C_4H_{10}), and isobutane (C_4H_{10}). It can also contain small amounts of other hydrocarbons such as propylene (C_3H_6) and butylene (C_4H). LPG is stored and transported in a liquid state under moderate pressure, making it convenient for various uses. Propane burns cleanly, producing fewer emissions compared to gasoline and diesel. Its high energy content and reliability make it a popular choice for residential heating and cooling, industrial applications, agriculture, transportation, portable stoves/heaters, and hot water systems.

Overview

- **Compatibility**: LPG is not compatible with gasoline or diesel-powered equipment, necessitating retrofits or the acquisition of new equipment designed specifically for LPG use.
- **Current Market & Growth Projections**: The 2023 U.S. market revenue of LPG was $18 billion with a Compound Annual Growth Rate (CAGR) of 3.9% from 2024-2030. By 2030, the market is projected to reach $23.5 billion by 2030.[302]
- **Regulatory Environment**: Occupational Safety and Health Administration (OSHA's) standard 1910.110 covers the storage and handling of LPG, including container specifications, safety measures, and fire protection.[303] National Fire Protection Association (NFPA) 58 sets the benchmark for LPG storage and handling safety across the U.S.[304]

[302] Grand View Research. (2024). U.S. Butane Market Size & Outlook, 2023-2030
[303] OSHA. 1910.110 - *Storage and Handling of Liquefied Petroleum Gases*
[304] NFPA. *NFPA 58 Team Training*

Benefits & Challenges

Benefits	Challenges
• LPG emits about 33% less carbon dioxide than coal and 12% less than oil.[305] • LPG is often more cost-effective than other fossil fuels like coal and oil. • LPG has a lower energy density compared to gasoline and diesel, but it is still an efficient and effective fuel source.	• Converting existing equipment and vehicles to LPG powered would require investment and technical expertise. • LPG prices can be volatile, influenced by global oil prices. • Ensuring compliance with state and federal safety regulations, such as those set by the NFPA, require regular inspections, maintenance, and staff training.

Infrastructure Needs for GA (General Aviation) Airports

- **GA Airport's Responsibility:** GA airports need LPG storage tanks, piping, and dispensing units that meet safety and operational standards.
- **Other Stakeholders' Responsibility:** LPG production facilities require raw material supply, processing units, storage tanks, safety systems, and distribution infrastructure. LPG is transported in tanks via delivery trucks, barges, tanker ships, trucks, and rail.

Additional Resources

- **Case Studies:** Commercial airports that previously had LPG Ground Support Equipment (GSE) vehicles are converting them to Compressed Natural Gas (CNG) and Electric Ground Support Equipment (eGSE) vehicles. This shift is driven by advancements in technology, improved cost feasibility, government incentives, and environmental considerations**. San Francisco International Airport (SFO)[306] and Dallas Fort Worth International Airport (DFW)**[307] changed out their LPG GSE vehicles to CNG and eGSE vehicles.
- **Potential Funding and Incentives:**
  - The North Carolina Clean Energy Technology Center (NCCETC) offers support for clean transportation projects.[308]
  - Federal grant programs are currently being evaluated and are pending approval to continue.

[305] World Liquid Gas Association. (2018). *The Role of LPG in Shaping the Energy Transition*
[306] SFO. (2021). *SFO Clean Vehicle Fact Sheet*
[307] DFW. (2024). *Environmental, Social, and Governance Report*
[308] NC Clean Energy Technology Center. *Clean Transportation*

Summary Ratings

- **Near Term**, LPG can be used in the U.S. and North Carolina now. In North Carolina, numerous companies supply LPG. Suppliers include Amerigas, Ferrellgas, and Growmark Inc.
- **Insignificant Impact**, LPG is derived from petroleum and not renewable resources. While LPG emissions are generally cleaner than gasoline and diesel, producing lower levels of carbon monoxide (CO), hydrocarbons (HC), and NOx, and virtually no Particulate Matter (PM), it is comparable to CNG in terms of reduced greenhouse gases and air pollutants. However, there are cleaner alternative fuels available than LPG.
- **High Cost**, implementing LPG requires significant investment in new equipment or retrofitting existing equipment, which can be costly. Additionally, purchasing new storage and refueling infrastructure is necessary to support LPG use at GA airports.
- **High Risk**, with the market shifting away from LPG for GSE vehicles, investing in LPG-powered GSE is risky due to the infrastructure requirements and the potential for future obsolescence.

Recommendations

For GA airports, it is essential to conduct a comprehensive feasibility study to assess energy needs and explore more viable alternatives to LPG, as the market is shifting away from this fuel source. It is important to ensure the adoption of secure and future-proof energy solutions.

Biofuels for Diesel and Gasoline Engines

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Ground Support Equipment, Fleet Vehicles, Airport Facilities, Infrastructure	Near Term	Medium Impact	Medium Cost	Medium Risk

Biofuels are renewable energy sources derived from organic materials like plants, algae, and animal waste. They are used as alternatives to traditional fossil fuels, offering a more resilient and public health friendly option for powering vehicles, generating electricity, and heating. There are numerous types of biofuels that cater for diesel and gasoline engines. Some of the biofuels that can be used in diesel engines include biodiesel, renewable diesel, hydrotreated vegetable oil (HVO), and biomass-to-liquid (BTL). Some biofuels for gasoline engines include ethanol, biobutanol, biomethanol, and biogasoline.

Overview

- **Compatibility**: Biofuels like biodiesel are generally compatible with most diesel engines, especially newer models, but older engines (pre-1994) might require modifications due to biodiesel's solvent properties. For gasoline engines, ethanol blends such as E10 (10% ethanol) are widely compatible, though higher blends may necessitate engine adjustments and can impact fuel efficiency.
- **Current Market** & **Growth Projections**: The U.S. biofuels market is projected to grow from $64.06 billion in 2024 to around $106.02 billion by 2034, with a Compound Annual Growth Rate (CAGR) of 5.17%.[309]
- **Regulatory Environment**: Currently, biofuels must be blended with conventional fuels, as current regulations limit a maximum of 20% biodiesel in the mixture for diesel engines and up to 10% ethanol for gasoline engines.[310][311] The U.S. regulatory environment for biofuels is shaped by the Environmental Protection Agency (EPAs) Renewable Fuel Standards (RFS), which mandates specific blending volumes for biodiesel and ethanol to increase air quality and promote energy independence.[312]

[309] Precedence Research. (2025). *Biofuels Market*
[310] U.S. DOE. *Alternative Fuels Data Center: Biodiesel Codes, Standards, and Safety*
[311] EPA. (2024). *Federal Gasoline Regulations*
[312] EPA. (2025). *Overview of the Renewable Fuel Standard Program*

Benefits & Challenges

Benefits	Challenges
• Biofuels reduce the reliance on fossil fuels, increase energy security, and can be produced domestically. • Biofuels enhance air quality when compared to traditional fossil fuels. • Growing biomass crops for biofuel production can create new economic opportunities for farmers.	• High production costs of biofuels are significant economic barriers to their widespread adoption. • Biofuels must be blended with conventional fuels due to regulations limiting biodiesel to 20% for diesel engines and ethanol to 10% for gasoline engines. • The use of 100% biofuels for diesel or gasoline engines is not approved.

Infrastructure Needs for General Aviation (GA) Airports

- **GA Airport's Responsibility:** To adopt pre-blended biofuels, a GA airport needs infrastructure for storage and distribution, including dedicated tanks. If the airport opts to blend its own fuels, a blending system would also be necessary.
- **Other Stakeholders' Responsibility: Biofuel** production facilities include feedstock processing, conversion technologies, refining and purification systems, storage and distribution infrastructure, quality control labs, and environmental and safety measures. Biofuels are transported from production facilities to distribution terminals using rail, trucks, and barges. Rail is commonly used for long-distance transport, while trucks and barges handle regional and local distribution.

Additional Resources

- **Case Studies:**
  - **San Francisco International Airport (SFO)** operates some transit and airfield buses, 23 highway coaches, and 122 staff and utility vehicles on renewable diesel.[313]
  - **Lambert-St. Louis International Airport (STL)** as of 2018, has 200 biodiesel powered vehicles.[314]
  - **San Diego International Airport (SAN)** uses renewable diesel for all diesel-powered airside vehicles and equipment, like baggage tugs and belt loaders.[315]
- **Potential Funding and Incentives:**
  - The North Carolina Clean Energy Technology Center (NCCETC) offers support for clean transportation projects.[316]
  - Federal grant programs are currently being evaluated and are pending approval to continue.

[313] *SFO. (2021). SFO Clean Vehicle Fact Sheet*
[314] STL. (2018). *STL Promotes Fleet of Alternative Fuel Vehicles and Sustainability Efforts*
[315] SAN. (2023). *San Diego International Airport Begins Using Renewable Diesel for Airside Equipment*
[316] NC Clean Energy Technology Center. *Clean Transportation*

Summary Ratings

- **Near Term**, blended biofuels can be used in the U.S. and North Carolina now. In North Carolina, several companies supply pre-blended biofuels. Suppliers include Premier Operations and Engineering Technology, Renewable Energy Group, and Clean Energy.
- **Medium Impact**, blended biofuels still contain fossil fuels, such as ethanol blends like E10 (10% ethanol, 90% gasoline) and biodiesel blends like B20 (20% biodiesel, 80% petroleum diesel). Their use can slightly enhance energy security by reducing reliance on imported petroleum.
- **Medium Cost**, implementing blended biofuels at a GA airport would incur costs due to the need for infrastructure upgrades, such as dedicated storage tanks and distribution systems. Additionally, ongoing expenses for purchasing pre-blended biofuels and ensuring regulatory compliance contribute to the overall cost.
- **Medium Risk**, blended biofuels pose less risk as they can often utilize existing vehicles and Ground Support Equipment (GSE). However, the costs associated with necessary storage infrastructure upgrades can increase the overall risk.

Recommendations

For GA airports to integrate biofuels for diesel or gasoline engines, conduct a comprehensive feasibility study to assess fuel compatibility, storage requirements, and infrastructure modifications. Implement biofuel storage and dispensing systems, ensuring compliance American National Standards Institute (ASTM) D6751[317] for biodiesel and ASTM D4814[318] for ethanol-blended gasoline, while addressing any engine performance and emissions considerations.

[317] ASTM. (2023). *ASTM D6751 Standard Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels*
[318] ASTM. (2023). *ASTM D6751 Standard Specification for Automotive Spark-Ignition Engine Fuel*

Liquefied Natural Gas (LNG)

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Ground Support Equipment, Fleet Vehicles, Airport Facilities, Infrastructure	Near Term	Insignificant Impact	High Cost	Medium Risk

LNG is natural gas, primarily composed of methane (CH_4) with small amounts of ethane (C_2H_6), that has been cooled to approximately -162°C (-260°F) to convert it into a liquid form for easier storage and transportation. LNG is obtained by extracting natural gas from underground reservoirs, processing it to remove impurities, and then cooling it to liquefy it. LNG is odorless, colorless, non-toxic, and non-corrosive, making it a practical fuel option. General Aviation (GA) airports can use LNG for several applications, including powering Ground Support Equipment (GSE) such as baggage tugs and fuel trucks, providing heating and cooling for terminal buildings, and generating electricity for airport operations.

Overview

- **Compatibility**: While LNG often requires engine modifications, certain types of LNG, like synthetic LNG and bio-LNG blends, can be used as drop-in fuels in specific applications. LNG can be used as a drop-in fuel for natural gas applications.
- **Current Market** & **Growth Projections**: The U.S. LNG market was valued at approximately $2.91 billion in 2023.[319] The U.S. LNG market is expected to grow at a Compound Annual Growth Rate (CAGR) of 5.70% from 2024 to 2031, reaching $4.54 billion by 2031.[320]
- **Regulatory Environment**: LNG use is regulated by the North Carolina Utilities Commission (NCUC) and must comply with state and federal safety standards.

[319] Markets & Data. (2024). *United States LNG Market Assessment, Opportunities and Forecast, 2017-2031F*
[320] Id.

Benefits & Challenges

Benefits	Challenges
• LNG prices are generally lower than diesel and gasoline prices on a per-unit energy basis. This can result in significant cost savings, especially for large-scale operations. • Utilizing LNG can decrease reliance on imported oil, enhancing energy security for airports. • LNG-powered vehicles and equipment may have lower maintenance costs due to cleaner combustion and reduced engine wear. • LNG significantly lowers emissions of SOx, NOx, and particulate matter, leading to improved air quality around airports.	• The upfront costs for converting equipment and building infrastructure (storage and refueling station) can be high. While there may be long-term savings, the initial investment can be a barrier. • LNG must be stored at extremely low temperatures (-162°C or -260°F), which necessitates advanced insulation and cooling systems. • Converting existing GSE and vehicles to run on LNG involves modifying or replacing engines, which can be costly and technically complex.

Infrastructure Needs for GA Airports

- **GA Airport's Responsibility:** Storage tanks must be designed to store LNG at extremely low temperatures (-162°C or -260°F) to keep it in a liquid state. Specialized cryogenic pumps and piping systems are required to handle the transfer of LNG from storage tanks to refueling stations.
- **Other Stakeholders' Responsibility:** LNG production involves natural gas pre-treatment units, cryogenic heat exchangers, liquefaction units, LNG storage tanks, cryogenic pumps, and boil-off gas compressors. Cryogenic tankers, trucks, ships, and rail are used to transport LNG from production facilities to airports.

Additional Resources

- **Case Studies:**
  - Numerous commercial U.S. airports utilize Compressed Natural Gas (CNG) powered GSE or fleet vehicles, but not LNG. In general, airports prefer CNG over LNG for fleet vehicles because CNG is easier and safer to store and handle. Additionally, CNG is generally less expensive and sufficient for the operational needs of airport ground transportation.
  - **Los Angeles International Airport (LAX)** greatly decreased the size of their LNG vehicle fleet from 2019 to 2020.[321]
- **Potential Funding and Incentives:**
  - The North Carolina Clean Energy Technology Center (NCCETC) offers support for clean transportation projects.[322]

[321] Los Angeles World Airports. (2023). *LAWA 2023 Sustainability Report*
[322] NC Clean Energy Technology Center. *Clean Transportation*

- Federal grant programs are currently being evaluated and are pending approval to continue.

Summary Ratings

- **Near Term**, LNG can be used for fueling fleet vehicles and GSE vehicles in the U.S. and North Carolina. North Carolina has numerous LNG suppliers, ensuring a reliable fuel supply and supporting infrastructure. LNG suppliers include Shell, TotalEnergies, and Southern Company Gas.
- **Insignificant Impact**, LNG enhances energy security by diversifying energy sources and reducing dependence on specific regions for natural gas. While LNG produces lower emissions than coal and oil, its lifecycle emissions, including methane leaks, can be significant.[323]
- **High Cost**, LNG implementation at a GA airport is costly due to the investment required for building specialized infrastructure, such as cryogenic storage tanks, pipelines, and refueling stations. Additionally, LNG is generally more expensive than diesel and gasoline.
- **Medium Risk**, implementing LNG at a GA airport involves risks such as high infrastructure costs for specialized cryogenic storage tanks, pipelines, and refueling stations. Additionally, there are safety concerns related to potential leaks, fires, and regulatory compliance, which require advanced safety systems and rigorous monitoring.

Recommendations

For a GA airport to integrate LNG, conduct a comprehensive feasibility study to assess energy demands, infrastructure requirements, and potential environmental impacts. Install LNG storage and fueling facilities, ensuring compliance with stringent safety and environmental regulations, and engage with staff to address technical and operational concerns.

[323] Resources for the Future. (2025). *Unpacking the Department of Energy's Report on US Liquefied Natural Gas Exports*

Synthetic Fuels for Diesel and Gasoline Engines

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Ground Support Equipment, Fleet Vehicles, Airport Facilities, Infrastructure	Long Term	Medium Impact	Medium Cost	High Risk

Synthetic fuels, or synfuels, are man-made fuels produced from syngas—a mixture of carbon monoxide and hydrogen—derived from sources like coal, natural gas, or biomass. These fuels can be used in transportation, aviation, and industrial processes. In this section, we will focus on synthetic fuels for diesel and gasoline engines. Composed of hydrocarbons similar to those found in conventional fuels, synfuels are compatible with existing diesel and gasoline engines and infrastructure. In the U.S., synthetic fuels can be used either as a 100% replacement or blended with conventional fuels to reduce emissions and enhance fuel performance.

Overview

- **Compatibility**: Synfuels like Fischer-Tropsch diesel and Hydroprocessed Esters and Fatty Acids (HEFA) can be used in diesel engines without significant modifications. Synfuels such as Methanol-to-Gasoline (MTG) and other synthetic gasoline variants can be used in gasoline engines, as they are designed to be drop-in fuels.
- **Current Market** & **Growth Projections**: The market size was valued at approximately $6.27 billion in 2024 and is expected to reach around $47.30 billion by 2034, growing at a Compound Annual Growth Rate (CAGR) of 22.40%.[324]
- **Regulatory Environment**: Synthetic fuels for diesel and gasoline engines are regulated under the Clean Air Act, which mandates stringent emissions standards and fuel quality requirements enforced by the Environmental Protection Agency (EPA).

Benefits & Challenges

Benefits	Challenges
• Synfuels do not require dedicated agricultural land or substantial water resources, avoiding land-use and water scarcity issues. • When produced with renewable energy and captured CO_2, synfuels can be nearly carbon-neutral. • Synfuels produce fewer pollutants, leading to improved air quality.	• Synfuels are generally more expensive than conventional gasoline and diesel. • Ensuring existing storage and distribution systems can handle synfuels without contamination or degradation.

[324] Skyquest. (2024). *Synthetic Fuel Market Size, Share, and Growth Analysis*

Infrastructure Needs for General Aviation (GA) Airports

- **GA Airport's Responsibility:** The infrastructure required for storage and handling depends on the specific type of synfuels. Generally, this includes fuel storage tanks, dispensing systems, and refueling stations. For synfuels that require low-temperature storage, cryogenic equipment may also be necessary.
- **Other Stakeholders' Responsibility:** Synfuel production requires feedstock processing facilities, synthesis reactors, storage tanks, and catalysts. Additionally, if low-temperature storage is necessary, temperature control systems must be included. Synfuels distribution involves modular feeder plants converting feedstock into intermediates like methanol, sent to centralized hubs for final fuel conversion. These fuels are then distributed through existing pipelines, storage tanks, and dispensing systems.

Additional Resources

- **Case Studies:** There is a lack of extensive public documentation on the use of synthetic fuels for diesel and gasoline engines specifically at U.S. airports. Most synfuel efforts are in the aviation sector focused on Sustainable Aviation Fuels (SAFs).
- **Potential Funding and Incentives:**
  - The North Carolina Clean Energy Technology Center (NCCETC) offers support for clean transportation projects.[325]
  - Federal grant programs are currently being evaluated and are pending approval to continue.

Summary Ratings

- **Long Term**, synfuels for diesel and gasoline engines require further development before they can be widely deployed. Synfuel suppliers include Synfuels Americas and Chemieanlagenbau Chemnitz (CAC) Synfuel.
- **Medium Impact**, synfuels can be produced from a variety of feedstocks, including biomass, natural gas, and even captured carbon dioxide. This diversification reduces dependence on traditional fossil fuels and enhances energy security by providing alternative sources. Synfuels generally produce fewer pollutants, such as Sulphur Oxides (SOx) and Nitrogen Oxides (NOx), contributing to improved air quality.
- **Medium Cost**, synfuels need specialized storage and distribution systems, which may involve upgrading existing infrastructure or installing new systems.
- **High Risk**, the market for synfuels is still developing, and fluctuations in production costs and demand can create financial instability.

Recommendations

If the synthetic fuels market continues to develop and becomes a viable alternative to gasoline and diesel, evaluate its feasibility for the GA airport. If deemed viable, develop a comprehensive strategy to integrate synfuels

[325] NC Clean Energy Technology Center. *Clean Transportation*

into airport operations, considering factors such as infrastructure requirements, cost-effectiveness, and environmental benefits.

Hybrid Electric Systems

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Ground Support Equipment, Fleet Vehicles, Airport Facilities, Infrastructure, Utilities	Near Term	Medium Impact	Medium Cost	Low Risk

In this section, we will exclusively refer to non-plug-in hybrid electric vehicles (HEVs) when discussing hybrid electric system alternatives for General Aviation (GA) airports. This distinction is made because plug-in hybrids can benefit from recommendations outlined in the Electricity section. HEV systems combine an Internal Combustion Engine (ICE) with one or more electric motors and a battery pack to improve fuel efficiency and reduce emissions. These systems typically include components such as regenerative braking, which captures energy during braking to recharge the battery, and a power management system that optimizes the use of both the engine and electric motor. HEVs offer a cost-effective solution for GA airports looking to transition their fleet and Ground Support Equipment (GSE) vehicles from gasoline and diesel. By integrating HEVs, airports can significantly reduce fuel costs and emissions, while benefiting from the reliability and efficiency of hybrid technology.

Overview

- **Compatibility**: To fully implement HEV technology, new HEVs and hybrid electric GSE vehicles must be purchased, as existing gasoline and diesel-powered vehicles cannot be converted easily.
- **Current Market** & **Growth Projections**: The U.S. HEV market was valued at approximately $96.09 billion in 2025 and is projected to reach between $101.66 billion and $159.60 billion by 2033, growing at a Compound Annual Growth Rate (CAGR) of 5.8%.[326]
- **Regulatory Environment**: The regulatory environment for HEV and hybrid electric GSE at U.S. airports is focused on reducing emissions through federal, state, and local initiatives, alongside airport-specific programs and technological advancements.

[326] Global Growth Insights. (2025). *Hybrid Vehicles Market*

Benefits & Challenges

Benefits	Challenges
• HEVs recharge their batteries through regenerative braking and the ICE, eliminating the need for charging infrastructure. • HEVs produce fewer emissions compared to conventional vehicles, leading to better health outcomes for airport workers. • Enhanced fuel efficiency leads to reduced fuel expenses over time. • HEVs are quieter, reducing noise pollution and creating a more pleasant working environment for airport staff.	• The upfront cost of purchasing HEVs and hybrid electric GSE can be higher than traditional gasoline or diesel-powered equipment and vehicles. • The dual powertrain system (ICE and electric motor) can lead to more complex and potentially costly maintenance. • HEVs typically have a shorter electric-only range compared to plug-in hybrids. • The lifespan of hybrid batteries and the cost of replacement can be a concern, especially in high-usage environments like airports.

Infrastructure Needs for GA Airports

- **GA Airport's Responsibility:** GA airports need to set up specialized maintenance facilities to support HEVs and hybrid-electric GSE. Additionally, they require staff training programs, battery management systems, and data management systems.
- **Other Stakeholders' Responsibility:** Production facilities need advanced manufacturing equipment, energy management systems, and quality control systems to support HEV and hybrid-electric GSE. Additionally, they require research and development (R&D) labs, supply chain integration, workforce training programs, and environmental compliance systems. HEV and hybrid-electric GSE suppliers need a robust supply chain system, vehicle delivery, specialized maintenance services, and comprehensive training programs.

Additional Resources

- **Case Studies:** Numerous commercial airports have been converting their gasoline and diesel fleets to fully electric or plug-in HEVs and GSEs.
- **Potential Funding and Incentives:**
  - The North Carolina Clean Energy Technology Center (NCCETC) offers support for clean transportation projects.[327]
  - Federal grant programs are currently being evaluated and are pending approval to continue.

Summary Ratings

- **Near Term**, HEV and hybrid-electric GSEs can be used in the U.S. and North Carolina. The technology is mature and can be deployed efficiently. As HEV and hybrid-electric GSE use traditional fuels, traditional fuel suppliers include Shell, Mobil, and Marathon.

[327] NC Clean Energy Technology Center. *Clean Transportation*

- **Medium Impact**, HEVs and hybrid-electric GSEs still rely on gasoline, which means they do not entirely eliminate dependence on imported fossil fuels. However, they do offer significant benefits by reducing air pollutants and emissions compared to traditional diesel and gasoline vehicles.
- **Medium Cost**, integrating HEVs and hybrid-electric GSE incurs moderate costs due to the investments required for new HEVs and hybrid-electric GSEs. Additionally, providing staff training further contributes to the overall expense.
- **Low Risk**, integrating HEVs and hybrid–electric GSE poses low risk for a GA airport due to the proven reliability and safety of the technology. The ability of these vehicles to use gasoline provides an excellent middle ground between traditional diesel and gasoline vehicles and fully electric options, making the transition smoother and more flexible.

Recommendations

Conducting a feasibility study will help assess the long-term savings potential, including available grants and incentives to offset costs. By reducing dependency on fossil fuels and increasing energy efficiency, hybrid-electric technologies can provide more stable and predictable energy costs, contributing to greater operational resilience and sustainability.

Electrification

Electrification offers numerous opportunities to convert equipment and vehicles from fossil fuels to electricity, enhancing energy security, reducing emissions, improving public health, and lowering operational costs. This shift is supported by commercially available technology and requires upgrading existing infrastructure to accommodate future electrification efforts. Key benefits include:

- **Energy Security:** Electrification reduces dependence on imported fossil fuels, enhancing energy security and resilience by increasing reliance on domestically and renewably produced electricity. This shift supports the use of renewable energy sources like solar and wind, further diversifying and stabilizing the energy supply.
- **Cost Savings:** EVs are approaching price parity when compared to their internal combustion counterparts in many vehicle classes and offer reduced fuel, operation, and maintenance expenses, making them more economical in the long run.
- **Improved Public Health:** Lower emissions from EVs lead to enhanced air quality, reducing respiratory and cardiovascular diseases and contributing to overall better public health. A benefit for any electrified vehicle is that over time, as the grid gets cleaner, the greenhouse gas (GHG) reduction benefits of the vehicle also increase.

While the Alternative Fuels section provided a brief overview of electrification, primarily focusing on eGSE and vehicles, this section will delve into specific categories of vehicle, equipment, and infrastructure electrification efforts that can be implemented. The electrification section will discuss energy security in terms of landside, airside, and fleet operations. Landside includes EV charging in parking areas for public and support for EV TNC/Taxi use. Airside includes eGSE, electric aircraft, pre-conditioned air (PCA) systems, and ground powered units (GPUs). Then, fleet includes maintenance vehicles, shuttles, firetrucks, and ground maintenance Equipment.

There are three levels of electric vehicle (EV) chargers available:

- Level 1 (L1)– Standard Outlet Charging
  - Power Range: <2.0kW
  - Power Source: 120 volts alternating current (AC)
  - Charging Speed: ~3–5 miles of range per hour
  - Use Case: Charging for plug-in hybrids or overnight/multi-day charging when speed isn't critical
  - Pros: Low cost, no special equipment needed
  - Cons: Very slow; not practical for EVs with long duty cycles
- Level 2 (L2) – Faster, Common Public and Home Charging
  - Power Range: >2.0kW and < 19.2kW
  - Power Source: 240 volts AC
  - Charging Speed: ~10–30 miles of range per hour
  - Use Case: Home, workplace, and public charging stations (airports, malls, etc.)
  - Pros: Balanced speed and cost; ideal for daily use
  - Cons: Requires installation of a dedicated charging unit and 240V supply
- DC Fast Charging (DCFC) – High Demand Charging
  - Power Range: >50kW and 350+kW
  - Power Source: 400-1,000V DC
  - Charging Speed: ~60–250+ miles of range in 20–30 minutes
  - Use Case: High-traffic commercial sites, TNC/taxi, and along highways
  - Pros: Very fast charging
  - Cons: Expensive to install and operate; not all EVs are compatible or can accept these higher power levels

Landside

The landside portion of the airport, accessible to the general public before the security checkpoint, plays a role in energy security, public health, and safety around GA airports. This section will focus on airport-owned parking areas and TNC/taxi vehicles in terms of electrification. Although TNC/taxi vehicles are not owned by the airport, various incentive programs can be implemented by a GA airport to support their electrification. The presence of TNCs and taxis idling at airports contributes to higher levels of ambient air pollution, which can negatively impact public health.

Parking Areas

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Airport Facilities, Infrastructure, Utilities	Near Term	Insignificant Impact	Medium Cost	Medium Risk

Electrifying parking areas at General Aviation (GA) airports involves installing electric vehicle (EV) chargers to support the growing number of EVs. This initiative not only enhances the airport's sustainability efforts by encouraging the reduction of fossil fueled vehicles. Furthermore, these chargers can incentivize the use of EVs among passengers and staff, promoting cleaner air and improved public health. Upgrading parking areas with EV chargers is a strategic move that aligns with broader goals of energy security stewardship, and environmental benefits.

Overview

- **Compatibility:** Existing parking lots without integrated conduit are generally not compatible with EV chargers, as they lack the necessary infrastructure for electrical wiring. Retrofitting these lots often requires upgrades, including the installation of conduit pathways and electrical capacity assessments. Installing chargers close to the electric supply point and along undeveloped areas (e.g. grass covered areas) can minimize installation costs.
- **Current Market & Growth Projections:** The U.S. EV charging market is rapidly growing, currently valued at around $5.09 billion[328] and projected to grow at a Compound Annual Growth Rate (CAGR) of 30.3% from 2025 to 2030.[329] By 2030, the number of EVs on U.S. roads is expected to reach approximately 28 million [330], driving significant expansion in charging infrastructure.
- **Regulatory Environment:** Installing EV chargers in parking lots requires compliance with local building codes, parking ordinances, and accessibility requirements to ensure safety and accessibility. Chargers must adhere to the National Electrical Code (NEC) and be Underwriters Laboratories (UL) listed to meet electrical safety standards. Additionally, installations should follow the U.S. Access Board's Americans with Disabilities Act (ADA) Recommendations for EV Chargers[331] to ensure accessibility for individuals with disabilities.

Benefits & Challenges

Benefits	Challenges
• Ability to collect revenue from public EV chargers to receive some earnings for the airport.	• Ensuring the existing electrical infrastructure can support the additional

[328] Grand View Research. (2025). *U.S. Electric Vehicle Charging Infrastructure Market, Report 2030*
[329] Id.
[330] U.S. DOE. *EVGrid Assist: Charts and Figures*
[331] U.S. Access Board. (2023). *Design Recommendations for Accessible Electric Vehicle Charging Stations*

Benefits	Challenges
• Encourage the use of EVs around the airport, resulting in enhanced air quality, reduced emissions and a healthier environment for airport users and staff. • As EV adoption continues to grow, having charging infrastructure in place ensures the airport is prepared to meet future demand and remain competitive. • Enhance the user experience for pilots, passengers, and staff that drive EVs.	load of EV chargers may require substantial upgrades. • The initial investment in equipment, electrical upgrades, and installation can be significant. This includes costs for trenching, conduit installation, and upgrading electrical panels. • Finding suitable locations within the parking lot that can accommodate the chargers without disrupting the parking flow or accessibility can be difficult. This is especially challenging in densely packed or older lots. • Potential for low initial demand and underutilized assets in the early years.

Infrastructure Needs

- **GA Airport's Responsibility:** A GA airport's responsibilities for installing EV chargers for public use include conducting a thorough site assessment to evaluate electrical infrastructure and suitable locations for chargers. The airport must ensure compliance with local building codes, fire safety regulations, and accessibility requirements, adhering to standards like the NEC. Engaging stakeholders, including local government and utility companies, is essential for successful implementation. Additionally, managing consultants for the design and contractors for the installation is crucial to ensure the project is completed efficiently and meets all regulatory requirements. The airport would establish a plan for ongoing maintenance, operation, and revenue collection to ensure the chargers remain functional and accessible to the public. The necessary EV charger infrastructure includes electrical upgrades, conduit and wiring, EV chargers, mounting equipment, software for management, and appropriate signage and lighting.
- **Other Stakeholders' Responsibility:** Local government provides permits and ensures zoning compliance. Utilities assess and upgrade electrical infrastructure to ensure reliable power supply. EV charger manufacturers supply equipment and technical support. Consultants are responsible for designing the plans to ensure the project meets all regulatory and technical requirements, while contractors handle physical installation.

Additional Resources

- **Case Studies:**
  - Numerous commercial airports have public EV chargers at airport parking lots. The list includes **Dallas Fort Worth International Airport (DFW), Portland International Airport (PDX), Los Angeles International Airport (LAX), San Franciso International Airport (SFO), Hartsfield-Jackson Atlanta International Airport (ATL), John Wayne Airport (SNA), Salt Lake City International Airport (SLC),**

Seattle-Tacoma International Airport (SEA), Denver International Airport (DEN), and Chicago O'Hare International Airport (ORD). [332]

- **LAX** has 400 EV charging stations spread across three terminal parking lots, with plans to add 1,200 more chargers to accommodate the growing number of EV users.
- **SFO** offers 176 EV chargers in its parking garages, providing free charging for both Level 2 and Level 1 chargers.

- **Potential Funding and Incentives:**
  - The Volkswagen Environmental Mitigation Trust[333] provides funding for the installation of public EV chargers to reduce emissions and improve air quality. These grants support the purchase and installation of charging equipment at various locations, including public buildings, workplaces, and retail sites. The Volkswagen grant ends October 2nd, 2027, although remaining funding allocations are unknown.[334]
    - The National Electric Vehicle Infrastructure (NEVI) Formula Program[335], established by the Infrastructure Investment and Jobs Act (IIJA), allocates $7.5 billion to build a nationwide EV charging network along highways and in communities. NEVI funds are distributed to states to deploy EV chargers, ensuring accessibility and supporting the transition to EVs. The status of the NEVI Formula Program remains uncertain while current administration policies are under review.

Summary Ratings

- **Near Term**, EV chargers are commercially available and can be deployed immediately, contingent upon supply chain availability.
- **Insignificant Impact**, public EV chargers will have a minimal effect on the airport's energy security efforts. However, the increased use of EVs around the airport, as opposed to traditional fuel vehicles, will lead to reduced emissions and improved public health in the area.
- **Medium Cost**, retrofitting a parking lot with EV chargers involves significant upfront costs, including the price of chargers and necessary electrical infrastructure upgrades. Additional expenses include permits, site preparation, and installation.
- **Medium Risk**, Installing EV chargers at the GA airport's parking areas presents several risks, including moderate upfront costs, uncertain usage patterns, and ongoing maintenance and operational expenses.

Recommendations

GA airports can deploy EV chargers in parking lots to meet the growing demand for EVs. Conducting a survey to gauge interest from airport users can help determine demand. If interest is high, a feasibility study of the parking areas should be conducted. If the project is within budget and prioritized by the airport, proceed with planning, designing, procurement, and installation of the EV chargers.

---

[332] EV Charging Summit. (2024). *The Top 10 Airports with EV Charging Technology*
[333] NCDEQ. *Volkswagen Settlement*
[334] NCDEQ. (2025). *Volkswagen Settlement Community and Destination Zero-Emission Vehicle Infrastructure Program*
[335] NCDOT. (2025). *NEVI Program Information*

Transportation Network Companies (TNC)/Taxi

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Fleet Vehicles, Airport Facilities, Infrastructure, Utilities	Medium Term	Insignificant Impact	Low Cost	High Risk

Electrifying TNC and taxi fleets involves transitioning these fleets from internal combustion vehicles (ICEs) to electric vehicles (EVs), including battery-electric vehicles (BEVs) and plug-in hybrid vehicles (PHEVs). Although GA airports do not own and operate TNC and taxi companies, they can incentivize electrification by offering EV priority pick-up zones, installing charging infrastructure, reducing airport access fees, and lowering advertising fees for EV TNCs and taxis. This transition poses challenges such as high upfront costs for the General Aviation (GA) airport to support by installing direct current fast charging (DCFC). By reducing emissions of harmful pollutants like Nitrogen Oxides (NOx), Particulate Matter (PM), and Volatile Organic Compounds (VOCs), electrification can improve air quality around airports, leading to fewer respiratory and cardiovascular diseases among airport employees and nearby residents. Overall, electrification aligns with regional energy security goals and contributes to greater energy resilience and public health improvements.

Overview

- **Compatibility:** To transition to electrification, new EVs or PHEVs must be acquired. EVs would need compatible port types with charging infrastructure the GA airport can provide.
- **Current Market & Growth Projections:** Growth projections indicate that the adoption of EVs within TNC and taxi fleets will accelerate over the next few years. Factors such as advancements in EV technology, decreasing battery costs, and expanded charging infrastructure are expected to support this trend.
- **Regulatory Environment:** EVs are exempt from state emissions inspection requirements, which helps reduce operational costs. Qualified PHEVs, dedicated natural gas vehicles, and fuel cell electric vehicles (FCEVs) can use high-occupancy vehicle (HOV) lanes regardless of the number of occupants.

Benefits & Challenges

Benefits	Challenges
• Enhance air quality around the airport from decreasing the amount of ICE TNC and taxis idling and operating in the area. • Providing chargers and/or incentives for EV TNCs/taxis give passengers more transportation options to/from the airport. • Opportunities for revenue generation by collecting fees for charging.	• Airports must work closely with TNC and taxi companies, which they do not own, to implement electrification initiatives. This requires effective collaboration and alignment of goals. • If the GA airport decides to install chargers on-site for TNCs and taxis, it will face challenges, including the high upfront costs of the chargers, ongoing operations and maintenance expenses, and the complexities of securing necessary permits and complying with regulations.

	• Smaller GA airports likely have limited TNC or taxi traffic which could lead to underutilized charging infrastructure.

Infrastructure Needs

- **GA Airport's Responsibility:** GA airports can designate EV priority pick-up zones to improve operational efficiency and lower or waive airport access fees to make the switch more cost-effective. Also, GA airports can install DCFCs at the airport parking lot to further incentivize TNCs and taxis to electrify their fleets. Installing EV chargers involves major infrastructure needs and can be referenced in the beginning of the Electrification section.
- **Other Stakeholders' Responsibility:** TNCs and taxi operators can support fleet electrification by adopting EVs, offering driver incentives, expanding charging infrastructure, providing education and training, and advocating for supportive policies.

Additional Resources

- **Case Studies:**
  - **Portland International Airport (PDX)** enhanced amenities for gig drivers by installing free DC fast chargers in the TNC staging lot. This initiative led to a sharp rise in the number of EV gig drivers operating at the airport in the following months.[336]
  - **Los Angeles International Airport (LAX)** is partnering with bp pulse and Hertz to create fast-charging hubs specifically for TNC and taxi drivers.[337]
- **Potential Funding and Incentives:**
  - The Volkswagen Environmental Mitigation Trust[338] provides funding for the installation of public EV chargers to reduce emissions and improve air quality. These grants support the purchase and installation of charging equipment at various locations, including public buildings, workplaces, and retail sites. The Volkswagen grant ends October 2nd, 2027, although the remaining funding allocations are unknown.
  - The National Electric Vehicle Infrastructure (NEVI) Formula Program[339], established by the Infrastructure Investment and Jobs Act (IIJA), allocates $7.5 billion to build a nationwide EV charging network along highways and in communities. NEVI funds are distributed to states to deploy EV chargers, ensuring accessibility and supporting the transition to EVs. The status of the NEVI Formula Program remains uncertain while current administration policies are under review.

[336] Forth. (2024). *Best Practices For Gig Drivers' Transition to Electric Vehicles*
[337] bp pulse. (2022). bp pulse to Launch Gigahub EV Fast-Charging Hubs for Ride-Hail Fleet Charging Near Airports and Other High-Demand U.S. Locations
[338] NCDEQ. *Volkswagen Settlement*
[339] NCDOT. (2025). *NEVI Program Information*

Summary Ratings

- **Medium Term**, while EVs and charging infrastructure are commercially available, the transition depends on TNCs and taxi owners converting their fleets to EVs. GA airports can support this shift by offering incentives such as EV priority pick-up zones and installing chargers.
- **Insignificant Impact**, electrifying TNCs and taxi vehicles will have a minimal impact on the airport's energy security efforts. However, the increased use of EVs around the airport, compared to traditional fuel vehicles, will significantly reduce emissions and enhance public health in the area.
- **Low Cost**, hosting EV priority pick up zones and waiving or lowering airport access fees are cost-effective incentives for GA airports to encourage TNC and taxi owners to electrify their fleets. However, if the GA airport installs chargers, specifically DC fast chargers that would be needed by TNCs or taxis, then implementation cost would increase.
- **High Risk**, installing DCFCs at a GA airport could pose a big risk since it could be unlikely that it would have high utilization.

Recommendations

The GA airport can first survey TNCs and taxis that serve the airport to determine what rate their fleet is electrifying, and what the airport can do to help the transition.

Airside

The airside of the airport, defined as the secure area past security checkpoints and passport control, plays a role in energy security, safety and critical sensitive airport infrastructure. This section will focus on airport-owned eGSE, electric aircraft, pre-conditioned air (PCA) systems and ground powered units (GPUs) in terms of electrification. In 2022, the FAA and the aviation industry established the Airport Climate Challenge with the ultimate goal of reducing greenhouse gas emissions at airports to zero by 2050. Shifting to or increasing the number of eGSE will not only reduce the overall carbon footprint of GA airport and reduce reliance on fossil fuels but can reduce noise pollution and maintenance requirements and provide overall cost savings to GA airports. This will require GA airports to add EV chargers to airside facilities. As electric vertical takeoff and landing (eVTOL) aircraft reach full certification, GA airports should consider installing chargers that are compatible with advanced air mobility (AAM) and ground equipment to allow for multi-modal charging and provide largest return on investment of installation. PCA systems and GPUs provide temperature-controlled air to aircraft while they are parked on the ground allowing a comfortable cabin environment without using auxiliary power units (APUs) which produce carbon emissions. Both electrically powered GPUs and PCA systems reduce noise pollution, reduce emissions, lowers fuel consumption, lowers maintenance costs and support airport sustainability efforts.

Electric Ground Support Equipment (eGSE)

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Ground Support Equipment; Airport Facilities; Infrastructure; Utilities	Near Term	Significant Impact	Medium Cost	Medium Risk

eGSE encompasses a wide variety of vehicles and machinery including baggage tractors, belt loaders, pushback tugs, lavatory collection tugs, air starter units, air conditioning units, and ground powered units. The transition from gasoline and diesel powered to eGSE at General Aviation (GA) airports is a significant move towards sustainability and operational efficiency. The Airport Climate Challenge, launched by the Federal Aviation Administration (FAA) in 2022, focused on reducing airport emissions on the ground and placed the transition to zero-emission vehicles, such as eGSE, at the top of the list of ways to reduce greenhouse gas emissions. eGSE vehicles produce zero direct emissions which significantly reduce an airport's carbon footprint. In contrast to a gasoline-powered vehicle, which uses roughly 12%-30% of the energy generated by burning fuel to move the wheels, electric vehicles (EVs) use over 77% of the battery's energy for motion.[340][341] This translates to greater efficiency and lower energy costs. eGSE runs more quietly than gasoline-powered vehicles, reducing noise hazards and improving the working environment for operators and staff, and also requires less maintenance with no oil changes and fewer moving parts. Pre-Conditioned Air (PCA) systems provide temperature-controlled air to aircraft while they are parked at the gates. The system allows the aircraft to maintain a comfortable cabin environment without using auxiliary power units (APUs) which burn fuel and produce carbon emissions. Ground powered units (GPUs) supply electric power to aircraft when they are on the ground that is used for air conditioning and other onboard systems such as lighting and avionics. Electric GPUs can be either battery powered or solid state (e.g. plugged into a building). Electric GPUs eliminate emissions and operate more quietly than gas powered GPUs reducing noise pollution at airports. One of the biggest challenges with shifting to eGSE is the charging infrastructure. GA airports will need to install charging equipment and should place charging stations at strategic locations throughout the facility to support efficient operations without having to travel long distances to charge. For larger airside operations, or operations that are likely to grow in the future, smart charging systems, which optimize power usage and reduce strain on electrical grid using electric load management algorithms, are recommended.

Overview

- **Compatibility:** eGSE vehicles are highly compatible with GA airports and technological advances in battery technology, charging infrastructure, and electric motors have made eGSE increasingly viable and can have a substantial impact on airport sustainability efforts and operational costs.

[340] U.S. DOE and EPA. *All-Electric Vehicles*
[341] U.S. DOE and EPA. *Where the Energy Goes: Gasoline Vehicles*

- **Current Market & Growth Projections:** The global eGSE market was valued at $3.5 billion in 2024 and is expected to grow at a Compound Annual Growth Rate (CAGR) of 8.5% annually to $7.2 billion by 2033 driven by pressure to reduce airport carbon emissions and efforts that support sustainability.[342]
- **Regulatory Environment:** The regulatory environment regarding eGSE at GA airports is driven by North Carolina's adoption of the National Electrical Code (NEC) with state-specific amendments most recently updated in 2020. These standards, which set requirements for safety, design, and construction, require permitting and inspection for the installation of charging stations. The Clean Air Act, most recently updated in March 2024, mandates the reduction of air pollution from various sources including airport operations. Airports must comply with state-related air quality responsibilities which is driving the adoption of low-emission technologies like electrically powered PCAs and GPUs. The FAA sets standards for airport operations to include the use of Ground Support Equipment (GSE) and encourages the adoption of electric GPUs and PCA systems to further enhance sustainability and operational efficiency.

Benefits & Challenges

Benefits	Challenges
• eGSE produces zero emissions, which improves air quality, reduces airport's carbon footprint, and supports sustainability efforts • eGSE runs quietly, reducing noise pollution and creating a better working environment for staff. • eGSE requires less maintenance than fossil-fuel powered vehicles which reduces operating costs. eGSE do not require oil changes and have fewer moving parts which reduces wear and tear on components, maintenance requirements, and can improve reliability. • Use of eGSE will reduce fuel costs providing long-term savings. • eGSE provides superior torque characteristics, enabling faster acceleration and improved performance in tasks such as aircraft pushback.	• GA airports will need to install strategically located, robust charging infrastructure depending on facility size. • Initial costs of the equipment itself and installing charging infrastructure can be high. • Airports need to investigate electric grid capacity to determine if grid can handle increased demand and electrical service may require upgrades to accommodate the additional power demand. • Additional planning requirements to address vehicle charging time.

Infrastructure Needs

- **GA Airport's Responsibility:** GA airports have multiple responsibilities during the transition to eGSE. Airports will need to ensure compliance with the state electrical code and NEC, specifically for the

[342] Verified Market Reports. (2025). *Airport Electric Ground Support Equipment Market*

installation of charging stations, and completion of the necessary permits and inspections to ensure compliance with safety and design standards. It is crucial that GA airport coordinate early and often with utility providers to determine grid capacity and any required enhancements or upgrades to support transition to eGSE. GA airports will need to identify strategic locations for the installation of charging infrastructure. GA airports should engage with tenants to communicate the shift to eGSE equipment, installation of charging infrastructure, and overall project timeline. Airports will need to provide training for staff on the operation and maintenance of the new eGSE and develop a process for regular maintenance and safety checks as well as an emergency response plan. Charging systems may require grid upgrades to handle demand. Airports will need to apply for appropriate permits and satisfactorily pass associated inspections. Airports should seek available grant funding to offset upfront costs of installation.

- **Other Stakeholders' Responsibility:** When a GA airport is transitioning to eGSE it will require early and close coordination with local utility providers to determine capacity and identify any needed improvements or upgrades. Once charging infrastructure is in place, tenants will need to decide if they also want to transition their eGSE and arrange for use of the chargers which may involve establishing a charging schedule. Local governments will need to ensure the appropriate permits are obtained and that required inspections are satisfactorily passed. While airports typically own and install GPUs and PCA systems and are responsible for maintaining the infrastructure that supports these systems, tenants often take on the day-to-day operational and preventative maintenance to ensure they are functioning correctly when needed.

Additional Resources

- **Case Studies:**
  - **Boston International Airport (BOS)** was awarded funding to convert 25 diesel powered GSE to eGSE by the EPA under the Diesel Emissions Reduction Act. The GSE includes baggage tractors, belt loaders, and push back tugs.[343]
  - **Dallas Fort Worth International Airport (DFW)** has between 230 - 430 eGSE.[344] They are expanding their infrastructure, as a 2021 board resolution approved a contract for the installation of eGSE charging stations at Terminal E.[345]
  - **Denver International Airport (DEN)'s** 2025 budget submission includes an electrification plan of acquiring 126 eGSE to replace diesel units.[346]
  - **Seattle International Airport (SEA)** has more than 400 eGSEs[347] and a total of around 561 eGSE charging locations. They project to save around $2.8 million in fuel costs per year.[348]

[343] Massport. (2018). *EPA Awards $541,000 to Massport to Replace Diesel Equipment at Boston Logan Airport*
[344] National Renewable Energy Laboratory (NREL). (2017). *Electric Ground Support Equipment at Airports*
[345] DFW. (2021). *DFW Virtual Board Meeting with Video Conference*
[346] DEN. (2024). *2025 Budget Submission*
[347] Facilities Dive. (2024). *Airport fleet electrification takes off across the US, but challenges persist*
[348] Port of Seatle. *SEA Airport Climate and Air Programs*

- **Philadelphia International Airport (PHL)** used FAA's Voluntary Airport Low Emissions (VALE) program funding to build eGSE charging unit corrals[349] and 12 eGSE chargers (24 total ports)[350] at Terminal E. Southwest at the airport has 29 eGSE (15 baggage tugs and 14 belt loaders).[351]

- **Grant Funding Opportunities:**
  - FAA's Airport Improvement Program (AIP) provides grants for various projects including projects focused on sustainability and energy efficiency and are awarded based on passenger volume.[352]
  - GA airports can apply for AIP grants to fund the purchase of eGSE and the installation of required charging infrastructure by applying for the Zero Emissions Vehicle (ZEV) and Infrastructure Pilot Program.[353]
  - The FAA's Voluntary Airport Low Emissions (VALE) program can be used to reduce on-airport emissions and improve air quality, particularly in areas not meeting air quality standards by funding low-emission vehicles, charging stations, gate electrification, and other air quality improvement projects.[354]
  - As part of the Infrastructure Investment and Jobs Act, the Airport Infrastructure Grant (AIG) allocates funding over five years starting in FY2022 to improve sustainability projects such as the transition to eGSE.[355]
  - The state-funded Airport Grant Program and FAA State Block Grant Program is administered by the NCDOT Division of Aviation and can be used for a variety of airport improvement programs to include those aimed at sustainability and the reduction of emissions.[356]
  - GA airports should check with their utility providers for any rebates or incentives of energy-efficient lighting that could offset the upfront cost of installation.

Summary Ratings

- **Near Term**, essentially all GSE types are commercially available for purchase as electric.
- **Significant Term**, while airplanes are responsible for most airport emissions, the shift to eGSE can reduce an airport's carbon footprint and help achieve the North Carolina Department of Environmental Quality (NCDEQ) goal of zero emissions by 2050.[357]
- **Medium Cost**, transitioning from fossil fuel powered to eGSE will require a significant upfront cost for both purchasing the vehicles and the installation of required charging infrastructure. These costs can be offset over time by decreased fuel and maintenance costs and by seeking state and federal grants and any available incentives.
- **Medium Risk**, GA airports seeking to transition to eGSE will need to decide if upfront vehicle purchase and charging equipment installation costs align with long-term environmental and sustainment goals.

---

[349] Burns. *Philadelphia International Airport, Vehicle Charging System*
[350] PHL. (2024). *PHL and Southwest Collaborate on Ground Support Equipment Electrification Project*
[351] Id.
[352] *FAA. (2025). AIP*
[353] FAA. (2025). *Airport Zero Emissions Vehicle and Infrastructure Pilot Program*
[354] *FAA. (2025). VALE*
[355] FAA. (2023). *$201M in Bipartisan Infrastructure Law Lights the Way to Improve Runway Safety*
[356] NCDOT Division of Aviation. (2024). *State Aid to Airports Program: General Legislative Funds*
[357] NCDEQ. (2019). *Clean Energy Plan*

Recommendation

As North Carolina GA airports consider the shift from fossil-fuel powered GSE to eGSE, they will need to decide if this is something they change to over time or as a wholesale shift. This will most likely depend on the available electric capacity and the number of charging stations needed to support. Prior to making any decisions, GA airports will need to identify utility capacity and any obstacles to required upgrades that may prohibit or limit adaptation. For example, lead times on electric service equipment like switchgear and transformers have grown exponentially from 8 weeks or less, to upwards of 2 years. The use of eGSE will substantially reduce airport carbon emissions and support environmentally responsible sustainability efforts.

Electric Aircraft

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Airport Facilities, Infrastructure, Utilities	Medium Term	Significant Impact	Medium Cost	Medium Risk

A transformative step in aviation will be the transition from fossil fuel-powered to electric aircraft. The term of electric aircraft applies to electric vertical takeoff and landing (eVTOL), electric conventional takeoff and landing (eCTOL) and electric short takeoff and landing (eSTOL) vehicles. Aviation currently accounts for 2.5% of global carbon dioxide emissions and is estimated to have contributed roughly 4% of global warming to date due to greenhouse gases (both CO_2 and Nitrogen Oxides (NOx)) and high-altitude effects.[358] Additionally, since shorter flights produce higher emissions per mile due to greater fuel used at lower altitudes during takeoff and landing, a transition to electric aircraft for shorter operational legs can offer the opportunity for significant reductions to carbon emissions. Electric aircraft produce zero direct emissions, significantly reducing the carbon footprint, helping to meet global climate goals and reducing air pollution around airports. As electric aircraft reach full Federal Aviation Administration (FAA) certification and are introduced into the fleet, airports will need to install charging infrastructure to support operations. Notable original equipment manufacturers (OEMs) such as Joby Aviation and Beta Technologies have both developed charging systems that are designed to be compatible with other aircraft and have shared charging specifications with industry to promote standardization and interoperability. The General Aviation Manufacturers Association (GAMA) and notable OEMs such as Archer and Vertical Aerospace have endorsed the Beta Technologies Combined Charging Standard (CCS) and they are being deployed throughout the country though currently focused on the east coast and gulf locations. Joby's Global Electric Aviation Charging System (GEACS) is currently less prolific but offers additional security and integrated battery conditioning to maximize battery life and efficiency.

Overview

- **Compatibility:** While it is recognized that initial Advanced Air Mobility (AAM) flights will most likely use existing airport infrastructure, facilities will require modifications to align with FAA standards. GA airports will need to develop vertiports and vertistops for vertical takeoff and landing, install electric charging stations, and comply with FAA design and safety standards. Compliance with FAA regulations, such as 14 Code of Federal Regulations (CFR) Part 157[359] and 14 CFR Part 77[360], is essential, and infrastructure upgrades to existing facilities, like heliports, will be required to ensure compatibility with the National Airspace System.

[358] Our World in Data Organization. (2024). *What share of global CO_2 emissions come from aviation?*
[359] 14 CFR Part 157 - *Notice of Construction, Alteration, Activation, And Deactivation of Airports*
[360] 14 CFR Part 77 - *Safe, Efficient Use, And Preservation of the Navigable Airspace*

- **Current Market & Growth Projections:** The current global electric aircraft market was valued at $10.1 billion in 2023 and is expected to grow to $37.2 billion in 2030 and even more to $74.25 billion in 2034.[361] [362]
- **Regulatory Environment:** The regulatory environment for electric aircraft is highly regulated by the FAA for both vehicle certification and vertiport development.

Benefits & Challenges

Benefits	Challenges
• Electric aircraft provide significant environmental benefits as they produce zero direct emissions, reducing overall carbon footprint and greenhouse gas emissions. • Electric aircraft are much quieter than gas powered ultimately producing less noise pollution and providing an overall more pleasant environment for airport communities. • Electric aircraft provide more efficient drivetrains which leads to lower energy costs. • Electric propulsion systems can be scaled up or down more easily than traditional engines allowing for redundancy, greater efficiency and a large variety of aircraft designs.	• Current battery density limits the range of electric aircraft travel and size of the vehicle. • Electric aircraft require airports to install high-capacity charging stations and may require electrical grid updates to accommodate. • Slow progress in the development of standards and certification due to complexity of safe integration with existing aviation assets. • The upfront costs required to purchase electric aircraft can be significant. • The electric aircraft's range of travel is dependent on continued advancement in battery technology. • Uncertain utilization by local operators may make it hard to justify infrastructure costs.

Infrastructure Needs

- **GA Airport's Responsibility:** During the integration of electric aircraft, GA airports perform a supporting role to ensure infrastructure can meet aircraft needs such as sufficient energy supply, number and availability of charging stations, and charging speed. Airports will need to comply with FAA regulations and standards for safe infrastructure installment and operations and environmental regulations aimed at reducing emissions and supporting sustainability. Additionally, GA airports will need to be ready to address community concerns, questions, and gather feedback regarding electric aircraft.
- **Other Stakeholders' Responsibility:** The FAA, as the controller of all airspace inside U.S. airspace boundaries, is responsible to provide direction and guidance on how AAM is regulated and integrated into the National Airspace System. During the implementation of electric aircraft other stakeholders, such as

[361] Markets and Markets. (2023). *Electric Aircraft Market*
[362] Precedence Research. (2025). *Electric Aircraft Market*

OEMs, have vast responsibilities and requirement to achieve full FAA certification and launch initial operations. The slow progress of requirements and standards development has driven some companies out of business as they depleted available revenue. Other stakeholders, such as companies that are focused on the advancement of battery technology, are seeking to ensure AAM is scalable to meet future predicted demand for air travel. Lastly, local fire departments may need additional training to respond to emergencies with electric aircraft.

Additional Resources

- **Case Studies:**
  - **The Raliegh Executive Airport (TTA)** installed North Carolina's first electric plane charger.[363]
  - **Los Angeles International Airport (LAX)** is integrating electric aircraft infrastructure, including charging stations and vertiports.[364]
- **Potential Funding and Incentives:**
  - The FAA Airport Infrastructure Grant (AIG) Program provides funding for electric airport infrastructure projects, and the FAA's Voluntary Airport Low Emissions (VALE) Program provides funding for airport air quality improvements, including electric aircraft infrastructure, low emission vehicles, refueling and recharging stations, and gate electrification. [365]
  - The American Rescue Plan Act offers provisions for funding sustainable airport infrastructure projects. As AAM is integrated into the National Airspace System, GA airports may want to retrofit on-site heliports or construct vertiports to allow for inclusion of this new form of travel.[366]

Summary Ratings

- **Medium Term**, several of the OEMs that are closest to achieving full FAA certification forecast operations to begin as early as 2027 GA airports will need to safely integrate AAM into airfield operations. Given that the technology is still in its early stages, GA airports may choose to wait until the technology is more developed before installing electric aircraft infrastructure.
- **Significant Impact**, supporting the adoption of electric aircraft at the airport would slowly replace the aircraft trips by traditional fuel powered aircraft. This would increase the energy security of the airport by reducing the reliance on imported fuels.
- **Medium Cost**, the cost of supporting electric aircraft at GA airports will not be for the vehicles themselves but for the supporting infrastructure such as charging stations and vertiports. If airports purchase charging stations that can also charge electric vehicles (EVs) this redundancy would offer the best return on investment. GA airports can seek state and federal grants to support this infrastructure advancement.
- **Medium Risk**, the risk of electric aircraft integration at GA airports is assessed as medium if AAM activities do not scale as anticipated. Installing electric chargers that can service both aircraft and ground vehicles can help mitigate this risk.

---

[363] Spectrum Local News. (2025). *North Carolina gets its first electric plane charger*
NCDOT. (2025). *North Carolina's First Electric Aircraft Charging Station Powers Flight in Aviation Milestone*
[364] Urban Air Mobility News. (2024). *Los Angeles Airport issues RFIC to industry for vertiport development in three potential sites*
[365] FAA. (2023). *$201M in Bipartisan Infrastructure Law Lights the Way to Improve Runway Safety*
[366] FAA. *Airport Rescue Grants*

Recommendations

AAM is expected to initially operate from existing aviation infrastructure and activities. GA airports offer prime opportunities for many of the established use cases that will help AAM operations scale. GA airports can survey airport users to determine the demand for electric aircraft infrastructure and can seek to safely integrate electric aircraft into existing airfield operations. Also, the GA airport can look for and coordinate with electric aircraft companies for demonstration project opportunities.

Fleet

Electrifying GA airport fleet vehicles, including maintenance vehicles, shuttles, firetrucks, and ground maintenance equipment, presents a promising opportunity to enhance energy security and reduce environmental impact. The transition to EVs can significantly lower greenhouse gas emissions and improve air quality, contributing to public health benefits and improved quality of life. Additionally, EVs offer operational advantages such as reduced fuel and maintenance costs, and increased energy efficiency. Also, in the future, fleet vehicles could be used for Vehicle-to-Grid (V2G) applications. However, this shift also poses challenges, including the need for substantial investment in charging infrastructure, potential range limitations, and the requirement for specialized training for personnel. Balancing these benefits and challenges is crucial for successfully integrating EVs into GA fleets and achieving a sustainable transportation system.

Maintenance Vehicles

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Fleet Vehicles, Airport Facilities, Infrastructure, Utilities	Near Term	Significant Impact	Medium Cost	Medium Risk

Electrifying maintenance vehicles at General Aviation (GA) airports, which are specialized vehicles used for carrying parts, equipment, and personnel necessary for the upkeep and repair of airport facilities and infrastructure, offers significant energy security and public health benefits. Examples of airport maintenance vehicles include passenger cars, trucks, vans, and specialized vehicles (e.g., de-icing equipment, runway sweepers, snowplows). Transitioning to electric-powered maintenance vehicles can reduce dependency on fossil fuels, lower operational costs, and enhance energy resilience. Fortunately, maintenance vehicles typically operate on short trips within the airport, so range anxiety is likely not a significant concern when transitioning to electric vehicles (EVs).

Overview

- **Compatibility:** Existing Internal Combustion Engine (ICE) maintenance vehicles are not compatible with EV technology and cannot be easily retrofitted without major modifications. Therefore, electrifying these vehicles requires purchasing new electric-powered maintenance vehicles.
- **Current Market & Growth Projections:** The current U.S. market for electric airport maintenance vehicles is part of the broader ground support equipment (GSE) market, which is valued at approximately $2.5 billion in 2023 and is projected to reach around $4.5 billion by 2031, growing at a Compound Annual Growth Rate (CAGR) of 7.62% from 2024 to 2031.[367]
- **Regulatory Environment:** Many airport maintenance vehicles do not need to comply with the Federal Motor Vehicle Safety Standards (FMVSS), as they are only driven within the airport grounds. Airports in non-attainment areas must follow Environmental Protection Agency (EPA) regulations to reduce emissions and improve air quality.[368] Currently, all of North Carolina is in attainment with the federal National Ambient Air Quality Standards (NAAQS), meaning the state meets the required limits for major air pollutants set by the EPA. These standards are designed to protect public health and the environment by regulating pollutants like ozone, particulate matter, carbon monoxide, and sulfur dioxide. The Federal Aviation Administration (FAA) provides guidelines for the operation of ground vehicles at airports, focusing on safety and operational efficiency.

[367] Market Research Intellect. (2025). *Airport Electric Ground Support Equipment Market*
[368] FAA. (2025). *Airport Zero Emissions Vehicle and Infrastructure Pilot Program*

Benefits & Challenges

Benefits	Challenges
• By reducing dependency on fossil fuels, airports can enhance their energy resilience and security. • EVs generally have lower fuel and maintenance costs compared to ICE vehicles, leading to long-term savings. • EVs operate more quietly than their ICE counterparts, reducing noise pollution in and around the airport. • Transitioning to EVs helps lower greenhouse gas emissions and other pollutants, contributing to improved air quality and public health.	• The initial investment required for purchasing EVs and installing charging infrastructure can be substantial. • Specialized training for personnel and adjustments to maintenance practices are required to support the new technology. • Airports may face logistical challenges in integrating charging stations, especially in areas with limited space or existing infrastructure.

Infrastructure Needs

- **GA Airport's Responsibility:** GA airports need to invest in the necessary charging infrastructure, strategically installing charging stations to ensure accessibility and efficiency. Developing a comprehensive plan for transitioning existing ICE maintenance vehicles to EVs is essential, including assessing the current fleet, identifying suitable electric replacements, and setting timelines for the transition. Providing training for maintenance personnel on the operation and maintenance of EVs ensures staff are well-equipped to support the new technology. Additionally, airports can advocate for supportive policies and regulations that promote EV adoption, working with local governments and industry stakeholders to create a favorable regulatory environment. By fulfilling these responsibilities, GA airports can significantly reduce emissions, enhance energy security, and promote sustainable transportation.
- **Other Stakeholders' Responsibility:** Utilities are responsible for upgrading the grid infrastructure to ensure sufficient electrical capacity for EV chargers. EV vehicle suppliers provide electric maintenance vehicles, while EV charger suppliers supply the necessary charging equipment. Consultants manage the project, conduct feasibility studies to ensure a smooth transition, design, and offer technical expertise. Contractors install the EV chargers according to the designs and ensure they meet safety and operational standards.

Additional Resources

- **Case Studies:**
  - In 2023, the **Truckee Tahoe Airport (TFK)** electrified two fleet vehicles, replaced a gas-powered flatbed with a Ford E-Transit-350 all electric cargo van and purchased a Ford Mustang Mach-E for airport transportation.[369]

[369] Truckee Tahoe Airport. (2023). *Sustainability Report*

- **Seattle-Tacoma International Airport (SEA)** has over 400 electrified vehicles, which includes electric maintenance trucks.[370]

- **Potential Funding and Incentives:**
  - The FAA awards grants for airport development as part of the Airport Improvement Program (AIP) Supplemental Grant Program.[371]
  - The 2024 NCDOT North Carolina Airports Program Guidance Handbook has state and federal funding sources and program details.[372]
  - Commercial Property Assessed Clean Energy (C-PACE) funding allows commercial property owners to obtain low-cost, long-term financing for energy efficiency and renewable energy projects, prepaid through property tax assessments.[373]

Summary Ratings

- **Near Term**, Electric maintenance vehicles and EV chargers are commercially available. Depending on supply chain availability, these can be implemented within 0-3 years. This timeframe allows for the procurement of vehicles and chargers, installation of necessary infrastructure, and training of maintenance staff to ensure a smooth transition to electric operations.
- **Significant Impact**, converting maintenance vehicles from ICE vehicles to EVs would enhance energy security by reducing dependence on fossil fuels, lower emissions contributing to cleaner air, and decrease noise pollution, creating a quieter and cleaner airport environment.
- **Medium Cost**, electric maintenance vehicles generally have a higher upfront cost compared to ICE vehicles. Additionally, installing EV chargers can incur significant expenses, depending on the required power level and infrastructure upgrades needed to support them.
- **Medium Risk**, given the federal funding uncertainties and maturity of EV technology and the industry's trend towards electrification, it presents a moderate risk opportunity for GA airports to begin transitioning their maintenance work vehicles to electric. If GA airport has the funding to purchase electric maintenance work vehicles, this transition can be implemented with confidence, knowing that the technology is reliable and supported by a growing infrastructure.

Recommendations

GA airports can begin by reviewing the replacement cycles of their maintenance vehicles and conducting a feasibility study to assess the financial and technical viability of gradually converting these vehicles to electric. For EV chargers, it is important to determine the appropriate power levels (L1, L2, or DCFC) and locations for installing the charging infrastructure to support the electric maintenance vehicles, so a power demand study should also be completed. Next steps include securing funding through federal, state, and local grants or incentives, collaborating with utilities to upgrade the necessary electrical infrastructure, and partnering with EV vehicle and charger suppliers for the equipment. Additionally, working with contractors for the installation is crucial. Airports should also provide comprehensive training for maintenance staff on the operation and upkeep of EVs and chargers.

---

[370] Facilities Dive. (2024). *Airport fleet electrification takes off across the US, but challenges persist*
[371] FAA. (2025). *AIP*
[372] NCDOT Division of Aviation. (2024). *North Carolina Airports Program Guidance Handbook*
[373] C-PACE Alliance

Shuttles

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Fleet Vehicles, Airport Facilities, Infrastructure, Utilities	Near Term	Significant Impact	High Cost	Medium Risk

General Aviation (GA) airport shuttles, which include buses, vans, and minibuses designed to accommodate varying capacities and luggage, are used to transport airport users, and staff between various facilities. Electrifying these shuttles presents an opportunity to reduce dependency on imported fossil fuels, lower operational costs, and improve air quality by cutting emissions. Additionally, electric shuttles contribute to a quieter airport environment, enhancing the overall experience for everyone at the airport. Some GA airports may not have shuttle services and can skip this toolkit section.

Overview

- **Compatibility:** Converting existing Internal Combustion Engine (ICE) shuttles to Electric Vehicle (EV) technology is neither straightforward nor cost-effective. Therefore, transitioning to electric-powered shuttles typically requires purchasing new electric shuttles.
- **Current Market & Growth Projections:** The U.S. electric bus market was valued at approximately $1.27 billion in 2023 and is expected to grow significantly over the next few years. The market is projected to reach around $2.82 billion by 2030, with a Compound Annual Growth Rate (CAGR) of 14.5% during the forecast period from 2024 to 2030.[374]
- **Regulatory Environment:** The regulatory environment of electricity in the U.S. is governed by both federal and state policies, with the Federal Energy Regulatory Commission (FERC) overseeing wholesale electricity markets and transmission, while state regulators manage retail electricity sales and local distribution.

Benefits & Challenges

Benefits	Challenges
• Reduces reliance on imported fossil fuels by utilizing locally generated electricity for fuel. • Generally, lowers fuel and maintenance costs, leading to long-term savings. • Lower emissions, resulting in improved air quality and public health. • Decrease noise pollution in and around the airport.	• The initial investment required can be substantial for purchasing electric shuttle buses and installing charging infrastructure. • Personnel need specialized training, new personal protection equipment (PPE) safety gear, and maintenance practices must be adjusted to support the new electric shuttle buses.

[374] Prescient & Strategic Intelligence. (2025). *U.S. Electric Bus Market*
Grand View Research. (2024). *Electric Bus Market Size, Share and Growth Report, 2030*

Benefits	Challenges
	• Integrating charging stations can be difficult, especially in areas with existing infrastructure or limited space. Areas may lack the necessary electrical infrastructure to support the charging stations.

Infrastructure Needs

- **GA Airport's Responsibility:** GA airports must conduct a thorough assessment of their current ICE shuttle fleet, identify suitable electric replacements, and develop a timeline for the transition. To support electric shuttle buses, they may need to upgrade their electrical infrastructure to handle increased loads, including installing dedicated circuits for each charger to ensure safety and efficiency. Additionally, robust communication networks must be implemented for monitoring and managing the chargers, ensuring compliance with local electrical codes and standards to maintain operational reliability. Airports should set up sufficient charging stations throughout the airport, including Level 3, direct current fast charging (DCFC) for quick charging turnaround times. Providing specialized training for maintenance and operational staff to handle the new EVs and charging equipment is also essential.
- **Other Stakeholders' Responsibility:** Utilities are responsible for upgrading the infrastructure to ensure sufficient electrical capacity for EV chargers. Electric shuttle suppliers not only provide the vehicles but also offer maintenance support. Similarly, EV charger suppliers deliver the necessary charging equipment and include maintenance services. Consultants manage the transition, conduct feasibility studies to ensure a smooth deployment, design, and offer technical expertise. Contractors would install the EV chargers according to the designs and ensure they meet safety and operational standards.

Additional Resources

- **Case Studies:**
  - **Charlotte Douglas International Airport (CLT)** is adding electric buses to their fleet.[375]
  - **San Francisco International Airport (SFO)** has invested in electric shuttle buses to reduce emissions and improve air quality.[376]
  - **Los Angeles International Airport (LAX)** has incorporated electric buses into its shuttle fleet as part of its "Boldly Moving to Zero" sustainability initiative, which includes transitioning to 100% renewable energy and zero carbon emissions by 2045.[377]
  - **Seattle- Tacoma International Airport (SEA)** completed an electrification planning study in 2024 to estimate future electricity capacity to transition the fleet to EVs.[378].
  - **Denver International Airport (DEN)** has implemented electric shuttle buses to reduce its carbon footprint.[379]

[375] CLT. (2020). *Airport Adds Five Electric Buses*
[376] SFO. (2020). *SFO Deploys Its First All-Electric Zero-Emission Buses*
[377] LAX. (2020). *LAX at a Glance: Sustainability*
[378] Port of Seattle. *SEA Airport Climate and Air Programs*
[379] Simple Flying. (2023). *US Airports Investing Millions in Electric Buses*

- **Tampa International Airport (TPA)** also has electric shuttles to transport employees between the employee parking lot and the main terminal.[380]

- **Potential Funding and Incentives:**
  - The Airport Zero Emission Vehicle (ZEV) and Infrastructure Pilot Program enables airport sponsors to utilize Airport Improvement Program (AIP) funds for acquiring zero-emission vehicles and developing or upgrading the necessary infrastructure to support their use.[381]
  - The 2024 NCDOT North Carolina Airports Program Guidance Handbook has state and federal funding sources and program details.[382]
  - Commercial Property Assessed Clean Energy (C-PACE) funding allows commercial property owners to obtain low-cost, long-term financing for energy efficiency and renewable energy projects, repaid through property tax assessments.[383]

Summary Ratings

- **Near Term**, electric shuttle buses and EV chargers are readily available on the market. Depending on supply chain conditions, their implementation can take between 1 to 5 years. This period accounts for the procurement of buses and chargers, the installation of required infrastructure, and the training of maintenance staff to ensure a seamless transition to electric operations.
- **Significant Impact**, electrifying shuttle buses would significantly enhance energy security by reducing reliance on imported fossil fuels. This conversion would also lower emissions, leading to improved air quality, and decrease noise pollution, resulting in a quieter and cleaner airport environment.
- **High Cost**, electric shuttle buses typically have a higher initial cost compared to ICE buses. Furthermore, the installation of EV chargers can be quite expensive, with costs varying based on the power level required and the extent of infrastructure upgrades needed to support them.
- **Medium Risk**, While the technology for electric shuttles is well-developed and the industry is clearly moving toward electrification, uncertainties around federal funding may make the transition less financially viable and risky for GA airports.

Recommendations

GA airports are encouraged to start by conducting a feasibility study and developing an implementation plan for electrifying their shuttle bus fleet. A route analysis can help determine the range and charging infrastructure needed to support the airport's shuttle service. If EV chargers are required, it is important to identify the appropriate power levels (L1, L2, or DCFC), locations, and other necessary steps for installing the charging infrastructure to support the electric shuttles. Next steps include securing funding through federal, state, and local grants, collaborating with utilities to upgrade electrical infrastructure, and partnering with electric shuttle and charger suppliers for equipment and installation. Additionally, providing comprehensive training for maintenance staff on the operation and upkeep of electric shuttles and chargers is crucial. Continuous monitoring and evaluation of the performance and impact of the electrification project will ensure its long-term success and sustainability.

---

[380] TPA. (2023). *TPA adds its first four electric buses to vehicle fleet*
[381] FAA. 2025. *Airport Zero Emissions Vehicle and Infrastructure Pilot Program*
[382] NCDOT Division of Aviation. (2024). *North Carolina Airports Program Guidance Handbook*
[383] C-PACE Alliance

Fire Trucks

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Fleet Vehicles, Airport Facilities, Infrastructure, Utilities	Near Term	Significant Impact	High Cost	High Risk

Electrifying fire trucks at General Aviation (GA) airports provides substantial benefits for energy security and public health. These specialized vehicles are essential for emergency response and firefighting operations within the airport. Examples of airport fire trucks include large pumpers, aerial ladder trucks, and rapid intervention vehicles designed to handle various emergency scenarios. The benefits of the electric fire trucks include protecting firefighters and staff from exhaust fumes, reducing dependency on imported fossil fuels, lowering operational costs, and improving overall air quality by reducing emissions. Given their critical role, ensuring reliable performance and adequate power levels for these vehicles is paramount, as the vehicles are not going to be able to leave the site of an emergency while one active duty to go and charge. Many GA airports may not have dedicated fire trucks or full-time firefighting services and depend on local fire departments. This section can be shared with the local fire departments as a resource for electrifying fire trucks.

Overview

- **Compatibility:** Existing Internal Combustion Engine (ICE) fire trucks cannot be retrofitted with electric vehicle (EV) technology. Therefore, electrifying these vehicles requires the acquisition of new electric-powered firetrucks.
- **Current Market & Growth Projections:** With the trends of more vehicles electrifying, the electric fire truck market is projected to grow. There is no current estimated market value of only electric fire trucks, as it is part of the broader fire truck market estimations.
- **Regulatory Environment:** Airport maintenance vehicles do not need to comply with the Federal Motor Vehicle Safety Standards (FMVSS), as they are only driven within the airport grounds. Airports in non-attainment areas must follow Environmental Protection Agency (EPA) regulations to reduce emissions and improve air quality. Currently, all of North Carolina are in attainment with all federal National Ambient Air Quality Standards (NAAQS). The Federal Aviation Administration (FAA) provides guidelines for the operation of ground vehicles at airports, focusing on safety and operational efficiency.

Benefits & Challenges

Benefits	Challenges
• Electric fire trucks can utilize electric-powered components without powering the vehicle. • By reducing dependency on fossil fuels, airports can enhance their energy resilience and security. • EVs generally have lower fuel and maintenance costs compared to ICE vehicles, leading to long-term savings.	• The initial investment required for purchasing EVs and installing charging infrastructure can be substantial. • Specialized training for personnel and adjustments to maintenance practices are required to support the new technology. • Airports may face logistical challenges in integrating charging stations, especially in

Benefits	Challenges
• EVs operate more quietly than their ICE counterparts, reducing noise pollution in and around the airport. • Transitioning to EVs helps lower greenhouse gas emissions and other pollutants, contributing to improved air quality and public health. • In the future, EVs and EV chargers equipped with V2G technology can feed stored energy back into the grid, helping to provide additional capacity.	areas with limited space or existing infrastructure.

Infrastructure Needs

- **GA Airport's Responsibility:** Installing EV chargers requires robust electrical infrastructure, including upgraded power supply systems to handle increased load, and dedicated circuits for each charger to ensure safety and efficiency. Additionally, it involves installing communication networks for monitoring and managing the chargers and ensuring compliance with local electrical codes and standards. Developing a comprehensive plan for transitioning existing ICE fire trucks to EVs is essential, including assessing the current fleet, identifying suitable electric replacements, and setting timelines for the transition. Providing training for shuttle maintenance personnel on the operation and electric firetrucks ensures staff are well-equipped to handle the new technology. Additionally, airports can advocate for supportive policies and regulations that promote EV adoption, working with local governments and industry stakeholders to create a favorable regulatory environment. By fulfilling these responsibilities, GA airports can significantly reduce emissions, enhance energy security, and promote sustainable transportation.
- **Other Stakeholders' Responsibility:** Utilities are responsible for upgrading the infrastructure to ensure sufficient electrical capacity for EV chargers. EV fire truck suppliers provide electric maintenance vehicles, while EV charger suppliers supply the necessary charging equipment. Consultants manage the project, conduct feasibility studies to ensure a smooth transition, design, and offer technical expertise. Contractors would install the EV chargers according to the designs and ensure they meet safety and operational standards.

Additional Resources

- **Case Studies:**
  - **The King County International Airport (BFI)** has a new hybrid electric aircraft rescue and firefighting (ARFF) vehicle. BFI also has a Ford F-150 Lightning pickup truck.[384]
  - **The Los Angeles Fire Department (LAFD)** deployed the Rosenbauer RTX, which is considered the first electric fire truck in North America.[385]

[384] King County. (2025). *King County International Airport unveils new hybrid electric fire truck*
[385] electrek. (2022). *The first electric fire truck is deployed in the US by LAFD*

- **The City of Madison, Wisconsin,** has also deployed an electric fire truck at its busiest station since 20212.[386]
- **Portland Fire & Rescue** incorporated an electric fire truck into its fleet to support its carbon reduction initiatives.[387]
- **Gilbert Fire and Rescue in Arizona** deployed one electric fire truck to minimize diesel exhaust exposure within fire stations.[388]

- **Potential Funding and Incentives:**
  - The Airport Zero Emission Vehicle (ZEV) and Infrastructure Pilot Program enables airport sponsors to utilize Airport Improvement Program (AIP) funds for acquiring zero-emission vehicles and developing or upgrading the necessary infrastructure to support their use.[389]
  - The 2024 NCDOT North Carolina Airports Program Guidance Handbook has state and federal funding sources and program details.[390]
  - Commercial Property Assessed Clean Energy (C-PACE) funding allows commercial property owners to obtain low-cost, long-term financing for energy efficiency and renewable energy projects, repaid through property tax assessments.[391]

Summary Ratings

- **Near Term**, electric fire trucks are commercially available and are being used currently. Depending on supply chain availability, electric fire trucks can be implemented within 0-3 years.
- **Significant Impact**, converting fire trucks from ICE vehicles to EVs would improve public health, enhance energy security, decrease noise pollution, and reduce harmful emissions.
- **High Cost**, electric fire trucks come with a higher initial cost compared to ICE fire trucks. Moreover, the installation of EV chargers can be quite costly, depending on the charger type (L1, L2, or DCFC) and the necessary infrastructure upgrades to support them.
- **High Risk**, The electric fire truck market is still emerging, and uncertainties around federal funding create financial challenges for their procurement. As a result, investing in electric fire trucks at GA airports currently represents a high-risk endeavor.

Recommendation

GA airports can work with their fire departments to understand fire truck needs and proceed with a feasibility study to understand what types of fire trucks are needed and if electrified firetrucks would fulfill the necessary services of the fire department.

[386] Western Fire Chiefs Association. (2024). *Evaluating the Use of Electric Fire Trucks in Firefighting*
[387] Id.
[388] Id.
[389] FAA. (2025). *Airport Zero Emissions Vehicle and Infrastructure Pilot Program*
[390] NCDOT Division of Aviation. (2024). *North Carolina Airports Program Guidance Handbook*
[391] C-PACE Alliance

Ground Maintenance Equipment

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Fleet Vehicles, Airport Facilities, Infrastructure, Utilities	Near Term	Significant Impact	Medium Cost	Medium Risk

Electrifying ground maintenance equipment at General Aviation (GA) airports offers considerable advantages for energy security and public health. These vehicles are crucial for the upkeep of airport grounds and infrastructure. Examples include tractors, mowers, and specialized equipment for various maintenance activities. Switching to electric-powered ground maintenance equipment can decrease reliance on fossil fuels, reduce operational expenses, and enhance air quality by cutting emissions. Furthermore, electric ground maintenance equipment creates a quieter airport environment, improving the overall experience for staff and passengers. Given their typical short-range operations within the airport, range anxiety is minimal, making the transition to electric vehicles (EVs) both feasible and practical.

Overview

- **Compatibility:** Ground maintenance equipment powered by diesel or gasoline would need to be replaced with electric ground maintenance equipment.
- **Current Market & Growth Projections:** The current U.S. market for electric airport ground maintenance equipment is part of the broader Ground Support Equipment (GSE) market, which is valued at approximately $2.5 billion in 2023 and is projected to reach around $4.5 billion by 2031, growing at a Compound Annual Growth Rate (CAGR) of 7.62% from 2024 to 2031.[392]
- **Regulatory Environment:** Airport ground maintenance equipment does not need to comply with the Federal Motor Vehicle Safety Standards (FMVSS), as they are only driven within the airport grounds. Airports in non-attainment areas must follow Environmental Protection Agency (EPA) regulations to reduce emissions and improve air quality. Currently, all of North Carolina are in attainment with all federal National Ambient Air Quality Standards (NAAQS). The Federal Aviation Administration (FAA) provides guidelines for the operation of ground vehicles at airports, focusing on safety and operational efficiency.

Benefits & Challenges

Benefits	Challenges
• Decreases reliance on imported fossil fuels by transitioning to electric powered ground maintenance equipment. • Offers lower fuel, operating, and maintenance costs compared to ICE vehicles.	• Electric ground maintenance equipment typically has higher upfront costs compared to ICE vehicles, and the installation of EV chargers (if needed) can be quite expensive.

[392] Market Research Intellect. (2025). *Airport Electric Ground Support Equipment Market*

Benefits	Challenges
• Reduces emissions, contributing to cleaner air quality around the airport. • Operates more quietly than ICE vehicles.	• Supporting the new technology requires specialized training for personnel and adjustments to maintenance practices. • Electric ground maintenance equipment requires dedicated areas for EV chargers to ensure they can charge as needed, which can pose challenges in terms of space allocation at the airport. • Some electric equipment may have shorter run times than traditional gas-powered units, requiring recharging mid-shift or having backup units.

Infrastructure Needs

- **GA Airport's Responsibility:** Developing a comprehensive plan for transitioning existing Internal Combustion Engine (ICE) ground maintenance equipment to electric vehicles (EV) is essential, including assessing the current fleet, identifying suitable electric replacements, and setting timelines for the transition. GA airports are responsible for upgrading their electrical infrastructure to support EV chargers, including enhancing power supply systems and ensuring dedicated circuits for safety and efficiency. They must strategically install EV chargers and allocate space for them, which can be challenging due to space constraints. Providing training for maintenance personnel on the operation of electric ground maintenance equipment ensures staff are well-equipped to handle the new technology.
- **Other Stakeholders' Responsibility:** Utility companies would upgrade the electrical grid to manage increased loads, while EV charging service providers will supply and support the chargers. Vehicle manufacturers need to provide reliable electric ground maintenance equipment and offer technical support. Additionally, consultants and contractors will plan, design, and install the EV chargers in coordination with the GA airport project manager.

Additional Resources

- **Case Studies:**
  - **Sugar Land Regional Airport (SGR)** utilizes three semiautonomous electric lawn mowers to efficiently maintain 400 acres of land on a weekly basis.[393]
  - **Dallas Fort Worth International Airport (DFW)** airport is testing automated electric lawnmowers for their 14,000 acres of grass.[394]
  - Starting in 2025, the state of **Colorado** will ban the use of gas-powered push lawnmowers and handheld landscaping tools under 25 horsepower on state property during the summer months.[395]

[393] Airport Improvements. (2025). Sugar Land Regional on the Cutting Edge With Autonomous Mowers
[394] Turf. (2025). Robotic Landscaping Put to the Test At DFW
[395] Colorado Department of Public Health & Environment (DPHE). Lawn and Garden Equipment Requirements

- **California** has banned the sale of new small gas engines, including lawnmowers and leaf blowers, starting in 2024.[396]
- **Washington, D.C.** has a strict ban on gas-powered leaf blowers, effective since January 1, 2022.[397]

- **Potential Funding and Incentives:**
  - The FAA awards grants for airport development as part of the Airport Improvement Program (AIP) Supplemental Grant Program.[398]
  - The 2024 NCDOT North Carolina Airports Program Guidance Handbook has state and federal funding sources and program details.[399]
  - Commercial Property Assessed Clean Energy (C-PACE) funding allows commercial property owners to obtain low-cost, long-term financing for energy efficiency and renewable energy projects, repaid through property tax assessments.[400]

Summary Ratings

- **Near Term**, commercially available electric ground maintenance equipment and EV chargers can be implemented within 0-3 years, depending on supply chain availability. This period allows for the procurement of vehicles and chargers, the installation of necessary infrastructure, and the training of maintenance staff to ensure a smooth transition to electric operations.
- **Significant Impact**, converting ground maintenance equipment from ICE to electric would enhance energy security, reduce emissions for cleaner air, and decrease noise pollution, creating a quieter and cleaner airport environment.
- **Medium Cost**, the upfront cost of electric ground maintenance equipment is generally higher compared to ICE vehicles. Additionally, the expenses for installing EV chargers can be significant, depending on the required power levels and the infrastructure upgrades needed to support them.
- **Medium Risk**, given the uncertainties around federal funding but the maturity of EV technology and the industry's shift toward electrification, transitioning maintenance vehicles at GA airports presents a moderate risk. If funding is available, airports can move forward confidently, supported by reliable technology and expanding infrastructure.

Recommendations

It is recommended for GA airports review the replacement cycles of their ground maintenance equipment and conduct a feasibility study to assess the viability of transitioning to electric vehicles in phases. GA airports would determine the appropriate power levels (L1, L2, or DCFC) and locations for EV chargers. Next steps include securing funding through grants and incentives, collaborating with utilities to upgrade infrastructure, and partnering with suppliers for equipment and installation. Additionally, airports would train maintenance staff on the operation and upkeep of electric ground maintenance equipment and chargers.

---

[396] California Legislative Information. (2021). *Assembly Bill No. 1346*
[397] DC Department of Licensing and Consumer Protection. *Leaf Blower Regulations*
[398] *FAA. (2025). AIP*
[399] NCDOT Division of Aviation. (2024). *North Carolina Airports Program Guidance Handbook*
[400] C-PACE Alliance

Security

Electrifying an airport fleet adds complexity, making both physical and cybersecurity critical. As operations shift to digital systems like electric vehicle (EV) charging stations and smart energy management, vulnerabilities to cyberattacks and tampering increase. Protecting these systems ensures operational continuity, data security, and resilience across transportation and energy networks. In today's interconnected world, security is a multifaceted discipline that encompasses both physical and cybersecurity measures to protect an airport's assets, personnel, and information. Physical security focuses on safeguarding tangible assets through measures such as access control, surveillance, and emergency response planning. Cybersecurity, on the other hand, aims to protect digital assets from cyber threats through network security, data protection, and incident response strategies. By integrating these two domains, GA airports can create a comprehensive security framework that addresses a wide range of potential threats and vulnerabilities, ensuring the safety and resilience of their operations. Some benefits include:

- **Protection of Critical Infrastructure:** Physical security measures such as access control and surveillance help safeguard energy infrastructure, including fuel storage and distribution systems, from unauthorized access and potential sabotage.
- **Resilience Against Disruptions:** By integrating physical and cybersecurity measures, general aviation (GA) airports can enhance their resilience against both physical and cyber threats, ensuring continuous and reliable energy supply.
- **Cybersecurity for Energy Management Systems:** Cybersecurity efforts protect digital systems that manage energy resources, ensuring that these systems are not compromised by cyberattacks. This includes securing data related to energy consumption, distribution, and storage.

Physical Security

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Airport Facilities; Infrastructure; Policies/ Practices; Management Systems	Near Term	Significant Impact	Medium Cost	Low Risk

Physical security is a critical component of ensuring the safety and operational integrity of General Aviation (GA) airports. Effective physical security measures protect the airport's infrastructure, personnel, and energy resources from unauthorized access, theft, vandalism, and other potential threats. Examples of physical security efforts at GA airports include implementing access control systems such as ID badges and biometric scanners and installing surveillance cameras and alarm systems to monitor and protect critical areas. Additionally, deploying security personnel for regular patrols and conducting emergency response drills are essential measures to ensure the safety and security of the GA airport's infrastructure and operations.

Overview

- **Compatibility:** Physical security efforts are compatible with GA airport's existing infrastructure and can be integrated with current operations.
- **Current Market & Growth Projections:** In 2024, the market size reached approximately $30.7 billion and is expected to grow at a Compound Annual Growth Rate (CAGR) of 4.5%, reaching $45.6 billion by 2033.[401]
- **Regulatory Environment:** The North Carolina Private Protective Services Board (PPSB) is responsible for administering licensing, education, and training requirements for individuals and entities engaged in private protective services within the state.

Benefits & Challenges

Benefits	Challenges
• Physical security measures protect critical energy infrastructure, such as fuel storage tanks and power generators, from physical threats, ensuring a reliable energy supply. • Preventing theft, vandalism, and sabotage through improved security measures can lead to significant cost savings by reducing losses and repair expenses. • Enhanced physical security includes robust emergency response plans and	• Security threats are constantly evolving, requiring GA airports to continuously update and adapt their security measures. Staying ahead of emerging threats and vulnerabilities is an ongoing challenge. • Implementing advanced physical security measures can be expensive. • Integrating various security technologies, such as surveillance cameras, access control systems, and alarm systems, into

[401] imarc. (2025). *United States Physical Security Market*

Benefits	Challenges
regular drills, ensuring that airport staff are well-prepared to handle security incidents and emergencies effectively.	a cohesive security framework can be technically challenging.

Infrastructure Needs

- **GA Airport's Responsibility:** GA airports can conduct comprehensive risk assessments and regular security audits to identify potential threats and vulnerabilities. In response, the GA airport can implement robust security measures, such as access control systems, surveillance technologies, and emergency response plans. The GA airport would also provide regular maintenance, continuous monitoring, and ongoing training for security personnel to ensure these measures remain effective. Finally, GA airports must stay updated on evolving threats and regulatory requirements, regularly reviewing and updating their security protocols.
- **Other Stakeholders' Responsibility:** GA airport users can adhere to security protocols and participate in training programs. Local law enforcement provides support and collaborates with airport security personnel. Security service providers offer advanced technologies and expert consultation.

Additional Resources

- **Case Studies:**
  - **Hartsfield-Jackson Atlanta International Airport (ATL)** has enhanced its security infrastructure by installing advanced surveillance systems and access control measures.
  - **Denver International Airport (DEN)** has also upgraded its physical security with improved perimeter security and advanced monitoring technologies.
  - **Los Angeles International Airport (LAX)** has implemented comprehensive security protocols, including biometric identification and enhanced emergency response plans.
- **Potential Funding and Incentives:**
  - Airport Improvement Program (AIP) grants can be used to enhance physical security measures. [402]
  - Airport Infrastructure Grant (AIG) can be utilized for various infrastructure improvements, including enhancing physical security. [403]

[402] *FAA. (2025). AIP*
[403] FAA. (2023). *$201M in Bipartisan Infrastructure Law Lights the Way to Improve Runway Safety*

Summary Ratings

- **Near Term**, physical security assessments and improvements at GA airports can be implemented within a timeframe of 1 to 5 years. This period allows for thorough planning, risk assessments, and the installation of necessary security measures.
- **Significant Impact**, implementing physical security improvements at GA airports can significantly enhance energy security by protecting critical energy infrastructure from unauthorized access and potential threats. Also, these physical security measures help prevent incidents that could lead to environmental damage, such as fuel spills.
- **Medium Cost**, implementing physical security improvements at GA airports can entail medium costs, as some enhancements require significant financial investment. Some costs would include access control systems, surveillance technologies, and perimeter security enhancements.
- **Low Risk**, implementing physical security improvements at GA airports is generally considered a low-risk activity. The enhancements typically involve straightforward measures such as installing access control systems, surveillance technologies, and perimeter security features, which are well-established and proven effective. The primary risks associated with these improvements are minimal and include potential disruptions during installation, the financial investment required, and the need for ongoing maintenance and staff training.

Recommendations

It is recommended for GA airports to perform risk assessments and regular security audits at least annually. GA airports can enhance their energy security by implementing physical security improvements such as robust perimeter fencing, advanced access control systems, high-definition surveillance cameras, and comprehensive emergency response plans.

Cybersecurity

Applicable Use Cases	Timeframe	Impact	Cost	Risk
Airport Facilities; Policies/ Practices; Management Systems	Near Term	Significant Impact	Medium Cost	Low Risk

Cybersecurity is a critical component of the energy security toolkit, aimed at protecting digital assets, systems, and networks from cyber threats. This aligns with the U.S. Department of Energy's (DOE's) focus on reducing the risk of energy disruptions due to cyber events by leveraging the expertise of the Federal government, National Laboratories, private sector partners, academia, and state and local governments.[404] In the context of General Aviation (GA) airports, cybersecurity measures are essential for safeguarding communication networks, operational technologies, and general safety of the airport users, staff, and the public. Key elements of a robust cybersecurity strategy include implementing strong access controls, encrypting sensitive data, and ensuring continuous monitoring and incident response capabilities. By securing these digital infrastructures, GA airports can prevent unauthorized access, data breaches, and cyber-attacks that could disrupt energy supply and airport operations.

Overview

- **Compatibility:** Cybersecurity measures are compatible with existing infrastructure, allowing for seamless integration without the need for extensive modifications. Modern cybersecurity solutions are designed to work with a wide range of systems and technologies, ensuring that they can be implemented effectively within current operational frameworks.
- **Current Market & Growth Projections:** In 2025, the market size is estimated to reach approximately $92.73 billion and is expected to grow to $136.82 billion by 2030, at a Compound Annual Growth Rate (CAGR) of 8.09%.[405]
- **Regulatory Environment:** Key federal regulations include the Cybersecurity Information Sharing Act (CISA), which facilitates the sharing of cyber threat information between the government and private sector, and the Federal Information Security Modernization Act (FISMA), which mandates federal agencies to implement comprehensive information security programs. The North Carolina Identity Theft Protection Act requires businesses to implement and maintain reasonable security procedures to protect personal information. The state also follows the North Carolina Department of Information Technology's (NCDIT) policies and standards, which provide a framework for securing state government information systems. Additionally, North Carolina participates in the Multi-State Information Sharing and Analysis Center (MS-ISAC), which enhances collaboration and information sharing on cybersecurity threats among state and local governments.

[404] U.S. DOE. (2024). *Cybersecurity*
[405] Mordor Intelligence. (2025). *US Cybersecurity Market*

Benefits & Challenges

Benefits	Challenges
• Contributes to the overall safety and security of GA airports by protecting energy. resources and systems from cyber threats. • Prevents disruptions and damage of GA airport systems that could impact operations. • Increases the resiliency of the GA airport's systems against potential cyber-attacks.	• Implementing advanced cybersecurity measures can be costly, requiring significant investment in technology, infrastructure, and skilled personnel. • Cyber threats are constantly evolving, necessitating continuous updates and adaptations to cybersecurity protocols to stay ahead of potential attacks.

Infrastructure Needs

- **GA Airport's Responsibility:** GA airports can develop comprehensive cybersecurity plans that identify critical systems, assess vulnerabilities, and outline mitigation strategies. GA airports would regularly apply security patches and updates, along with developing and adopting incident response plans. GA airports can also educate airport users and staff on cybersecurity best practices. When necessary and if the budget allows, outsourcing cybersecurity support to specialized firms can provide access to advanced expertise and resources.
- **Other Stakeholders' Responsibility:** Private sector partners supply advanced cybersecurity technologies, consulting services, and ongoing support, and can assist in vulnerability assessments and incident response planning. Airport users must adhere to established cybersecurity policies, report suspicious activities, and participate in training programs. Industry associations, such as the National Business Aviation Association (NBAA), advocate for best practices and provide resources, training, and support to enhance the overall cybersecurity strategy of GA airports.

Additional Resources

- **Case Studies:**
  - In 2024, **Seattle-Tacoma International Airport (SEA)** was hit with a ransomware attack that caused widespread outages including ticketing, baggage handling, flight display boards and Wi-Fi. The attack also compromised airport employee data, although the airport did not pay the ransom and worked with federal authorities to recover.[406]
  - **Major commercial airports** have cybersecurity strategies and policies, although information is not readily available to the public due to the security risk.
  - In 2023, Transportation Security Administration (TSA) issued new cybersecurity requirements for airport and aircraft operators to enhance cybersecurity resilience. These requirements include developing network segmentation policies, creating access control measures, implementing

[406] Associated Press. (2024). *Hackers demand $6 million for files stolen from Seattle airport operator in cyberattack*

continuous monitoring and detection policies, and applying security patches and updates in a timely manner.[407]

- **Potential Funding and Incentives:**
  - The State and Local Cybersecurity Grant Program (SLCGP), established through the Infrastructure Investment and Jobs Act of 2021, helps eligible entities address cybersecurity risks and threats to information systems.[408]
  - While traditionally focused on physical infrastructure, recent Federal Aviation Administration (FAA) Airport Improvement Program (AIP) guidance emphasizes incorporating cybersecurity considerations into funded projects. [409] [410]

Summary Ratings

- **Near Term**, cybersecurity efforts can be implemented within a 0-3 year timeframe. However, cybersecurity is not a one-time project but an ongoing strategy that requires continuous updates and improvements to adapt to evolving threats.
- **Significant Impact**, cybersecurity efforts would greatly enhance the energy security and resiliency of the airport. By implementing robust cybersecurity measures, airports can protect critical infrastructure from cyber threats, ensuring uninterrupted operations and safeguarding sensitive data.
- **Medium Cost**, cybersecurity effort costs vary depending on the scope of the initiative. These efforts can become expensive if significant changes, such as Internet Protocol (IP) changes, network reconfigurations, or the implementation of advanced security measures, are required. Additionally, ongoing costs include regular vulnerability assessments, continuous monitoring, and staff training to maintain a robust cybersecurity posture.
- **Low Risk**, implementing cybersecurity efforts at GA airports is considered a low-risk initiative. These efforts primarily involve enhancing existing systems and protocols to protect against cyber threats, which do not introduce new vulnerabilities or significant operational risks.

Recommendations

To enhance cybersecurity at GA airports, it is recommended that airport operators adopt a comprehensive cybersecurity strategy that includes several best practices. First, implement network segmentation to ensure that critical operational systems are isolated from other network components, reducing the risk of widespread cyber-attacks. Second, establish robust access control measures to prevent unauthorized access to sensitive systems and data. Continuous monitoring and detection policies should be in place to identify and respond to potential threats in real-time. Regular vulnerability assessments and timely application of security patches are essential to mitigate risks associated with unpatched systems. Additionally, investing in cybersecurity training programs for staff will foster a culture of cybersecurity awareness and preparedness.

[407] TSA. (2023). TSA issues new cybersecurity requirements for airport and aircraft operators
[408] Cybersecurity & Infrastructure Security Agency. *State and Local Cybersecurity Grant Program*
[409] FAA. (May 12, 2025). Reauthorization Program Guidance Letter (R-PGL) 25-06: Planning and Project Eligibility
[410] *FAA. (2025). AIP*