WSDOT Aviation Division

NOVEMBER 2020

Washington Electric Aircraft Feasibility Study

Prepared by

WSP

This page intentionally left blank.

NOVEMBER 2020

Washington Electric Aircraft Feasibility Study

Prepared for

WSDOT Aviation Division

Prepared by

WSP

In conjunction with

Kimley-Horn

PRR

Table of Contents

Acknowledgements

- Aerospace Futures Alliance
- AeroTEC
- Andrew Graham Aircraft Consulting
- Avista Utilities
- Center for Excellence in Aerospace and Advanced Manufacturing
- Community Air Mobility Initiative
- Department of Commerce
- Diamondstream Partners
- Elcon
- Federal Aviation Administration
- Greater Seattle Partners
- Joby Aviation
- Kenmore Air
- Kitsap Aerospace Defense Alliance
- magniX
- National Business Aviation Association
- National Renewable Energy Laboratory
- Pierce County
- Puget Sound Energy
- Seattle Tacoma International Airport
- Stellar Aerospace
- The Boeing Company
- University of Washington
- Verdego Aero
- Volta Enterprises
- Washington State University
- Wenatchee Pangborn Memorial Airport
- Zunum Aero
- WSP
- Kimley Horn
- PRR

Executive Summary

Background

For more than a century since Boeing Plant #1 opened in Seattle in 1917, Washington State has been at the forefront of the aerospace industry. Electric aircraft, including unmanned aerial systems (UAS) and electric vertical takeoff and landing (eVTOL) aircraft, represent the next frontier for aviation. These technologies have the potential to reduce the cost of flight, provide new options for passenger and cargo air transport in congested urban areas and hard-to-serve rural communities, reduce the environmental footprint of aviation, and grow jobs and the economy. In order to ensure Washington retains its leadership in the aerospace industry, it is important to consider and plan for these coming technologies.

The state legislature tasked the Washington State Department of Transportation (WSDOT) Aviation Division with forming the Electric Aircraft Working Group (EAWG) in 2018 to explore electric aircraft service across the state. The EAWG comprises over 30 members representing state and local government, airports, manufacturing, the FAA, pilots, energy utilities, and consultants. Engrossed Substitute House Bill 2322 gave clear direction to act upon a key recommendation of the EAWG's 2019 Working Group Report to commission this Electric Aircraft Feasibility Study (Feasibility Study) to provide a roadmap for policy makers, airports, industry, and the general public to facilitate the growth of the electric aircraft industry by reporting on the following key elements:

- Infrastructure requirements necessary to facilitate electric aircraft operations at airports
- Potential economic, environmental, and other public benefits
- Potential future aviation demands catalyzed by electric aircraft
- Workforce and educational needs to support the industry
- Available incentives to industry to design, develop, and manufacture electric aircraft
- Impacts to Washington's existing multimodal transportation network

Methodology

Research for this report was conducted over several months in 2020. The research focused on five scenarios, shown in **Table e.1**, regarding the types of aircraft and purpose of flight. These include small aircraft with capacity of 15 or fewer passengers, light cargo, and pilot training. Input was provided by 16 interviews with the EAWG, two half-day workshops with EAWG, and analyzing numerous research reports and datasets.

Table e.1: Electric Aircraft Operations and Use Cases

Use Case	Description	Companies
Regional Commuter Less than 5 passegers	Carrying 1-4 passengers closer to 50 mile range	Joby, Bell, Hyundai, Jaunt
Regional Commuter Less than 15 passengers	Carrying up to 9 passengers for scheduled operations	Ampaire, Eviation, magniX
GA/Personal + Business	1-6 passengers, average flight time 43 minutes	Pipistrel, Bye Aerospace
Light Air Cargo	Maximum payload of 7500 lbs, cruise speed around 200 mph	Ampaire, magniX
Pilot Training	1 pilot and 1 passenger, cruise speed around 125 mph	Pipistrel, Bye Aerospace

Key Findings

The following summarizes the key findings of the report:

1. **Infrastructure Readiness:** The key infrastructure needs for airports will occur on the airside to provide power and charging capabilities for electric aircraft. As with electric automobiles, adoption of electric aircraft will require pilots to be confident that their aircraft charging and maintenance needs can be met at the airports they utilize. This will require coordination of charging standards to ensure that aircraft of different size, capability, and from all manufacturers can utilize airport charging equipment.

   Battery swapping rather than plug-in charging has several benefits including reducing turn-around times while charging, obviating the issue of different charging standards types that have impacted electric automobile charging interoperability, reducing demands on the energy grid since a lower rate can be utilized when charging speed is not critical. However, the FAA would need to approve battery swapping procedures as it could be considered a major repair or alteration, which would make this option less feasible.

   The increased electric infrastructure needs of electric aircraft will also need to be balanced with other new landside electric demands including transportation and heating and cooling (HVAC). Early engagement with utility companies is needed to ensure capacity is not a constraint for aircraft charging. FAA safety and security approval is another critical path to both standardization and implementation of technologies.

2. **Economic Impact:** The deployment of electric aircraft for passenger and cargo transport may have several effects on the economy. Reducing the time and cost for people and goods to travel, particularly over short and congested routes, will help create business activity and jobs. Lower-cost flight will enable also help connect the rural areas of the state with employment centers along the I-5 corridor. The smaller carbon footprint of electric aircraft will reduce net emissions and the environmental and health costs. Quieter aircraft have the potential to reduce the negative externalities of aviation. In addition, the major investments needed to scale

up power systems and airport infrastructure, as well as the financial impacts on airports, must be also be considered.

Quantifying these affects is problematic and requires making numerous assumptions about the timing of aircraft, the cost of flight, and the future change in the cost, time, and environmental impacts of ground transportation alternatives. Therefore, this study provides a framework for quantifying economic impacts that that can be adjusted as data becomes available.

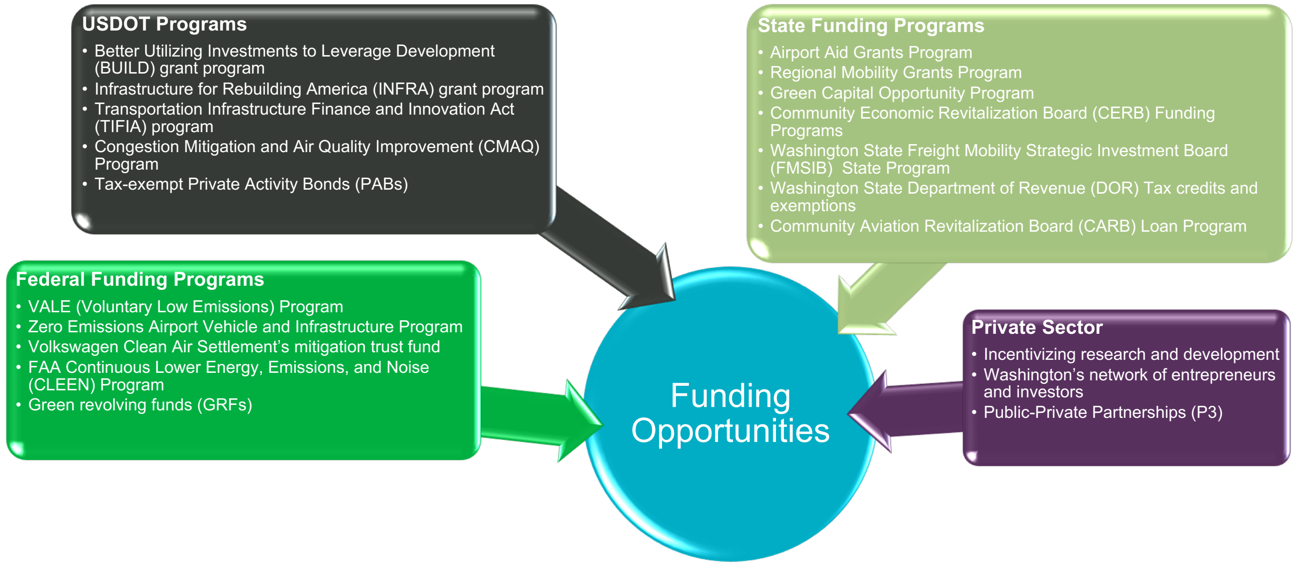
a. **Economic Impacts:** As detailed in the demand analysis of this report, electric aircraft have the potential to increase flight activity and encourage growth on and off-airports that will support jobs and create business revenues. The 2020 WSDOT Aviation Economic Impact Study (AEIS) found that airports directly employed over 83,000 workers in 2018. These jobs support other businesses that are patronized by aviation workers, along with visitor and construction spending enabled by aviation. Including these multiplier effects, airports (excluding Sea-Tac) generate over 255,000 jobs in Washington, $19 billion in labor income, and nearly $85 billion in business revenue. The multipliers in the study can be utilized to calculate the downstream effects on the economy as money related to aviation cycles through the economy due to growth created by electric aircraft.

   While the operation and maintenance of electric and hybrid-electric requires many of the same labor and skills needed to operate and maintain conventional aircraft, the aviation industry workforce will witness some variation in employment and skills needed to operate and maintain electric aircraft.

b. **Reduced Emissions:** Although aviation represented just 0.46% of emissions in Washington State according to a 2014 Washington Department of Ecology study, and 2.4% of global CO2 emissions, its footprint is growing rapidly due to increased demand for air travel. In addition, high-altitude emissions have been shown to have a greater effect on climate change than surface emissions, doubling the impact of aviation. Calculating the reduction in emissions due to electric aircraft is highly complex. Conventional aircraft are becoming more fuel efficient, sustainable aviation fuels (SAF) have the potential to decrease climate impact, and government regulation and public pressure on businesses to be greener are all key factors affecting future emissions. Furthermore, electric energy is only as clean as the source of production. Here, Washington State has an advantage, with 69% of net generation provided by hydroelectric power – though rising overall demand will likely require scaling up other sources.

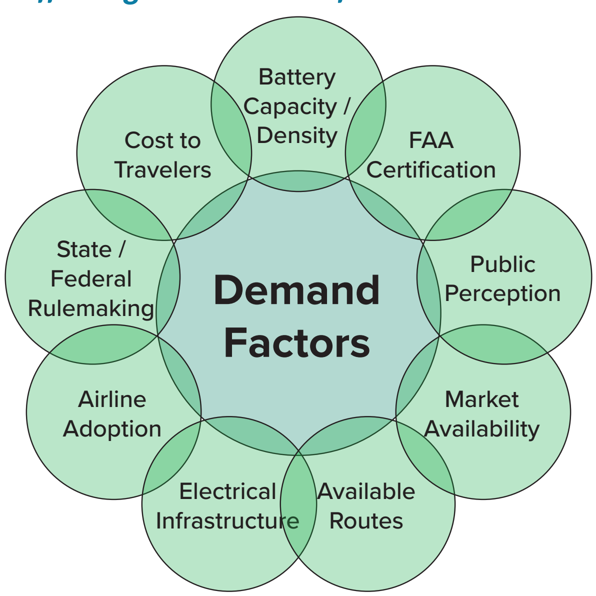
c. **Funding Opportunities:** The cost to provide infrastructure to support electric aircraft at airports is unknown, but could be considerable. Existing state and federal grant and loan programs can help mitigate part of the development cost, but funds will need to be identified at the local level to support supplying the infrastructure needed to charge aircraft and improve energy supplies. While some of the funding options may not be directly applicable to airport infrastructure, there may be instances in the future in which public transportation and advanced air mobility infrastructure and facilities, for example, may be combined. Hence, a range of funding opportunities that may be applicable now or in the future are provided for consideration. The report identifies numerous options, shown in **Figure e.1**, but these are likely to provide only part of the funds needed.

Figure e.1 Electric Aircraft Funding Opportunities



3. **Demand Assessment:** Demand for passenger flights on electric aircraft is dependent upon several factors. These include the following:
    a. Organic demand for air travel
    b. Availability of electric aircraft of various the sizes and range – with key factors shown in **Figure e.2**
    c. Induced demand for short-haul trips that are not feasible today but could be in the future if electric aircraft drive down costs as predicted and eVTOL increase the departure points available, particularly in congested urban areas.

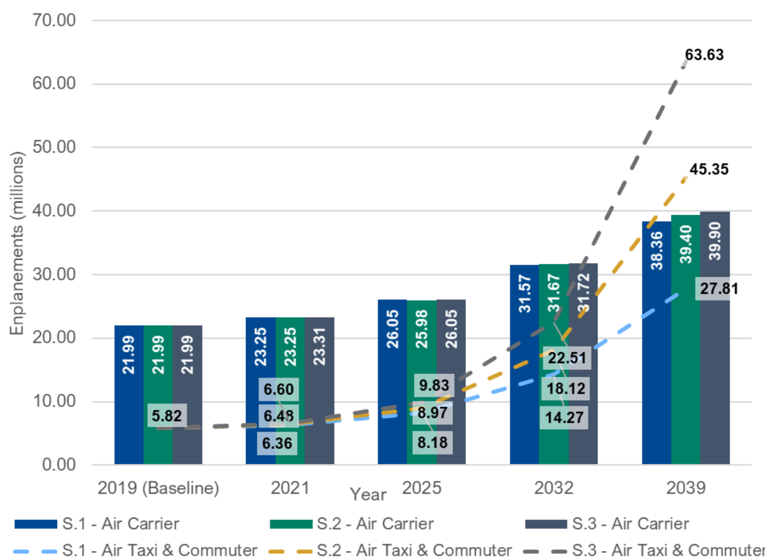
Figure e.2 Factors Affecting Electric Aircraft Demand



The existing Washington State Aviation System Plan (WASP) provides forecasts through 2034. A detailed Transportation Network Assessment was developed to assess demand for airport-to-airport trips within Washington and to nearby states/provinces.

As shown in **Figure e.3**, electric aircraft are forecast to start increasing air taxi & commuter passengers as soon as 2025, with dramatic growth after 2032. Air carrier passengers will see a less significant impact since larger electric aircraft will compete or substitute for existing aircraft rather than induce new short-haul routes.

Figure e.3 Enplanement Forecasts



4. **Workforce Development:** Washington State has a robust education and workforce development portfolio that provides skilled workers for the aerospace industry and job opportunities for residents. This includes high school dual-credit programs, apprenticeships, pilot training, community college centers of excellence, and certificate and degree programs. Through these programs, industry, government, and airports partner to educate and train workers in all aspects of aviation.

   Electric aircraft workforce development can build on this existing infrastructure by developing modules within existing workforce development programs and creating new aviation-focused training in industries related to manufacturing and support for electric aircraft is key to support the industry. Advanced materials manufacturing, battery and hydrogen energy systems, and electric propulsion systems are examples of areas that will need enhanced training.

   A key part of incorporating electric aircraft into workforce development is connecting with new entrants into the industry. Nearly half of the companies focused in this area are startups, with less than 20% being traditional major aerospace companies.

Table e.2 Electric vs. Conventional Aircraft

Electric Aircraft Industry	Conventional Aircraft Industry
Hybrid-electric and electric propulsion systems	Conventional propulsion systems
Advanced materials manufacturing	Conventional airframe manufacturing
Battery and hydrogen energy systems	Conventional fuel systems
Semiconductors and digital computer systems	Analog computational systems
Integration technologies (Internet of Things, RFID, Big Data analytics)	Analog electrical and maintenance systems
Pilot training on electric aircraft	Pilot training on conventional aircraft
Mechanic training on electric aircraft	Mechanic training on conventional aircraft
Rapid integration Industry 4.0 technologies	Slower integration of Industry 4.0

5. **Selection of Beta Test Sites:** The team developed a multi-phased methodology to select a system of airports to demonstrate the functionality of electric aircraft technologies when deployed as a system and provide equitable access to the benefits of electric aircraft across Washington state. These Beta test sites could become the champions of electric aircraft for their communities and statewide.

   All airports in Washington were ranked based on their appropriateness to serve as a Beta test site. Key factors include the availability of a 3,000 foot runway, need for aviation services, connectivity to airports within 500 nautical miles, existing on-airport aerospace manufacturing, the presence of a fixed-base operator (FBO), geographical dispersion, and the availability of jet fuel at the airport to support hybrid electric aircraft. The initial beta test site rankings are provided in **Table e.3**.

Table e.3 Initial Beta Test Site Recommendations

Associated City	FAA ID	Airport	Service	WSDOT Region	WA Classification
Chehalis	CLS	Chehalis-Centralia	GA	Southwest	Regional
Moses Lake	MWH	Grant County International	GA	North Central	Major
Olympia	OLM	Olympia Regional	GA	Olympic	Regional
Seattle	BFI	Boeing Field/ King County International	Commercial Service	Northwest	Major
Spokane	SFF	Felts Field	GA	Eastern	Regional
Yakima	YKM	Yakima Air Terminal (McAllister Field)	Commercial Service	South Central	Major

In addition to these Beta test sites, a network 15 airports is proposed to form the initial system for electric aircraft in Washington, as shown in **Figure e.4**.

Figure e.4 Proposed Electric Aircraft Airport System in Washington

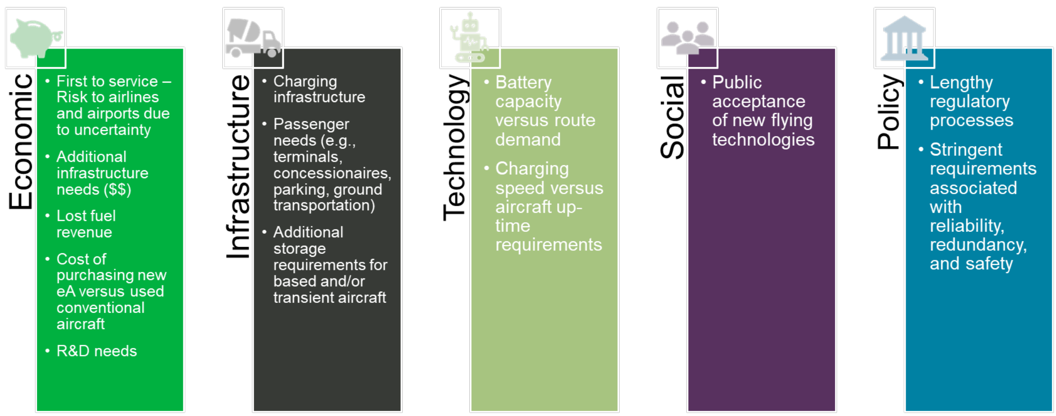
Source: WSDOT Aviation 2020, Kimley-Horn 2020

Timeline for Deployment

As described in the demand forecast, the adoption of electric aircraft is likely to start slowly before a critical mass of acceptance accelerates growth. There are significant obstacles that government, industry, and the public must overcome to reach this inflection point. Chief among these are manufacturers obtaining operating certificates for entry into service for their electric aircraft. According to an ICAO overview of manufacturers, by 2030 at least 20 electric or hybrid electric aircraft are planned to be in service, with over a dozen more in development. These include a fully-electric aircraft with capacity of 19 passengers and a hybrid electric 70 passenger aircraft, in addition to several eVTOL passenger aircraft.

In order for airports to be ready to service these new aircraft, significant obstacles need to be overcome, as detailed in **Figure e.5**.

Figure e.5 Barriers to Electric Aircraft Growth



Timeline Goals

State legislation funding this study requires that it recommend "specific, measurable goals for the years 2030, 2040, and 2050 that reflect progressive and substantial increases in the utilization of electric and hybrid-electric commercial aircraft."

In addition to ensuring infrastructure exists to support electric aircraft, regulations must be in place to ensure safe and secure flight. The timing requirements to meet electric aircraft needs largely depends on the pace of battery development that is needed for larger aircraft to rely on electric propulsion. The following metrics provide a roadmap to being prepared for full integration of electric aircraft by 2050.

Table e.4 Implementation Goals

	2030	2040	2050
Economic	• Fee structures in place to replace lost airport fuel-related revenue • Mechanisms in place to recharge eVTOL for urban and rural flights • Implement programs to share infrastructure costs with localities	• Electric aircraft infrastructure does not require subsidy	
Infrastructure	• Charging infrastructure available at all commercial airports for aircraft up to 10-15 passengers • Energy supply adequate to meet increased demand • Identify eVOTL platform sites	• Charging infrastructure available at all airports for general aviation • Infrastructure for aircraft up to 100 passengers at all commercial airports • Energy supply adequate to meet increased demand	• Infrastructure available for all aircraft at commercial airports

	2030	2040	2050
Social	• Implement public awareness campaign regarding electric aircraft safety		
Policy	• FAA certification of electric aircraft • Policies in place for the safety & security of eVTOL flight • Create workforce development programs at existing aviation schools • Consider infrastructure needs during airport planning process • Consider eVTOL platforms in state/local/regional planning	• FAA certification of electric aircraft	• FAA certification of electric aircraft

Key Recommendations

The key recommendations for policy makers and for airports are summarized below. **A complete list of recommendations, including additional details, is provided in the final section of the report.**

Recommendations

Chapter 1: Environmental Impacts, Economic Benefits, and Incentives

The research on environmental and economic benefits of electric aircraft in Washington State identified several actions to facilitate adoption. Key recommendations for policy makers and for airports are summarized in the table below:

Policymakers	Airports
Build partnerships with stakeholders to advance e-Aircraft integration within the state	Develop electric aircraft infrastructure and evaluate alternate technologies to generate or isolate power such as coordinating with utility companies to install microgrids or self-contained power sources such as fuel cells
Promote public acceptance by communicating the benefits of electric aircraft for economic growth and sustainability through emission reduction, noise mitigation, and economic impact benefits including direct and indirect job creation across sectors, labor income, and total business revenues.	Educate airport users, tenants, and community stakeholders regarding electric aircraft benefits and impacts
Develop incentives to support battery cluster and electrical engineering capabilities within Washington State	Continue developing partnerships with local universities to promote sustainable technologies such as WSU – Alaska Airlines woody biomass fuel partnership

Policymakers	Airports
Sponsor additional research that will help refine this analysis, focusing on infrastructure needs and funding requirements	Partner with utilities and energy service companies to build out infrastructure
Develop policies and regulation regarding revenue generation and safety/security for urban UAS operations	

Chapter 2: Transportation Network Assessment

The following key recommendations associated with the integration of electric aircraft into Washington's existing multimodal transportation network

Airports

- Develop a partnership with local planners, as electric aircraft may need to be incorporated into local comprehensive and transportation strategic planning efforts. Planners should be educated about electric aircraft's potential roles within and impact on the broader transportation network.

Policymakers

- Coordinate with other modal managers during all regional and statewide long-term transportation planning efforts.
- Consider zoning ordinances and land use regulations that may be required by future UAS and UAM applications.
- Include electric aircraft in long-term statewide aviation planning efforts.

Chapter 3: Workforce Development

Key recommendations to ensure a skilled workforce is trained and prepared to support the electric aircraft industry include the following:

Policymakers

Program Development

- Expand the capacity of apprenticeship programs and jobs skills training programs
- Promote pilot training to ensure supply of pilots meets demand
- Expand course content on the tools and technologies related to the manufacture of electronics, semiconductors and electric power systems and the emergence of Industry 4.0 tools and technologies
- Develop a program of continuing education opportunities for new and journeyman staff in the aerospace industry to facilitate upskilling and continuous development
- Identify and seek to limit the exposure of financial and market risk to operators and standardize operational regulations

Building Partnerships with Private Sector Entities

- Develop an incubator purposed to identify funding sources for research and business investment supporting the electric aircraft sector

Policy Changes

- Research and develop policies enabling the deployment of electric aircraft at the local level as an urban mobility solution
- Determine the compatibility of the operation of electric aircraft with laws governing the conditions of land use
- Identify and integrate the infrastructure systems necessary to operate electric aircraft in the urban environment
- Develop incentive programs targeted at industry firms to facilitate continuous learning related to electric aircraft systems for current employees

Funding Opportunities

- Leverage loan and grant funding programs administered by state government agencies providing public funds for business investments and infrastructure projects related to freight transportation, airport operations and electric vehicles

Airports

Airports can support workforce development for electric aircraft in several ways:

- Encouraging flight schools to integrate electric aircraft into their training
- Supporting connections with local industries for apprenticeships

Chapter 4: Infrastructure and Battery Charging

There are three main steps that need to be addressed first in order to advance the electric infrastructure front for electric aircraft:

- FAA/Regulatory involvement
- Standardization of charging technologies
- Early utility engagement to help advance the technology.

Recommendations for infrastructure an battery charging include the following:

- Early utility engagement to aid projects with increased infrastructure needs.
- Coordinate with utility companies and the Washington Utilities & Transportation Commission to develop EV specific rate-cases, or “charge ready” infrastructure plans

Chapter 5: Demand and Deployment

The following section provides recommendations to support the development of and prepare for the implementation of electric aircraft. Separate recommendations are provided by airports and policymakers.

Airports

- Consider if electric aircraft deployment should be incorporated into long-term planning efforts.

Policymakers

- Consider the need for new zoning ordinances addressing Urban Air Mobility/Advanced Air Mobility activities,
- Permanently codify the CARB fund to provide airports with access to funds for hangar storage.
- Become involved in the long-term planning efforts of other transportation modes and communicate the potential future impacts of electric aircraft on the state's roadway network.

Chapter 6: Selection of Beta Test Site Airports

The Electric aircraft Feasibility Study offers the following key recommendations for the six Beta test site airports: Chehalis-Centralia, Grant County International (Moses Lake), Olympia Regional, Boeing Field/King County International, Felts Field (Spokane), Yakima Air Terminal.

Airports

- Re-evaluate TSA requirements to screen cargo transported on passenger aircraft at a level of security commensurate with the level of security of passenger checked baggage.
- Consider electrical infrastructure needs in terms of current power capabilities and density of expected demand during existing planning efforts to "future proof" against future utility constraints.
- Ensure Aircraft Rescue and Firefighting (ARFF) personnel are trained and equipped to manage the specialized needs associated with electric propulsion

Policymakers

- Advocate for the development of ASTM International standards for electric aircraft charging infrastructure for continuity between manufacturers.
- Work with each beta test site to understand specific needs in terms of infrastructure and planning.
- Develop innovative partnerships and programs to fund the installation of electric aircraft charging stations at beta test site airports.
- Provide low-interest loans to airports to install electric aircraft charging stations through the Community Aviation Revitalization Board (CARB) or another independent program specifically earmarked for electric aircraft infrastructure.
- Clearly tie commercial applications of electric aircraft to other state carbon emission/greenhouse gas reduction initiatives and goals where applicable.

Introduction

Background

Electric aircraft represent the cutting-edge of aviation technologies—promising a future where flight has the potential to be conducted cheaper and more sustainable than ever before. Full and hybrid-electric aircraft open a range of benefits in terms of enhanced mobility and access, increased aviation-related economic impact, and new educational and workforce opportunities within Washington State. At the same time, transitional impacts may arise as electric aircraft begin to operate at airports designed to support aircraft powered by conventional fossil fuels and enter the National Airspace System (NAS).

To better understand both the opportunities and potential challenges associated with the deployment of electric aircraft in Washington State, the state legislature tasked the Washington State Department of Transportation (WSDOT) Aviation Division with forming the Electric Aircraft Working Group (EAWG). Established in spring 2018, the EAWG had an initial goal of exploring the use of electric aircraft to expand regional passenger service across the state. The group published the Electric Aircraft Working Group Report in June 2019. The report provided an overview of the current state of the technology, its potential applications within the state, and the overarching recommendation that an in-depth assessment of the future of electric aircraft in Washington be conducted.

This Electric Aircraft Feasibility Study (Feasibility Study) is the outcome of that recommendation. The goal of this study is to provide specificity regarding the future of electric aircraft in Washington focusing on:

- Infrastructure requirements necessary to facilitate electric aircraft operations at airports
- Potential economic, environmental, and other public benefits
- Available incentives to industry to design, develop, and manufacture electric aircraft
- Impacts to Washington's existing multimodal transportation network
- Workforce and educational needs to support the industry
- Potential future aviation demands catalyzed by electric aircraft

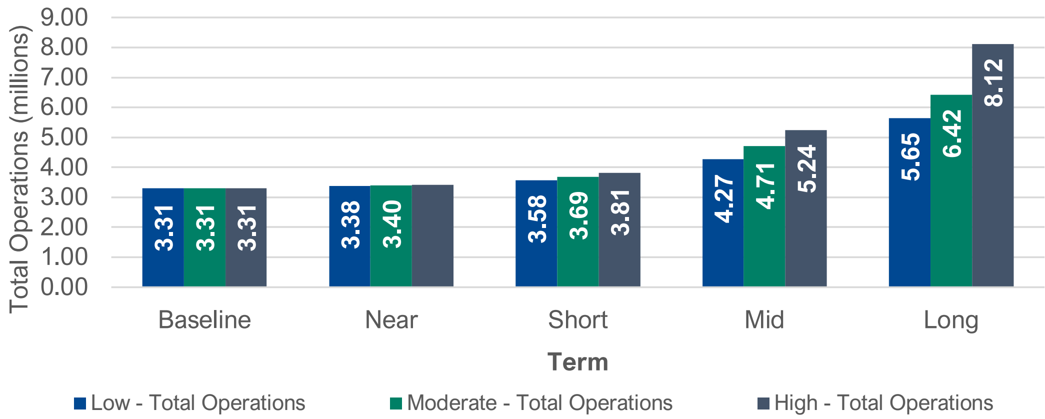
The report also identifies six "beta test site" airports that may be well positioned to host electric aircraft in the early years of commercial deployment. These airports were selected to form the foundation of a future electric aircraft airport network within Washington and will work closely with WSDOT Aviation and the EAWG to implement the recommendations offered throughout this Feasibility Study. It is important to note that all airports have access to the recommendations provided in this report, and airport managers and sponsors are encouraged to take advantage of the tools and resources provided to become better prepared for the arrival of full- and hybrid-electric aircraft.

It is important to note that study makes the key baseline assumption that electric aircraft will catalyze increased demand for all types of aviation activities, including scheduled commercial passenger service, general aviation, and air cargo. Electric aircraft are anticipated to provide a host of benefits in terms of economics and environmental sustainability. The projected lower cost of flying could lead to increased air service levels for areas of Washington that currently have limited air service, thereby enhancing mobility and access across the state. People may begin to shift away from ground-based travel options as flying becomes less expensive, more accessible, and convenient— particularly if service is added or expanded at smaller, less congested airports with streamlined passenger check-in, security, and boarding processes. Because of these key benefits, it is assumed that electric aircraft will shift some travelers away from other modes of travel, thereby creating new demand for air travel.

Should the key promises of this technology come to fruition—namely, the ability for travelers to reach their final destinations more cheaply, quickly, and with less hassle and fewer environmental impacts—the implications for the Washington aviation system and airports would likely be substantial. To illustrate the potential impacts of electric aircraft on airports and the state aviation system, this Feasibility Study developed three potential scenarios to understand the impacts of electric aircraft in Washington (presented in Chapter 5: Demand and Deployment). These scenarios applied low, moderate, and high growth scenarios to 2019 aircraft operations across Washington[1]. This reveals that operations may increase from 3.31 million in 2019 to between 5.65 and 8.12 million by 2039. This represents between 2.3 and 4.8 million more operations in 2039 than experienced today.

1 An operation is defined as a take-off or a landing. One flight represents two operations.

Figure i.1 Scenario Forecasts – Total Operations

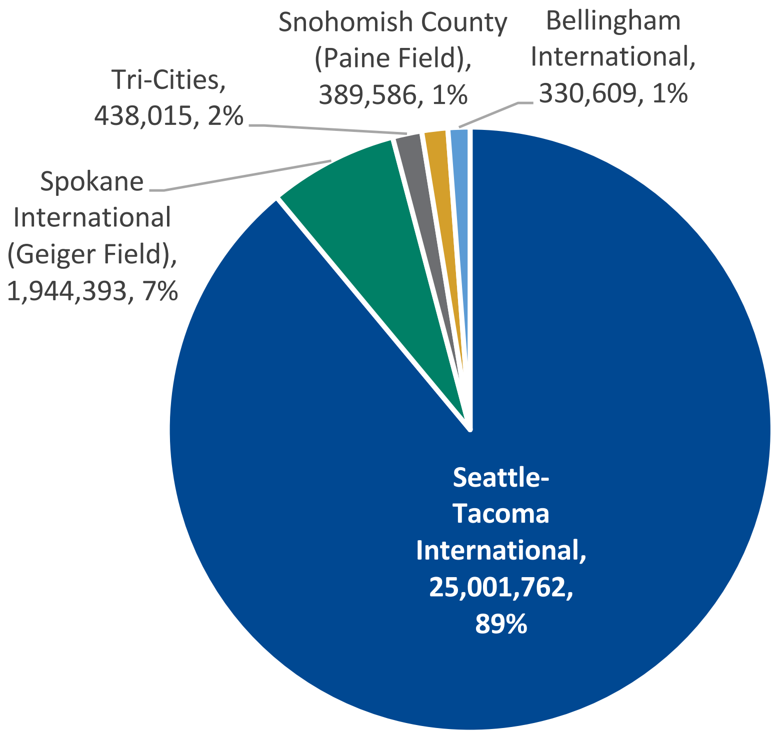


Sources: FAA Terminal Area Forecast (August 2020), FAA 5010 Master Record 2020, Washington Aviation Economic Impact Study 2020, Washington Aviation System Plan 2017, Seattle-Tacoma International Airport Sustainable Airport Master Plan 2018, Kimley-Horn 2020

Air Service Overview

Advocates of electric aircraft typically cite the technology's lower operating and maintenance costs as the technology's primary advantages. The cost of electricity is presently significantly cheaper and less variable than fossil fuels, particularly in Washington where abundant hydropower has resulted in some of the lowest electricity costs in the United States (U.S.). These lower costs have the potential to increase demand for air travel and provide new incentives for airlines to expand into smaller markets that currently have limited or no access to scheduled commercial service. Access to scheduled commercial service is generally considered to increase an area's economic development related to the ability to attract and retain businesses and professionals, increase tourism, and create jobs related to air transportation. A 2018 U.S. Government Accountability Office (GAO) report on the Federal Aviation Administration's (FAA) Essential Air Service Program noted that, "greater aviation activity in a region is correlated with some increase in the growth of population, employment, or per capita income". Air service connectivity also enhances residents' access to specialized medical care and other quality of life benefits associated with aviation.

Figure i.2 Top Five Airports in Washington in Enplanements (2019)



Source: FAA Air Carrier Activity Information System (ACAIS) CY2019

In Washington, five airports support 99 percent of all enplanements (revenue paying passengers boarding an aircraft), with 89 percent of all enplanements occurring at Seattle Tacoma International Airport (SEA or SeaTac) alone (2019) (see **Figure i.2**). Airlines are continuing to consolidate service at large “hub” airports and further reduce service levels to small, low-density markets. Should these trends continue, residents and businesses in certain markets could witness reduced service levels in terms of flight frequency and non-stop destinations served.

Because of lower anticipated operating costs, shorter take-off distance requirements, and fewer seats to fill on commercially viable electric aircraft in the near- and mid-terms (with smaller aircraft being first to market), electric aircraft could potentially increase access to scheduled and unscheduled air service across Washington. Air carriers holding Federal Aviation Regulations (FAR) Part 121 and 135 certifications may begin to serve new markets and increase service levels in terms of flight frequency and number of non-stop destinations, particularly in lower-density markets that have been historically underserved by certain types of air service.

Carriers may choose to offer more direct or “point-to-point” flights in which passengers board a flight at an origin airport and deplane at their final destinations—instead of having to first travel to a “hub” airport for a connecting flight to their final destinations. The point-to-point model of air service reduces overall travel time and associated costs. However, this model is generally restricted to only the largest markets due to the inability to consolidate air travels bound for multiple destinations onto a single flight. This limits the number of city-pairs that can economically support non-stop flights. Because electric aircraft are anticipated to be significantly more economical to operate than their conventionally fueled counterparts and are likely to offer a more limited number of passenger seats through the mid-term, point-to-point routing may become increasingly feasible in smaller markets.

Electric aircraft could also be used to provide “linear” service along a pre-determined route between multiple destinations. In a comparison study between the point-to-point and hub-and-spoke route system, authors Gerald Cook and Jeremy Goodwin note, “Similar to a bus or train system, on a linear system, an aircraft makes several stops en route between an origin and destination collecting and disembarking passengers at each stop.”[2] Some stakeholders interviewed as part of this study observed that a linear model may hold great promise for electric aircraft. This model may offer airlines the ability to vary flight frequency in response to demand, enhance connectivity between small- and mid-sized markets, and provide the lowest cost per available seat-mile per city-pair.

In addition to the movement of people, air cargo operations may be the first to witness the financial and environmental benefits associated with electric aircraft, especially operators transporting parcels along short- and mid-range routes. In addition to lower costs, the public and regulatory agencies may be more comfortable flying packages on an electric aircraft instead of people until the technology’s safety and reliability is demonstrated over time. Slovenian aircraft manufacturer Pipistrel recently introduced a new series of unmanned hybrid-electric aircraft specifically designed for the air cargo market. Pipistrel’s Nuuva series aircraft take-off and land vertically using electric propulsion and use a combustion engine for actual flight. The larger Nuuva series aircraft known as the V300 is designed for a payload of up to 1,000 pounds (460 kilograms) and can be loaded with a forklift, while the smaller V20 model is designed for light courier services.[3]

2 Cook, G. N., & Goodwin, J. (2008). Airline Networks: A Comparison of Hub-and-Spoke and Point-to-Point Systems. Journal of Aviation/Aerospace Education & Research, 17(2). https://doi.org/10.15394/jaaer.2008.1443

3 https://www.pipistrel-aircraft.com/aircraft/nuuva-v300/#tab-id-2

Figure i.3 Rendering of Pipistrel's Nuuva V300

Source: Pipistrel

Pipistrel and the many other electric aircraft manufacturers developing aircraft that can be used for air cargo may be positioned to support a market anticipated for exceptional growth in the coming decades. According to the Boeing World Air Cargo Forecast 2018-2037, air cargo traffic grew 10.1 percent in 2017 over the previous year and is anticipated to experience a long-term growth rate of 4.2 percent over the next 20 years.[4] This growth is bolstered by a burgeoning e-commerce industry as consumers increasingly expect near-immediate delivery of goods. The industry is also recovering more rapidly than passenger service as the current aviation downturn continues (at the time of this writing in November 2020). Part of this recovery is likely associated with consumers turning to e-commerce instead of traditional brick-and-motar stores as concerns about the COVID-19 virus continue. Global retail e-commerce sales are anticipated to double between 2017 and 2021, growing from $2.3 to $4.9 trillion. Growth is led by Washington-based Amazon, which accounts for nearly half of the e-commerce industry in the U.S.[5]

4 The Boeing Company (2017). World Air Cargo Forecast 2018-2037. Available online at https://www.boeing.com/resources/boeingdotcom/commercial/about-our-market/cargo-market-detail-wacf/download-report/assets/pdfs/2018_WACF.pdf. Accessed November 2020.

5 Ibid. p. 5

Timeline for Deployment

At the time of this writing (November 2020), an estimated that 215 different models of electric aircraft are currently under development, including 45 different aircraft in the western U.S. alone.[6] Each of these technologies is vying to become the first to become viable for large-scale commercial use for its specific applicate. While their approaches may differ, each of these companies are working to overcome the same key challenge: Batteries do not have the same energy density as fossil fuels. This means that batteries with enough capacity for flight are large and heavy and are the primary limiting factor in large-scale commercial deployment of electric aircraft. As the Electric Aircraft Working Group Report observes, "High battery storage capacity and lightweight batteries are critical to fully electric and hybrid-electric aircraft. In order to accommodate a commercially viable payload and range, batteries will need energy density of 500 watts per kilogram."

At this time, the timeline for that development is unknown. Elon Musk recently commented that batteries enabling flight may enter the market in "three to four years".[7] Further, Washington-based magniX and AeroTec recently partnered to retrofit a Cessna 208B Grand Caravan with a 750-horsepower Magni500 propulsion system. The "e-Caravan" made it's a 30-minute voyage from Moses Lake/Grant County International Airport in May 2020 to become the largest electric aircraft ever flown.

Figure i.4 magniX and AeroTec's all-electric Cessna Grand Caravan

Source: magniX

6 https://www.rolandberger.com/en/Point-of-View/Electric-propulsion-is-finally-on-the-map.html

7 https://electrek.co/2020/08/25/tesla-elon-musk-batteries-enabling-electric-aircraft-coming/

While the pace of development appears to be accelerating, market readiness and associated FAA airworthiness certification processes may still be years of even decades off, particularly for large commercial aircraft. The International Civil Aviation Organization (IACO) reports that many small- to mid-sized aircraft have entry-to-service target dates between 2020 and 2030. Large commercial aircraft, including those focusing on hybrid-electric technologies, are targeted to enter service after 2030.[8] Because of the inherent uncertainty regarding electric aircraft technologies, the Electric Aircraft Feasibility Study recommends that policymakers and airports consider taking actionable steps once specific technological milestones have been achieved.

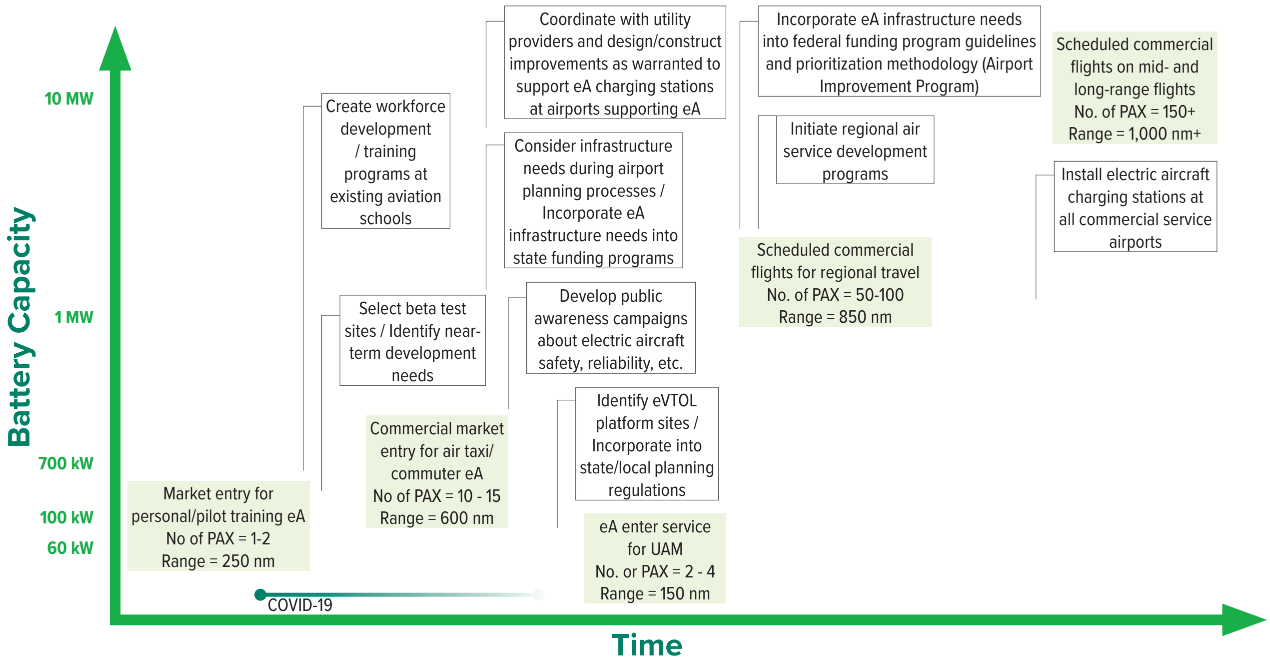
As such, the Feasibility Study has developed an actionable roadmap for deployment, which ties specific actions to aircraft entering commercial deployment. In this way, needs associated with airport infrastructure and funding policies, land use regulations, air service development, and the workforce evolve in conjunction with technological developments. The roadmap for the deployment of electric aircraft in Washington state is presented in **Figure i.5**. The green boxes identify specific high-value use cases utilized throughout this Feasibility Study, as well as the baseline assumptions in terms of range (nautical miles [nm]) and passengers (PAX):

- Regional commuter for five passengers or less
- Regional aircraft for up to 15 passengers
- Pilot training
- Personal business use
- Air cargo

The white boxes provide actionable steps that should be implemented at the state, federal, or local level to facilitate the implementation of each of these use cases. It is understood that each of these actions steps is complex, multifaced, and requires the involvement of multiple partners within the public and private spheres. The concepts presented are discussed in significantly more detail throughout this Electric Aircraft Feasibility Study, and additional recommendations are offered at the end of each chapter. **Table i.1** lists each key next step and the chapter readers can reference to learn more.

8 https://www.icao.int/environmental-protection/Pages/electric-aircraft.aspx

Figure i.5 Electric aircraft Roadmap to Deployment



Source: Kimley-Horn 2020

Acronyms: eA = electric aircraft, eVTOL = electric vertical take-off and landing, kW = kilowatt, MW = megawatt, nm = nautical miles, PAX = passengers.

Table i.1 Key Next Steps for Electric Deployment and Chapter for More Information

Key Next Steps	1: Environmental Impacts, Economic Benefits, and Incentives	2: Transportation Network Assessment.	3: Workforce Development	4: Infrastructure and Battery Charging	5: Demand and Deployment	6: Selection of Beta Test Site Airports
Create workforce development / training programs at existing aviation schools			✈			
Select beta test sites						✈
Identify near-term development needs				✈		✈
Coordinate with utility providers and design/construct improvements as warranted to support electric aircraft charging stations at airports supporting electric aircraft						✈
Consider infrastructure needs during airport planning processes				✈		
Incorporate electric aircraft infrastructure needs into state funding programs	✈					
Develop public awareness campaigns about electric aircraft safety, reliability, etc.					✈	
Identify electric vertical take-off and landing (eVTOL) aircraft platform sites / Incorporate into state/local planning regulations	✈			✈		
Incorporate electric aircraft infrastructure needs into federal funding program guidelines and prioritization methodology (Airport Improvement Program)	✈					
Initiate regional air service development programs					✈	
Install electric aircraft charging stations at all commercial service airports				✈		

Source: Kimley-Horn 2020

It is also important to observe that the aviation industry has been dramatically affected by the COVID-19 pandemic that arose during the development of this study. Commercial passenger service has been most acutely affected driven by a downturn in both leisure and business travelers. Many companies have shifted to a work-from-home model, with employees either prohibited or discouraged from attending in-person meetings and conferences. Air cargo and general aviation activities are showing rapid recovery and even upticks in activity levels at since the virus first struck the U.S. in early spring 2020. While challenges undoubtedly lie ahead, analysts generally expect a three- to five-year recovery period before air travel returns to pre-COVID levels. The market has experienced similar downturns before and has always rebounded to levels exceeding analysts' predictions. As such, the impacts of COVID-19 are expected to resolve in a similar fashion prior to large-scale commercial deployment of electric aircraft. Additional information about the impacts of COVID-19 on the future of electric aircraft is presented in Chapter 5.

Study Overview

In accordance with the study objectives identified by the Electric Aircraft Working Group Report, this Electric Aircraft Feasibility Study is comprised of the following chapters:

- Chapter 1: Environmental Impacts, Economic Benefits, and Incentives
- Chapter 2: Transportation Network Assessment
- Chapter 3: Workforce Development
- Chapter 4: Infrastructure and Battery Charging
- Chapter 5: Demand and Deployment
- Chapter 6: Selection of Beta Test Site Airports
- Recommendations

Each of the chapters concludes with specific recommendations for airports and policymakers to facilitate the deployment of electric aircraft in the state. These building upon the action steps presented in the roadmap above and provide more granular level details about each element of the deployment of electric aircraft in Washington. In particular, Chapter 5: Demand and Deployment includes an Airport Self-assessment Framework to help airports to understand their readiness to support electric aircraft. Additional tools and resources are also provided for airports to learn more about what they can do to facilitate the integration of electric aircraft into based and transient fleets. By taking actionable steps now, airports and communities will be best positioned to leverage the benefits of this exciting new technology, allowing Washington State to retain its position as a leader in aerospace technologies and aviation innovation for years to come.

Chapter 1:

Environmental Impacts, Economic Benefits, and Incentives

Introduction

This working paper provides an overview of the key considerations for evaluating the economic impact of electric aircraft for Washington state. As with any substantial technological change, electric aircraft will create significant benefits for the state economy, though they may also adversely affect certain people, regions, and industries. As discussed earlier in the introduction section, a working assumption for this analysis is that the lower costs and capabilities of electric aircraft will translate into enhanced connectivity and induced economic activity rather than simply attracting market share from existing transportation options. With key factors uncertain, such as the timing and pace of electric aircraft uptake and the cost of utilizing the new services, it is not possible to define the economic effects with any certainty. However, it is useful to establish a framework to asses these impacts as information becomes available. This working paper focuses on the following elements:

- Increased passenger and cargo travel will affect the flow of goods and people within and to/from the state.
- Mode shift for existing trips from ground transport to electric aircraft will benefit travelers as well as reduce congestion and emissions on the state's highway infrastructure.
- Changes in employment will occur as air service expands for passengers and cargo. The number of people working in the aerospace sector will be impacted, as will the profile of jobs needed to support electric aircraft.
- Environmental benefits in reduced emissions and reduced noise will accrue as electric aircraft replace some fossil fuel powered aircraft.
- Many of Washington state's 82 airports that have been identified as being capable of supporting electric aircraft will be affected. Operations profiles will shift, revenue streams will adjust as fuel sales decline, and investment in new infrastructure to support electric aircraft will be needed.
- Funding and financing tools will be needed to cover the cost of new on and off-airport infrastructure to support electric aircraft.

There are several caveats which concern the uncertain nature of each assumption. Further detailed analysis may be necessary to validate these assumptions once additional information becomes available. Additionally, it should be mentioned that the significant shift to telecommuting as a result of the COVID-19 pandemic may also impact the need for business travel. Each of these topics is explored in this document, and frameworks are suggested for quantifying the economic impacts electric aircraft will have on the state.

Section 1: Mode Shift Analysis

Mode Shift Factors

The introduction of small electric aircraft may eventually make flying feasible for trips where ground transport is the only current option. The Transportation Network Assessment presented in Chapter 2 provides an assessment of drive time versus flying between 10 Washington airports and commercial service airports in Seattle, Spokane, Boise, Portland, and Salt Lake City. The value of travel time savings is calculated for leisure, business, and all-purpose travelers based on FAA requirements for FAA benefit-cost analysis. However, analyzing mode shift from surface to air in selected corridors requires a more detailed approach.

A framework for assessing propensity for mode shift to air depends on several factors, and how individuals weigh them. Factors that affect choice of travel mode include the following:

- Itinerary: The travel itinerary reflects the actual trip origin and destination locations as opposed to airport-to-airport.
- Schedule: Driving enables the traveler to depart at any time and without committing to a schedule in advance. Flying (or rail/bus) involves selecting an available departure time that may not be convenient. Even in an "Uber-style" on-demand flight, schedule is impacted by the availability of flights and the lead time to reserve them.
- Travel time: There are several components to travel time to consider:
    - In-vehicle travel time is the actual time in motion between the origin and destination. This is what is examined in the Transportation Network Assessment in Chapter 2
    - Research on travel has shown that time spent waiting at a station or airport to depart is viewed more onerously than in-vehicle travel time
    - Travel from the point of origin to an airport/station and then to the final destination
- Trip Cost: The monetary cost of the trip, including ticket/fare, ground transport to/from the airport, and parking compared to the cost of operating a motor vehicle (i.e., fuel, insurance, depreciation, parking, etc.).
- Trip Reliability:
    - Corridors that experience congestion make for unreliable drive times. For example, according to Google Maps, driving from Tacoma to Bellingham on a Friday afternoon typically takes between 2 hours and 10 minutes and 3 hours and 10 minutes. Time of day, day-to-day variability, and peak hours and travel direction can have an impact on congestion levels which translate into travel uncertainty. Travelers that need to be on time for an event must take this unreliability into account when deciding when to depart.

- Weather reliability for air travel also needs to be considered as many locations may not be suited for all-weather approaches and can only accommodate flights under visual flight rules. Additionally, equipping aircraft for Instrumental Flight Rules (IFR) approach procedures will also be a factor.

- Number of travelers: The cost of air/rail/bus travel increases with each additional member of the traveling party, while the cost for driving stays constant (up to the vehicle capacity limit).
- Baggage and cargo: Some trips entail transporting large or heavy items that may not be appropriate for air travel.
- Value of time: For benefit-cost analysis, the FAA requires the use of calculated Value of Travel Time Savings (VOTTS) for leisure and business travel. The Transportation Network Analysis utilized the FAA-required VOTTS based on the median wage rate. However, individuals who would consider air travel can assume to be on the high end of the VOTTS spectrum.

Mode Shift Analysis

All else being equal, travelers are assumed to select electric aircraft rather than driving when the full cost of the journey, including their value of travel time savings and improved trip reliability, outweigh increased travel cost, reduced flexibility, and travel time to/from the airport.

A quantitative analysis of mode shift propensity requires certain data not currently available, such as existing trip data, electric aircraft flight routes, cost, and schedule. That is, the trip reliability may or may not improve depending on the origin and destination of the trip as well as the weather conditions, as stated earlier. Since we do not know the endpoints of trips being analyzed (i.e., the actual start and destination addresses), assumptions are needed to estimate mode shift. The framework of key assumptions is described below. Each can be flexed to examine results under a range of scenarios.

1) Cost Comparison for flying versus driving

    a. Prior to comparing costs across modes, a comparison between conventional and electric aircraft showed that direct operating costs of electric aircraft represent roughly 30% of conventional aircraft costs[9]. For example, the direct operating cost of the Eviation Alice is estimated at $200 per hour, which compares to $1,100 per hour for the Pilatus PC-12[10], a single engine turboprop.

    b. Estimate the cost of electric aircraft travel as a fixed amount plus a per mile cost. This is, of course, simplified, since longer flights will have a lower cost per mile than shorter trips. A fixed value of $50 was selected as a starting point and a per-mile cost of $0.25.

9 This cheap, clean, electric airplane could reshape regional air travel. https://thedriven.io/2018/11/12/this-cheap-clean-electric-airplane-could-reshape-australian-regional-air-plane-travel/

10 https://www.guardianjet.com/jet-aircraft-online-tools/aircraft-brochure.cfm?m=Pilatus-PC-12-147

c. The IRS reimbursement rate for auto travel is 57.5 cents per mile for 2020.

2) Value of travel time savings

a. The analysis uses the business traveler value of time savings of $75.84, since people who value their time highly are more likely to consider the higher out-of-pocket cost of air travel and most value the reliability of air travel versus driving in congested areas.

b. Assume that starting point to air departure is 45 minutes; likewise, air arrival to destination is 45 minutes. Thus, 90 minutes are added to all electric aircraft flight times for comparison to driving. It is also assumed that short trips will be operated at uncongested airports and therefore, taxiing time is not expected to significantly impact total travel time.

c. Assume a Planning Time Index to account for travel congestion and reliability. A planning time index represents the additional time buffer most travelers should add to a free-flow travel time to ensure arriving on-time to their destination 95% of the time.[11] This index accounts for recurring delays such as peak-hour congestion and nonrecurring delays such as those caused by a vehicle crash. Free-flow travel time typically corresponds to a free-flow speed of 60 mph on freeways.[12] Since data is not available at this time to calculate the 95th percentile travel time for specific routes, an index ranging between 1.2 and 2, corresponding to a 50 mph and 30 mph speed, respectively, is tested to account for the potential variations in planning travel time.

d. light of the Transportation Network Assessment, an airspeed of 250 miles per hour is selected as a starting point. The selected airspeed is of course an average speed as the aircraft's speed varies during the different stages of flight (take-off, cruise and landing).

Table 1.1.1 below shows the benefit (or disbenefit marked in red) of flying via electric aircraft versus driving for various lengths of routes, assuming a time to/from air departure and arrival of 90 minutes and a planning time index of 1.5, which corresponds to an average driving speed of 40 mph. It is shown for methodological purposes – in reality flight time and drive time distances will vary, and other factors such as travel speed and drive time reliability will factor in. With the assumptions utilized, a business traveler would be indifferent between flying and driving at a trip length of 86 miles.

11 Measuring Congestion, Reliability Costs and Selection of Calculation Method Direct Costs. http://documents1.worldbank.org/curated/ar/650141468248419267/016824232_2014031110400358/additional/718450ESW0Whit0ing0Annexes00PUBLIC0.pdf

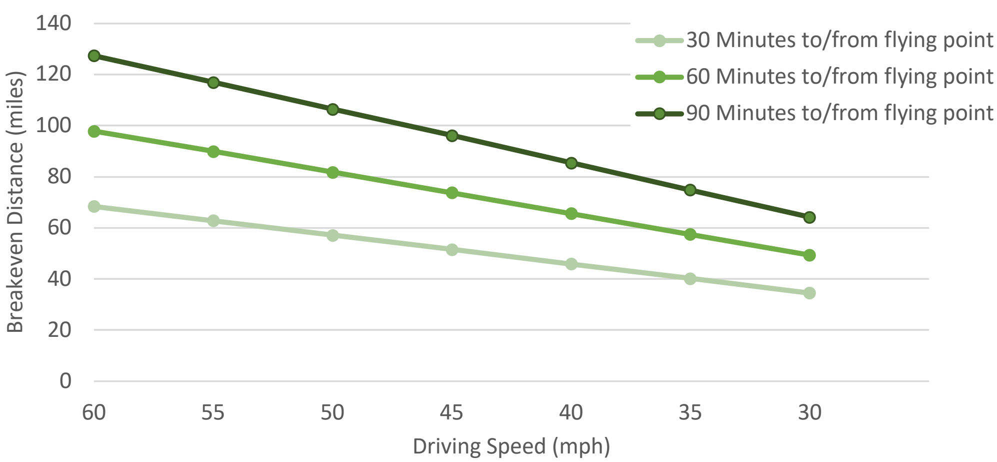
12 https://ops.fhwa.dot.gov/congestion_report/chapter2.htm

Table 1.1.1 Example Mode Shift Analysis

	Input	Cost at Selected Miles of Travel				Breakeven
		50	100	200	300	85.40
Flight Fixed Cost	$50.00	$50.00	$50.00	$50.00	$50.00	$50.00
Flight Cost per Mile, Variable Cost	$0.25	$62.50	$75.00	$100.00	$125.00	$71.35
Auto Cost per Mile, Variable Cost	$0.58	$28.75	$57.50	$115.00	$172.50	$49.10
Flight Cost Savings		($33.75)	($17.50)	$15.00	$47.50	($22.25)
Time Savings	**Input**	**Minutes at Selected Miles of Travel**				
Time To/From Point of Departure/Arrival & Waiting	90	90	90	90	90	90
Flight MPH, Flight Time	250	12	24	48	72	20
Planning Time Index	1.5					
Drive MPH, Drive Time	40	75	150	300	450	128
Air Time Travel Saving		27	36	162	288	18
VOTTS	$75.84	($34.13)	$45.50	$204.77	$364.03	$22.25
Total Air Savings		($67.88)	$28.00	$219.77	$411.53	($0.00)

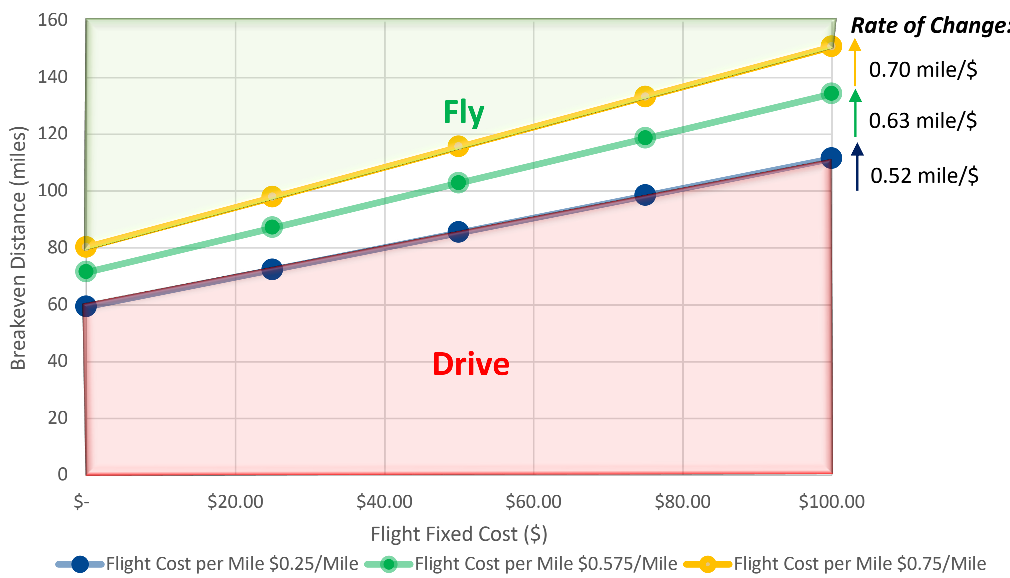
Faster driving speeds reduce the travel time saved by flying. To illustrate the impact of driving speeds on the distance at which travelers will be indifferent between flying and driving, **Figure 1.1.1** shows the variation in breakeven distance for various driving speeds and for three different times to get to and from the point of air departure and arrival, respectively. Additionally, the longer it takes to get to/from the point of air departure/arrival, the greater the trip distance that will get travelers to switch from driving to flying.

Figure 1.1.1 Breakeven Distance vs Driving Speed



To further explore the cost assumptions incorporated in the methodology, **Figure 1.1.2** shows the variations in breakeven distance for different fixed and variable flying costs. Each trendline represents a different variable flying cost ($0.25, $0.575 equal to the cost of driving, and $0.75 per mile) and shows the distance at which flying is more viable than driving for various fixed flying costs. As shown, the relationship between fixed flying cost and breakeven distance is linear. For each additional dollar in fixed costs and for a variable cost of $0.25 per mile, the breakeven distance increased by 0.52 miles. Additionally, the greater the fixed and variable costs of flying, the greater the distance at which travelers are likely to make a switch from driving to flying. If the fixed cost is zero, travelers would choose flying for trips as short as 60 miles if variable cost is $0.25 per mile, or 81 miles if variable cost is $0.75 per mile.

Figure 1.1.2 Breakeven Distance vs Flying Cost



Note: Distances correspond to a driving speed of 40 mph and a time to/from point of air departure and arrival of 90 minutes.

Table 1.1.2 explores the benefit (or disbenefit marked in red) of flying via electric aircraft versus driving for routes across Washington state's main corridors. Four different scenarios were explored that consider the driving speed and the time to get to the point of electric aircraft departure and from its arrival to the traveler's final destination. It is important to note that for each route scenario below, driving distance is estimated between city to city through Google Maps and excludes multi-modal routes (e.g., ferry commute) whereas the flying distance is retrieved from the Great Circle Mapper website[13] based on an airport-airport path distance.

13 http://www.gcmap.com/

Table 1.1.2 Route Mode Shift Analysis

Route Scenarios	Driving Distance (miles)	Flying Distance (miles)	Total Air Savings ($)			
			90 mins to/from air departure/arrival		60 mins to/from air departure/arrival	
			50 mph driving speed	40 mph driving speed	50 mph driving speed	40 mph driving speed
Olympia-Seattle (I-5 N)	61.1	43	($59.75)	($36.58)	($21.83)	$1.34
Olympia-Vancouver (I-5 S)	105.7	94	$5.33	$45.41	$43.25	$83.33
Spokane-Vancouver (I-84 W)	355.4	280	$424.72	$559.49	$462.64	$597.41
Spokane-Seattle (I-90 W)	278.7	224	$295.27	$400.96	$333.19	$438.88
Olympia-Yakima (I-90 E)	183	115	$155.40	$224.80	$193.32	$262.72
Olympia-Everett (I-5 N)	89.3	71	($16.25)	$17.61	$21.67	$55.53
Everett-Yakima (I-90E)	163.9	123	$111.02	$173.17	$148.94	$211.09
Everett-Seattle (I-5 S)	28.3	32	($122.27)	($111.54)	($84.35)	($73.62)
Seattle-Port Angeles (I-5 S)	139.2	72	$87.58	$140.36	$125.50	$178.28

Note: A fixed and variable flying cost of $50.00 and $0.25/mile respectively is assumed for the purpose of scenario development.

Section 2: Employment Profiles

Employment Profiles

The deployment of electric aircraft for passenger and cargo transport will affect the employment market. Electric and hybrid-electric aircraft are projected to increase regional transportation and grow air taxi and commuter operations. The projected expansion in air service will increase demand for aviation professionals, and the new technology will require different skills. While the operation and maintenance of electric and hybrid-electric requires many of the same labor and skills needed to operate and maintain conventional aircraft, the aviation industry workforce will witness some variation in employment and skills needed to operate and maintain electric aircraft. In addition, workers will be needed to produce and deliver electrical power to aircraft.

The latest Economic Impacts and Workforce Analysis study of the Aerospace Industry in Washington[14], reported that the aerospace industry directly employed 83,400 workers in Washington state in 2018, covering a diverse range of skills and experience. The study focused on aerospace jobs typically involved in production and manufacturing. Since many of the occupations that fall within the aerospace industry may also be involved

14 Aerospace in Washington: Economic Impacts and Workforce Analysis, CAI, 2019. https://aerospaceworksforwa.com/wp-content/uploads/2019/03/CAI.AWW-Econ-Impacts-and-Talent-Pipeline.Report.2019-0307.pdf

in the air transportation industry, the employment profiles corresponding with the five high-value use cases of electric aircraft were derived from the aerospace workforce analysis and further developed to include additional prominent occupations within the air transportation industry.

Table 1.2.1 provides an overview of the projected electric aircraft demand scenario with most growth captured by the air taxi and commuter operations to help assess future employment needs for regional use cases and GA operations. It is important to note that this scenario assumes that commercial electric powered air carrier aircraft with 60+ seats do not reach commercial deployment in the analysis timeframe.

Table 1.2.1 Scenario 1 Electric Aircraft Forecast Overview

Aviation Activity Indicator		Short-term (2-5 years)	Mid-term (6-12 years)	Long-term (13-20 years)
Enplanements	Air carrier	3.10% (WASP) / 2.8% (SeaTAC)		
	Air taxi/commuter	6.0%	8.0%	10.0%
Operations	Air carrier	2.00% (WASP) / 2.3% (SeaTac)		
	Air taxi/commuter	4.0%	6.0%	8.0%
	GA	0.07% (WASP)	2.0%	4.0
Based aircraft		1.1% (WASP)	2.2%	4.3%

Kimley-Horn 2020, WSDOT Aviation 2020, WASP 2017, SAMP 2018

The employment profiles developed for each of the planned use cases of electric aircraft should consider the skills needed to operate and maintain these aircraft, while also accounting for the workforce needed during the transition phase. Since hybrid-electric aircraft are likely to be deployed before all-electric aircraft, technicians for turbine- and piston- engines will have an opportunity to work on these aircraft and develop skills for future all-electric airplanes. In addition, the demand for technicians possessing additional skills in working on batteries and electric powerplants will increase with the deployment of hybrid-electric and full-electric aircraft. Nonetheless, electric aircraft manufacturers are working on developing airframes that are similar to existing aircraft in an effort to minimize retraining hours needed to maintain their aircraft[15].

Several factors may impact the employment needs for electric aircraft related aviation jobs. One of the key components is assessing maintenance needs. The electric plane startup Ampaire reported that an electric aircraft can have a 50% reduction in maintenance compared to conventional fossil fuel aircraft[16]. Although electric motors

15 Electric Aircraft Working Group Report, WSDOT 2019. https://wsdot.wa.gov/sites/default/files/2019/07/15/ElectricAircraftWorkingGroupReport-June2019.pdf

16 Green for Take Off – Inside the Electric Airplane Industry. https://www.toptal.com/finance/market-research-analysts/electric-airplanes

require less maintenance compared to conventional aircraft engines, the need for technicians will increase since electric aircraft are expected to increase flying rather than replace conventional aircraft. The lower operating costs is expected to drive a new regional travel market, which will translate into growth in electric technicians' demand, specifically airframe and powerplant (A&P) licensed mechanics.

Since hybrid-electric aircraft will precede the deployment of full-electric air transportation, the demand for mechatronics and aircraft mechanics as well as service technicians is anticipated to remain stable as the operation of these aircraft require a workforce skilled in working on piston- and turbine- powered engines. The deployment of fully electric aircraft will likely slow down the growth in demand for mechanic technicians if conventional aircraft start being replaced with electric aircraft, thus changing existing fleet composition. However, as electric aircraft market share grows over time, demand for electrical, electromechanical and avionics technicians will increase in the medium- and long-term.

The projected lower flying cost of electric aircraft and potential enhanced connectivity may also result in an increase in personal/business aviation activities and flight training. For example, the design of the Pipistrel's two-seat Alpha Electro targets the flight training industry with an operating cost as low as $3/hour for electricity[17], compared to about 5 gallons of fuel per hour for two seat piston aircraft. Based on 263 FBOs reported data, the average Jet A fuel cost is $4.16 in the Northwest Mountain Region[18]. Increased flying will create commensurate growth in demand for flight instructors and licensed pilots. It is expected that current licensed pilots may only need to go through a few hours of training to obtain certification to operate electric aircraft. However, in 2013, the FAA increased the training regulations for first officers of commercial airlines and required an Air Transport Pilot license with a minimum of 1,500 flight hours instead of requiring a commercial pilot certificate with 250 hours of flight time[19]. As a result, the industry warned of a long pilot shortage and student enrollments for pilot training in the US has not been able to keep up with the national demand[20].

Table 1.2.2 summarizes the estimated number of active pilots and flight instructors in Washington state between 2014 and 2019. Note that the total number of pilots excludes flight instructors and remote pilots to avoid any double-counting as these categories most likely include active pilots as well. Between 2014 and 2019, there was a 20% growth in flight instructors and approximately 85% increase in the number of students undergoing

17 Alpha Electro, Pipistrel USA. https://www.pipistrel-usa.com/alpha-electro/

18 https://www.airnav.com/fuel/report.html

19 Press Release – FAA Boosts Aviation Safety with new Pilot Qualification Standards. https://www.faa.gov/news/press_releases/news_story.cfm?newsId=14838

20 The Airline Pilot Shortage isn't going away, Flexair 2020. https://www.goflexair.com/the-airline-pilot-shortage-isnt-going-away/

pilot training. The latter indicates that, unlike the trends observed at the national level, Washington state witnessed a significant growth in the number of enrollments between 2018 and 2019 and may continue to increase once electric aircraft enter the market. The lower flying cost achieved by electric aircraft will offset the high educational and training costs and potentially attract more students to enter the field.

Table 1.2.2 Estimated Active Pilots and Flight Instructors, Washington 2014-2019

	Certificate Type						
Year	Students	Private	Commercial	Airline Transport	Miscellaneous (Recreational & Sport)	Flight Instructor	Total Pilots
2014	3,358	6,052	3,330	5,744	181	3,518	18,665
2015	3,492	6,010	3,271	5,923	192	3,619	18,888
2016	3,786	5,739	3,170	6,199	203	3,730	19,097
2017	4,459	5,793	3,245	6,370	213	3,902	20,080
2018	5,045	5,985	3,288	6,555	216	4,037	21,089
2019	6,211	5,905	3,317	6,718	227	4,223	22,378

WSP 2020, FAA U.S. Civil Airmen Statistics 2014-2019

Table 1.2.3 summarizes the number of non-pilot airmen certificates held in the state of Washington between 2014 and 2019. Contrary to the growth in the number of active pilots over the years, the number of non-pilot airmen across most certificate types decreased in the last five years except for dispatchers and flight attendants. The demand for flight attendants associated with the deployment of electric aircraft is not expected to vary significantly in the near-term until the deployment of commercial air carrier electric aircraft operations start to grow. Furthermore, as air service will expand with the projected increase in electric aircraft operations, there will be a growing demand for airfield operations specialists such as flight dispatchers to ensure the safe takeoff and landing of aircraft and coordination between UAS and electric aircraft sharing airspace.

Table 1.2.3. Non-Pilot Airmen Certificates, Washington 2014-2019

	Certificate Type								
Year	Ground Instructor	Flight Engineer	Mechanic	Repair men	Parachute Rigger	Dispatcher	Flight Navigator	Flight Attendant	Total Non- Pilot Airmen
2014	2,507	1,929	12,354	1,646	309	506	12	6,420	25,683
2015	2,487	1,861	12,407	1,627	294	514	9	6,819	26,018
2016	2,303	1,590	10,268	1,506	170	473	8	7,260	23,578
2017	2,365	1,481	10,452	1,534	174	477	5	7,712	24,200
2018	2,441	1,447	10,659	1,539	186	513	4	8,020	24,809
2019	2,506	1,333	10,942	1,585	203	557	4	8,490	25,620
CAGR	-0.01%	-7.12%	-2.40%	-0.75%	-8.06%	1.94%	-19.73%	5.75%	-0.05%

WSP 2020, FAA U.S. Civil Airmen Statistics 2014-2019

In addition to the projected increase in regional air travel demand, during the interviews conducted at the inception of the study in April 2020, a number of stakeholders emphasized that if the economics of operating electric aircraft are achieved, the use of electric aircraft for air cargo operations will likely be more competitive with ground-based cargo transportation. As a result, the demand for occupations directly related to air cargo handling such as aircraft cargo handling supervisors, laborer and material movers, transportation inspectors, etc. will likely increase.

Table 1.2.4 summarizes the occupational categories needed to operate and maintain aircraft based on Standard Occupational Classification (SOC) codes, published by the US Bureau of Labor Statistics[21]. The classification presented herein is based on the job duty, skills and education, and training required. Most of the occupations are common to all five use-cases with some jobs being specific to a use-case employment profile. The columns at the right show the projected increase (+), decrease (-) or multiple effects (±) caused by electric aircraft for each use-case.

21 Standard Occupational Classification Manual. Executive Office of the President Office of Management and Budget. https://www.bls.gov/soc/2018/soc_2018_manual.pdf

Table 1.2.4 Employment Profiles for Electric Aircraft Use Cases

Standard Occupational Classification (SOC) Code	Occupation	Job Description	Use Cases (1) Pilot Training	(2) Air Cargo	(3) Regional Commuter (≤ 5 Pax)	(4) Regional Commuter (≤ 15 Pax)	(5) Personal/ Business Use
11-1021	General and Operations Managers	Plan, direct, or coordinate the operations of public or private sector organizations, overseeing multiple departments or locations. Duties and responsibilities include formulating policies, managing daily operations, and planning the use of materials and human resources		±			
11-3013	Facilities Managers	Plan, direct, or coordinate operations and functionalities of facilities and buildings		±			
11-3071	Transportation, Storage, and Distribution Managers	Plan, direct, or coordinate transportation, storage, or distribution activities		+			
13-1081	Logisticians	Analyze and coordinate the ongoing logistical functions of a firm or organization. Responsible for the entire life cycle of a product		+			
17-2071	Electrical Engineers	Research, design, develop, test, or supervise the manufacturing and installation of electrical equipment, components, or systems for commercial, industrial, military, or scientific use	+	+	+	+	+
17-2072	Electronics Engineers, Except Computer	Research, design, develop, or test electronic components and systems for commercial, industrial, military, or scientific use employing knowledge of electronic theory and materials properties	+	+	+	+	+
17-3021	Aerospace Engineering and Operations Technologists and Technicians	Operate, install, adjust, and maintain integrated computer/ communications systems, consoles, simulators, and other data acquisition, test, and measurement instruments and equipment, which are used to launch, track, position, and evaluate air and space vehicles	+	+	+	+	+

Standard Occupational Classification (SOC) Code	Occupation	Job Description	Use Cases				
			(1) Pilot Training	(2) Air Cargo	(3) Regional Commuter (≤ 5 Pax)	(4) Regional Commuter (≤ 15 Pax)	(5) Personal/ Business Use
17-3023	Electrical and Electronic Engineering Technologists and Technicians	Apply electrical and electronic theory and related knowledge, usually under the direction of engineering staff, to design, build, repair, adjust, and modify electrical components, circuitry, controls, and machinery for subsequent evaluation and use by engineering staff in making engineering design decisions	+	+	+	+	+
17-3024	Electro-Mechanical and Mechatronics Technologists and Technicians	Operate, test, maintain, or adjust unmanned, automated, servomechanical, or electromechanical equipment. May operate unmanned submarines, aircraft, or other equipment to observe or record visual information at sites	+	+	+	+	+
43-5011	Cargo and Freight Agents	Expedite and route movement of incoming and outgoing cargo and freight shipments in airline, train, and trucking terminals and shipping docks. Prepare and examine bills of lading to determine shipping charges and tariffs		+			
49-1011	First-Line Supervisors of Mechanics, Installers, and Repairers	Directly supervise and coordinate the activities of mechanics, installers, and repairers. May also advise customers on recommended services	±	±	±	±	±
49-2091	Avionics Technicians	Install, inspect, test, adjust, or repair avionics equipment, such as radar, radio, navigation, and missile control systems in aircraft or space vehicles	+	+	+	+	+
49-3011	Aircraft Mechanics and Service Technicians	Diagnose, adjust, repair, or overhaul aircraft engines and assemblies, such as hydraulic and pneumatic systems	-	-	-	-	-
53-1041	Aircraft Cargo Handling Supervisors	Supervise and coordinate the activities of ground crew in the loading, unloading, securing, and staging of aircraft cargo or baggage. May accompany aircraft as member of flight crew and monitor and handle cargo in flight and assist and brief passengers on safety and emergency procedures. Includes loadmasters.		+			

Standard Occupational Classification (SOC) Code	Occupation	Job Description	Use Cases				
			(1) Pilot Training	(2) Air Cargo	(3) Regional Commuter (≤ 5 Pax)	(4) Regional Commuter (≤ 15 Pax)	(5) Personal/ Business Use
53-1042	First-Line Supervisors of Helpers, Laborers, and Material Movers, Hand	Directly supervise and coordinate the activities of helpers, laborers, or material movers, hand		+			
53-1044	First-Line Supervisors of Passenger Attendants	Supervise and coordinate activities of passenger attendants.			±	±	±
53-2011	Airline Pilots, Copilots, and Flight Engineers	Pilot and navigate the flight of fixed-wing aircraft, usually on scheduled air carrier routes, for the transport of passengers and cargo. Requires Federal Air Transport certificate and rating for specific aircraft type used. Includes regional, national, and international airline pilots and flight instructors of airline pilots	+	+	+	+	+
53-2012	Commercial Pilots	Pilot and navigate the flight of fixed-wing aircraft on nonscheduled air carrier routes, or helicopters. Requires Commercial Pilot certificate. Includes charter pilots with similar certification, and air ambulance and air tour pilots. Excludes regional, national, and international airline pilots	+	+	+	+	+
53-2022	Airfield Operations Specialist	Ensure the safe takeoff and landing of commercial and military aircraft. Duties include coordination between air-traffic control and maintenance personnel, dispatching, using airfield landing and navigational aids, implementing airfield safety procedures, monitoring and maintaining flight records, and applying knowledge of weather information	+	+	+	+	+
53-2031	Flight Attendants	Monitor safety of the aircraft cabin. Provide services to airline passengers, explain safety information, serve food and beverages, and respond to emergency incidents.			±	±	±

Standard Occupational Classification (SOC) Code	Occupation	Job Description	Use Cases				
			(1) Pilot Training	(2) Air Cargo	(3) Regional Commuter (≤ 5 Pax)	(4) Regional Commuter (≤ 15 Pax)	(5) Personal/ Business Use
53-6032	Aircraft Service Attendants	Service aircraft with fuel (hybrid-electric aircraft) and recharge batteries (electric aircraft). May de-ice aircraft, refill water and cooling agents, empty sewage tanks, service air and oxygen systems, or clean and polish exterior	±	±	±	±	±
53-6051	Transportation Inspectors	Inspect equipment or goods in connection with the safe transport of cargo or people		+	+	+	+
53-7061	Cleaners of Vehicles and Equipment	Wash or otherwise clean vehicles, machinery, and other equipment. Use such materials as water, cleaning agents, brushes, cloths, and hoses		+	+	+	+
53-7062	Laborers and Freight, Stock, and Material Movers, Hand	Manually move freight, stock, luggage, or other materials, or perform other general labor. Includes all manual laborers not elsewhere classified		+			

Sources: WSP 2020, U.S. Bureau of Labor Statistics 2018

Note: The signs featured in the table refer to the potential impact of electric aircraft on employment demands: – indicates a slow growth in demand; ± indicates uncertainty; + indicates a potential increase in employment demand.

The development of employment profiles also requires a deeper understanding of the profile for each of the occupations relevant to the electric aircraft use cases. Therefore, each occupation identified by its SOC code is matched in **Table 1.2.5** to the occupational employment and wage estimates in Washington state, published by the Washington State Employment Security Department and based on data collected from the Occupational Employment Statistics (OES) survey in June 2019[22]. The education level and training classification are based on the categories assigned by the Bureau of Labor Statistics to each occupation. These categories are defined by the typical education needed for entry, work experience commonly required, and the typical on-the-job training needed to obtain competency in a field.[23] It is important to note that the education levels may not fully reflect the employment practices in Washington state.

The employment percent share reflects the share of estimated employment attributed to the aerospace industry in 2018 as reported in the Aerospace Economic Impacts and Workforce Analysis[24]. It is assumed that the same 2018 percent share in the aerospace industry applies for 2019 employment levels. As such, the employment figures present in industries other than aerospace throughout the state of Washington can be estimated. Note that this share appears to exclude employment within the air transportation sector and focuses primarily on manufacturing and production within aerospace.

22 Occupational Employment Statistics. Washington State Employment Security Department. https://esd.wa.gov/labormarketinfo/occupations

23 Education and Training Data. U.S. Bureau of Labor Statistics. https://www.bls.gov/emp/documentation/education-training-system.htm

24 Aerospace in Washington: Economic Impacts and Workforce Analysis, CAI, 2019. https://aerospaceworksforwa.com/wp-content/uploads/2019/03/CAI.AWW-Econ-Impacts-and-Talent-Pipeline.Report.2019-0307.pdf

Table 1.2.5 Employment Profiles for Electric Aircraft: Minimum Education, Wages and Estimated Employment, Washington 2019

		BLS, 2019			OES, 2019			CAI, 2019
Standard Occupational Classification (SOC) Code	Occupation	Typical Education Level for Entry	Work Experience in Related Occupation	Typical On-the-job Training Needed	WA Median Hourly Wage	WA Annual Wage	WA Estimated Employment	Employment Share in Aerospace Industry*
11-1021	General and Operations Managers	Bachelor's degree	5 years or more	None	$52.44	$129,985	46,499	
11-3013	Facilities Managers	Bachelor's degree	Less than 5 years	None				
11-3071	Transportation, Storage, and Distribution Managers	High school diploma or equivalent	5 years or more	None	$53.56	$119,203	2,465	
13-1081	Logisticians	Bachelor's degree	None	None	$43.22	$90,919	6,451	61%
17-2071	Electrical Engineers	Bachelor's degree	None	None	$55.71	$118,478	6,030	25%
17-2072	Electronics Engineers, Except Computer	Bachelor's degree	None	None	$53.50	$109,571	3,662	14%
17-3021	Aerospace Engineering and Operations Technologists and Technicians	Associate degree	None	None	$45.16	$99,213	426	67%
17-3023	Electrical and Electronic Engineering Technologists and Technicians	Associate degree	None	None	$35.54	$73,790	2,395	
17-3024	Electro-Mechanical and Mechatronics Technologists and Technicians	Associate degree	None	None	$40.05	$78,529	230	53%
43-5011	Cargo and Freight Agents	High school diploma or equivalent	None	Short-term on-the-job training	$23.45	$56,047	2,155	
49-1011	First-Line Supervisors of Mechanics, Installers, and Repairers	High school diploma or equivalent	Less than 5 years	None	$36.67	$77,424	13,142	
49-2091	Avionics Technicians	Associate degree	None	None	$43.92	$85,807	3,176	76%

		BLS, 2019			OES, 2019			CAI, 2019
Standard Occupational Classification (SOC) Code	Occupation	Typical Education Level for Entry	Work Experience in Related Occupation	Typical On-the-job Training Needed	WA Median Hourly Wage	WA Annual Wage	WA Estimated Employment	Employment Share in Aerospace Industry*
49-3011	Aircraft Mechanics and Service Technicians	Post-secondary nondegree award	None	None	$32.69	$70,974	6,066	65%
53-1041	Aircraft Cargo Handling Supervisors	High school diploma or equivalent	Less than 5 years	None	$24.17	$60,266		
53-1042	First-Line Supervisors of Helpers, Laborers, and Material Movers, Hand	High school diploma or equivalent	Less than 5 years	None				
53-1044	First-Line Supervisors of Passenger Attendants	High school diploma or equivalent	Less than 5 years	None				
53-2011	Airline Pilots, Copilots, and Flight Engineers	Bachelor's degree	Less than 5 years	Moderate-term on-the-job training		$242,704	2,904	
53-2012	Commercial Pilots	High school diploma or equivalent	None	Moderate-term on-the-job training		$107,229	1,117	16%
53-2022	Airfield Operations Specialist	High school diploma or equivalent	None	Long-term on-the-job training	$32.73	$71,123	166	16%
53-2031	Flight Attendants	High school diploma or equivalent	Less than 5 years	Moderate-term on-the-job training		$81,337	4,254	
53-6032	Aircraft Service Attendants	No formal educational credential	None	Short-term on-the-job training				
53-6051	Transportation Inspectors	High school diploma or equivalent	None	Moderate-term on-the-job training	$43.90	$88,201	659	
53-7061	Cleaners of Vehicles and Equipment	No formal educational credential	None	Short-term on-the-job training	$15.49	$33,680	8,270	
53-7062	Laborers and Freight, Stock, and Material Movers, Hand	No formal educational credential	None	Short-term on-the-job training	$16.90	$37,672	64,881	

Sources: WSP 2020, U.S. Bureau of Labor Statistics 2018, WS Employment Security Department 2019, CAI 2019

Section 3: Framework for Assessing Economic Impact of Electric Aircraft on Airports

Overview of Framework Components

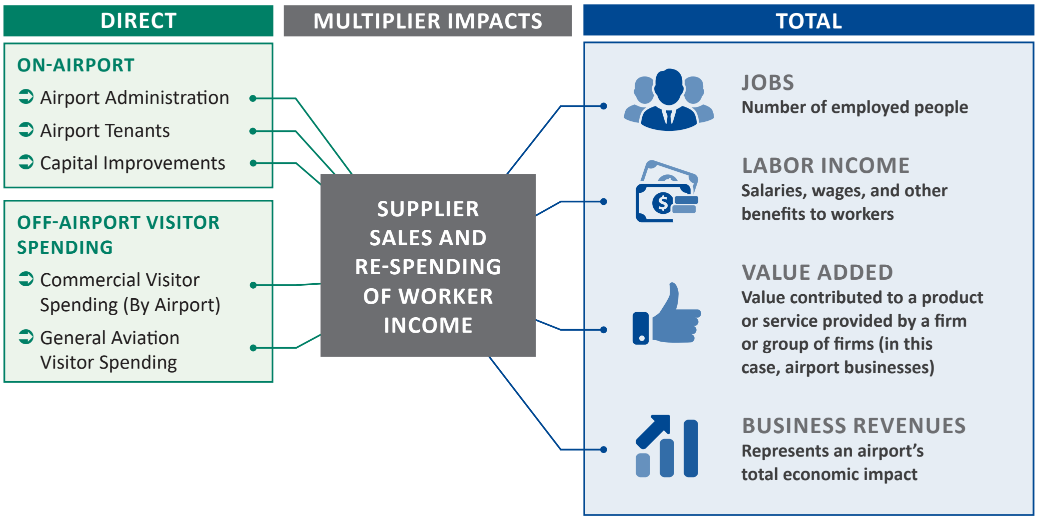
Washington's 134 airports support 8.9% of all jobs in Washington economy and nearly 12% of the total business revenues generated in the state economy[25]. The introduction of electric aircraft for regional air transportation in the state of Washington will potentially help achieve sustainability goals, enhance access and mobility and impact the state economy. This section provides a framework for assessing the economic impact of electric aircraft resulting from the five identified use cases. Information presented in this section builds upon the work of the WSDOT Aviation Division in developing the Aviation Economic Impact Study. The primary purpose of this framework is to understand the potential impact of electric aircraft in terms of direct impacts, supplier sales and income re-spending.

In 2019, the WSDOT Aviation Division conducted an Aviation Impact Study (AEIS) to quantify the economic impact of the aviation system on local regions and the overall state of Washington. The study collected direct input data related to on-airport activities (employment and operating expenses) as well as off-airport visitor spending data. These inputs were processed through the economic model (IMPLAN) that utilizes data from the U.S. Bureau of Economic Analysis (BEA), the U.S. Bureau of Labor Statistics (BLS), the U.S. Census Bureau and the U.S. Department of Commerce to generate statewide multipliers quantifying how different economic measures flow across 536 industry classifications.

The framework proposed in this Electric Aircraft Feasibility Study builds upon the AEIS's approach and assesses the economic direct and multiplier impacts of electric aircraft expressed by the following economic measures: 1) Jobs, 2) Labor Income, 3) Value Added, and 4) Business Revenues (total economic impact). **Figure 1.3.1** illustrates the association between direct, multiplier impacts and the economic measures.

25 WSDOT Aviation Economic Impact Study, Kimley Horn 2020.

Figure 1.3.1. Economic Impacts and Measures



Source: EBP US 2020, Kimley-Horn AEIS 2020

Direct economic impacts are defined by the on-airport activities that reflect airport operations in addition to off-airport spending generated by out of state visitors. These direct impacts translate into additional multiplier impacts that consist of:

- **Supplier sales:** Share of revenues used to purchase goods and services from Washington businesses, and
- **Income re-spending:** Income earned by workers that is re-spent as household spending in the state

he Washington AEIS calculated the supplier sales and income re-spending indirect effects for each region and the overall State of Washington. **Table 1.3.1** summarizes the direct and multiplier economic impacts of on-Airport activity and visitor spending for Washington airports, excluding Sea-Tac Airport. The number of additional indirect jobs created as a multiplier effect of direct jobs represent 65% of the total number of jobs, while every direct dollar generated in business revenues creates an additional $0.50 in business revenues within Washington. Labor (45%) and value added (39%) also have significant multiplier effects.

Table 1.3.1 Direct and Multiplier Economic Impacts of Washington Airports (excludes Sea-Tac)

Impact Type	Jobs (no.)	Labor Income ($)	Value Added ($)	Business Revenues ($)
Direct	88,973	$10,740,711,000	$24,111,467,000	$56,375,293,000
Supplier Sales	78,435	$5,011,601,000	$7,832,828,000	$15,402,431,000
Income Re-spending	88,232	$3,949,089,000	$7,832,828,000	$12,784,441,000
Total Multiplier Effects	166,667	$8,960,690,000	$15,114,933,000	$28,186,872,000
Total	255,640	$19,701,401,000	$39,226,400,000	$84,562,165,000
Multiplier Effects				
Multiplier % of Total	65%	45%	39%	33%

Sources: Airport Managers Survey 2019, Airport Tenants/FBO Surveys 2019, Kimley Horn 2020, Dean Runyan, Inc. 2018. Calculations by EBP US 2020 using the 2017 IMPLAN model

Note: Numbers may not sum due to rounding.

These multipliers can be used to derive the additional economic impact that results from changes in aviation activity and frequency associated with electric aircraft. The framework presented in this section looks specifically at potential economic impacts associated with the deployment of electric aircraft for each of the five use cases and proposes a high-level methodology for assessing the impact by building off the Aviation Economic Impact Study.

Air Cargo

Electric aircraft, in general, and vertical takeoff and landing (VTOL) and UAS, in particular, have the potential to greatly enhance cargo delivery by providing an efficient and reliable alternative to automobiles. Both congested urban areas and rural areas where trip cost for delivery is high are likely to benefit, creating economic benefits across the state.

Factors for Consideration

- Air cargo operated with electric aircraft may be more competitive compared to conventional aircraft and offer better connectivity compared to ground-based cargo transportation[26]
- Amazon, based in Washington state, accounts for nearly half of the U.S.'s $450 billion e-commerce industry (2017)[27]. Since its founding in 2015, Amazon Air (formerly known as Amazon Prime Air) has grown rapidly, from 18 aircraft in 2016 to 56 in 2020[28]. In August 2020, the company acquired its first Boeing 767 cargo plane that will operate under direct registration to Amazon rather than a leased from another airline[29]. Additionally, in September 2019, Amazon announced a

26 WSDOT Aviation Electric Aircraft Working Group (EAWG) Stakeholder Interviews, April 2020.

27 Boeing Air Cargo Forecast, 2018-2037

28 https://www.flightglobal.com/airlines/amazons-aviation-plans-will-benefit-from-cargos-rally/138636.article

29 https://www.fool.com/investing/2020/09/04/amazon-gets-its-own-767-cargo-plane-for-its-prime/

series of initiatives to reduce carbon emissions vis a vis the goals set forth in the Paris Agreement. As such, the aircraft electrification could be the next evolution of Amazon's investment in this emerging technology[30]

- Electric aircraft including UAV delivery services could be another option for first-and last-mile operations as the cost of air cargo decreases[31]
- Air Cargo services provided by airports to off-airports business across Washington support over 38,000 jobs in the state[32]
- Value of freight transported by air is expected to increase by 308% between 2015 and 2045[33]
- The Joint Transportation Committee's Washington Air Cargo Movement study projects Washington's air cargo value will increase at a 4.4% percent per year in real value out to year 2045[34].
- There are more than 1,400 aerospace-related companies in the state of Washington that contribute to the supply chain for every major aircraft manufacturer and air carrier in the world[35]

Potential Economic Impacts

- The top five Industries for direct jobs supported by air cargo are[36]:
  1. Transportation Equipment Manufacturing
  2. Computer and Electric Manufacturing
  3. Health Care and Social Assistance
  4. Crop Production
  5. Construction and Buildings
- The top five sectors by number of jobs generated from Air Cargo Total Impacts (Direct and Indirect)[37]:
  1. Transportation Equipment Manufacturing
  2. Health Care and Social Assistance
  3. Professional, Scientific and Technical Services
  4. Business Services
  5. Retail Trade

30 https://techcrunch.com/2019/09/19/amazons-climate-pledge-commits-to-net-zero-carbon-emissions-by-2040-and-100-renewables-by-2030/

31 WSDOT Aviation Economic Impact Study, Kimley Horn 2020

32 WSDOT Aviation Economic Impact Study, Kimley Horn 2020

33 WSDOT Aviation Economic Impact Study, Kimley Horn 2020

34 Joint Transportation Committee. Washington State Air Cargo Movement Study, 2018. http://leg.wa.gov/JTC/Documents/Studies/AirCargo/JTCAirCargoMovementStudy_FinalReport.pdf

35 The global leader in Aerospace. Washington State Department of Commerce. http://choosewashingtonstate.com/why-washington/our-key-sectors/aerospace/)

36 WSDOT Aviation Economic Impact Study, Kimley Horn 2020

37 WSDOT Aviation Economic Impact Study, Kimley Horn 2020

- Increase in avionics and electric technicians and air cargo handling jobs needed for on-site maintenance support services and on-site freight activities
- Jobs and Labor Income for temporary construction jobs related to capital-investment projects such as construction of facilities and infrastructure to accommodate electric aircraft integration and operations (Convert $ Capex to jobs)
- Leveraging the aerospace manufacturing sector: Direct economic impact from aerospace manufacturing facilities based in Washington state involved in electric aircraft final assembly and final delivery

Methodology

- Estimate value of air cargo commodities transported from Washington State Airport using electric aircraft: the focus should be on cargo that interacts with the local economy such as raw material or inputs used in manufacturing industry in Washington
- Impact on direct jobs, labor income and value added are calculated from the portion of commodity shipped associated with each industry and that rely on electric aircraft air cargo
- Multiplier impacts across jobs, labor income, value added, and business revenues generated by commodities can be estimated using IMPLAN data which tracks commodity flows between industries across 546 sectors

Relevant Data Sources

- WISERTrade: Reports value of commodities from the U.S. Census Bureau Foreign Trade Division
- Freight Analysis Framework (FAF): Tracks cargo movements by all modes of transportation
- Direct Airport Manager Input: Determine percent cargo operation by electric aircraft
- IMPLAN model: Tracks commodity flows across industry sections and generate effect multipliers

Pilot Training

The growth in aviation due to electric aircraft will create a commensurate demand for pilots. While some demand may be absorbed by pilots undergoing relatively brief training for certification on electric aircraft, it will also be met by new pilots. This expected growth in pilot training has substantial economic effects.

Factors for Consideration

- Industry warned of a long pilot shortage[38] causing ripple effects through the entire economy:
    - By 2022, almost 20,000 US airline pilots will retire
    - New FAA Training regulations demand that first officers of commercial airline flights obtain an Air Transport Pilot license requiring a minimum of 1,500 flight hours vs. the commercial pilot license requiring 250 hours

38 WSDOT Aviation Economic Impact Study, Kimley Horn 2020

- Prospective pilots face high education/training costs and relatively low entry-level wages
- Shortage affecting regional carriers, as pilots would prefer working for larger carriers offering better wages and more flight hours
- COVID-19 impact as many pilots are furloughed or offered early retirement packages from Airlines[39]

- Lower cost of flying compared to conventional fuel-operated aircraft will translate into pilot training. Flight training is especially well suited for electric aircraft (short flights, limited payload)
- Need to account for the initial investments made by training schools which may translate into high rental costs for students. Flight schools with newer aircraft generally have much higher rental rates for students
- Seventy-two (72) Airports in the Washington Aviation System Plan WASP reported supporting pilot training and certification activity. Majority of airports have runways' length greater than 3,000 ft and accommodate electric aircraft
- Pilot Training is expected to grow at a 4.2% annual rate between 2018-2038 in Washington State[40]

Potential Economic Impacts

- An increase in enrollment in flight schools from re-training existing pilots and new interest driven by the lower cost of flying made possible by electric aircraft will have an economic impact on revenues generated from flight schools and jobs for flight instructors
- The WSDOT AEIS reported that at an annual growth rate of 4.2% between 2018-2038, the direct economic impact of pilot training could support 2,457 direct jobs, generate $108.98 million in labor income, and contribute $318.42 million to business revenues

Methodology

- Estimate the growth in student pilots' enrollment in Washington state flight training schools following the deployment of Electric Aircraft and update the projected growth in pilot training to derive direct economic impact
- Calculate multiplier impacts across jobs, labor income, Value Added and Business Revenues can be estimated using IMPLAN model

Relevant Data Sources

- FAA Civil Airman Statistics: Estimate the number of active pilots and flight instructors in Washington state
- Washington State Training school surveys: Determine the number of students' enrollment and pilot re-training registration and fees

39 More than 80,000 airline workers face furloughs as COVID-19 devastates industry. CBS News, 2020. https://www.cbsnews.com/news/covid-19-airline-workers-furloughs/

40 WSDOT Aviation Economic Impact Study, Kimley Horn 2020

Passenger Transportation Service (≤5 pax) and Regional Airliner Service (≤15 pax)

The lower costs of electric aircraft will open routes that cannot economically be served today by traditional aircraft. The availability of intra-urban flights and passenger service to/from many more airports than are served today will grow the number of trips taken, affect travel mode, and, in the long run, potentially influence land uses.

Factors for Consideration

- Potential mode shift from auto to air service depending on various factors (cost per mile, driving speed, reliability, etc.) as discussed earlier in this chapter
- Induced passenger demand: flexibility of schedule if electric aircraft are used for on-demand travel, lower cost airfare, increased availability to regional air service.
- Identify industries reliant upon air passenger service for local travel for activities such as marketing, sales, client relations, etc.
- On-airport visitor spending accounts for 95% to 98% of impacts at Washington airports, excluding Sea-Tac Airport[41]. However, visitors may be less important for electric aircraft since they will be used for shorter trips, many of which are in-state
- According to the stakeholder interviews, from the perspective of passenger services, interviewees coalesced around a roughly 100-250 miles journey as a core priority for electric aircraft service operations[42]
- Aviation State tax revenues may be impacted on the long-term by the drop in Aviation Fuel Excise Tax. One thing to note is that Washington cities can impose a City Utility Tax of up to 6% on electric utilities without requiring voter approval[43]

Potential Economic Impacts

- Generating revenues through airline ticket sales from additional/induced demand and from additional facilities that meet pilot and passenger needs, such as parking, rental cars, and other concessionaires
- Airport capital improvements such as infrastructure projects and tenant construction to support electric aircraft regional operations that may have a direct economic impact on the construction industry
- On-Airport tenants fall within various market segments (MROs aviation related-maintenance, ground transportation, retail, storage, etc.). Additional direct jobs are added to an airport to support electric aircraft growing activity by on-airport businesses that employ skilled and non-skilled workers in a variety of sectors
- Electric aircraft is projected to have an impact on off-Airport visitor spending once commercial electric aircraft reach commercial deployment (60+ seats). Visitors traveling within Washington state simply circulate existing economic impacts to different areas within the State

41 WSDOT Aviation Economic Impact Study, Kimley Horn 2020

42 WSDOT Aviation Electric Aircraft Working Group (EAWG) Stakeholder Interviews, April 2020

43 Utility Taxes, MRSC Local Government Success. http://mrsc.org/Home/Explore-Topics/Finance/Revenues/Utility-Tax.aspx

- Washington State Tax/fees collected for on-airport activity
- Similar to the registration fee imposed on hybrid and plug-in electric vehicles, implementing an additional fee for electric aircraft registration may be a feasible

Methodology

- Estimate additional on-airport revenues and employment supported by electric aircraft (increased ticket sales, concession sales, on-airport tenant employment, etc.)
- Estimate Capital Improvement Funding's and convert $ Capex to jobs generated
- Classify on-airport activities by industries and sectors (Aerospace, Aviation, Car Rental, Food & Beverage, Retail, etc.) to derive direct economic activity (i.e., jobs, labor income, value added, and business revenues) and estimate supplier sales and income re-spending
- Labor income, employment levels, and business revenues data can be collected from the IMPLAN model and from airport managers' survey
- Utilize multipliers from the AEIS to estimate the indirect and induced effects passenger transportation has on the economy

Relevant Data Sources

- Airport Managers Survey and Tenants Direct Input: Determine funding available for Capital Improvement Projects, Direct Employment and payroll, Airline service operations
- ESRI's Community Analyst Business Locator reports to obtain tenant employment
- WSDOT Capital Improvement Grants
- FAA AIP and other federal grants

Personal and Business Use

The lower operating cost and enhanced operational flexibility electric aircraft will also affect their use for personal and business transportation. The economic effects will depend upon the pace of implementation and the extent to which UAS and VTOL provide new options for trips that cannot be taken by air now.

Factors for Consideration

- The demand and deployment Scenario 1 forecast projects that GA operations will grow annually by 2% and 4% in mid- and long-term respectively as lower cost of flying encourages new adopters
- Potential mode shift from auto to air service depending on various factors (cost per mile, driving speed, reliability, etc.)
- Induced passenger demand: lower cost airfare and increased availability of regional air service
- The AEIS noted that business/corporate aviation in Washington will grow at a Compound Annual Growth Rate (CAGR) of 3.14% between 2018-2038. This covers corporate aviation operated by conventional aircraft types[44]

44 WSDOT Aviation Economic Impact Study, Kimley Horn 2020

- Airports experience an estimated 20% true transient operations at General Use Airports in Washington's interior with minimal surrounding economic activity to 51% at major airports in urban areas with a significant number of nearby export industry employees[45]
- More than one million service and manufacturing jobs can be attributed to business and corporate aviation in the U.S.[46]
- Potential growth in corporate business/aviation with electric aircraft being a more sustainable attractive option to Fortune 500 companies headquartered in Washington

Potential Economic Impacts

- Additional revenue generated through hangar and terminal leases, landing and tie-down fees and ground leases from the aviation- and non-aviation-related business tenants located on airport property
- Increase in number of Airport tenants will impact on-airport spending
- Changes in employment for on-site transportation activities associated with FBOs and on-site supporting services associated with aviation training and education
- Implementation of capital improvement and infrastructure projects to support electric aircraft operations at airports will have a direct impact on jobs and labor income and workers re-spending: construction, maintenance and operations
- Growing need for electric aircraft storage and capital improvements: Hangar development, electric infrastructure, new or additional apron area, etc.
- Visitor Spending: if electric aircraft were able to achieve a greater distance range that is enough to perform state-to-state travel, visitor spending should be considered by looking at the percent of transient (non-local) electric aircraft activity and average number of people per operation[47]

Methodology

- Estimate the number of GA electric aircraft operations and average number of people per operation
- Calculate additional direct impacts supported by electric aircraft GA operations: on-airport tenant jobs, lease revenues, facility capital improvements
- Estimate breakdown in GA electric aircraft operations by personal (personal flying, medical flights, recreational) and business use
- Estimate percentage of transient electric aircraft operations to calculate visitor spending

Relevant Data Sources

- Airport Managers' Surveys, Terminal Area Forecast, 5010 Master Records: Determine GA electric aircraft operations and percent of itinerant operations

45 WSDOT Aviation Economic Impact Study, Kimley Horn 2020

46 WSDOT Aviation Economic Impact Study, Kimley Horn 2020

47 WSDOT Aviation Economic Impact Study, Kimley Horn 2020

- ESRI's Community Analyst Business Summary reports: Provide details about export industry employees that comprise a majority of business travel
- U.S. GSA "FY 2019 Per Diem Rates for Washington": Determine out-of-state visitor spending arriving in Washington State
- FAA Civil Airman Statistics: Estimate the number of Airmen Certificate holders

Section 4: Environmental Benefit Framework

Background

Electric aircraft offer several benefits that reduce the environmental impacts of transportation in Washington state. Principal among these benefits is the reduction of fossil fuel emissions during missions, the subsequent incentive to electrify support systems at airports, and the reduction of noise impacts on local communities and ecosystems. While the transition towards implementing electrical power is encouraging, stakeholders need to holistically evaluate the sources of this energy and ensure that policy and funding support the continued use of these new technologies.

Per the Washington Department of Ecology's Air Emissions Inventory, aircraft-related emissions comprised a total of 12,105 tons of CO per year in 2014[48]. While this represented only 0.46% of total carbon emissions in Washington state, aviation contributed 2.4% of global CO_2 emissions in 2018[49]—a 32% increase from 2013. In addition, flights under 500 miles are estimated to be twice as impactful on a per passenger mile basis since takeoff and landing are the most fuel-intense phases of flight. Moreover, aviation emissions have a greater effect on climate than surface level emissions, resulting in aviation being responsible for about 5% of global climate impact[50].

The importance of aviation's carbon footprint has taken on increased relevance. Prior to the COVID-19 pandemic, "flight shaming" had begun to have a material impact on travel in Europe, with surveys showing 21% of respondents had reduced flying – either shifting to rail travel or limiting trips[51]. Dutch airline KLM has actually encouraged reductions in short-haul flying due to environmental impacts. Once air travel recovers, it is likely that similar sentiments will begin to effect U.S. air travel, a trend that would benefit electric aircraft adoption.

This section details the environmental benefits and issues related to electric aircraft. The economic value of these benefits of reduced environmental impact is a key reason for encouraging electric aircraft development.

48 https://ecology.wa.gov/Research-Data?topics=27&searchtext=Aviation&searchmode=allwords

49 https://theicct.org/publications/co2-emissions-commercial-aviation-2018#:~:text=CO2%20emissions%20from%20all,over%20the%20past%20five%20years

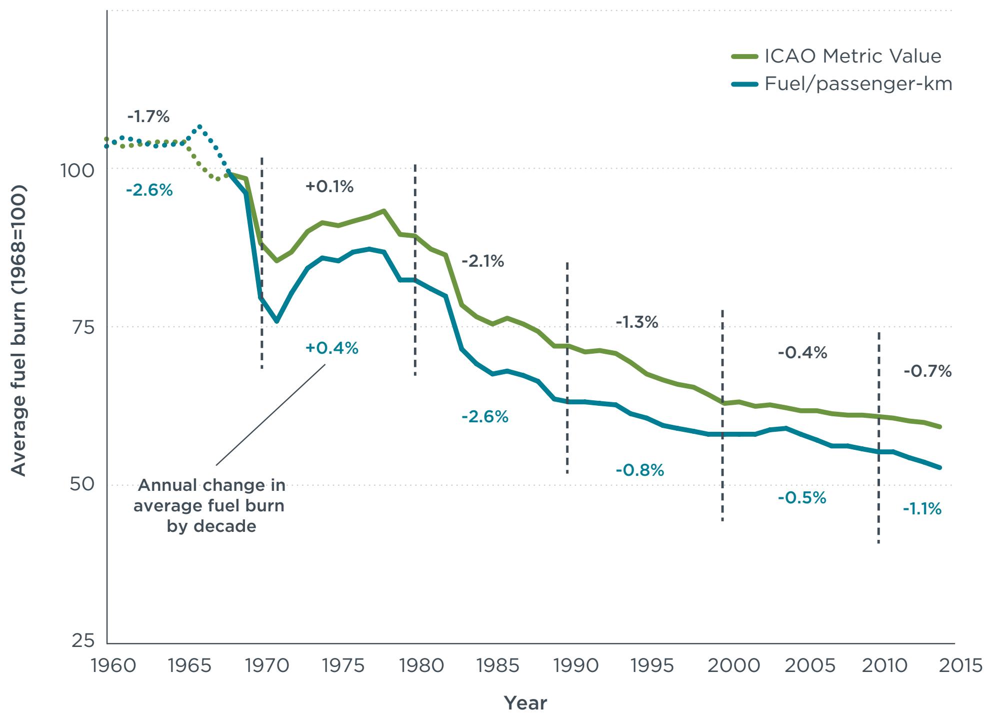
50 https://www.transportenvironment.org/news/aviation-2-3-times-more-damaging-climate-industry-claims

51 https://www.bbc.com/news/business-49890057

Emissions Reduction Goals

Technological improvements have generated steady reduction in the fuel and emissions impacts from aviation. As shown in **Figure 1.4.1** below, fuel burn per passenger mile dropped about 45% between 1968 and 2015. However, even with the introduction of efficient aircraft, such as the Boeing 787 and Airbus A350, and efforts to integrate sustainable aviation fuels (SAF), the growth in passengers is exceeding improvements in efficiency, resulting in an overall increase in global aviation emissions[52].

Figure 1.4.1 Average fuel burn for new jet aircraft, 1960-2014[53]



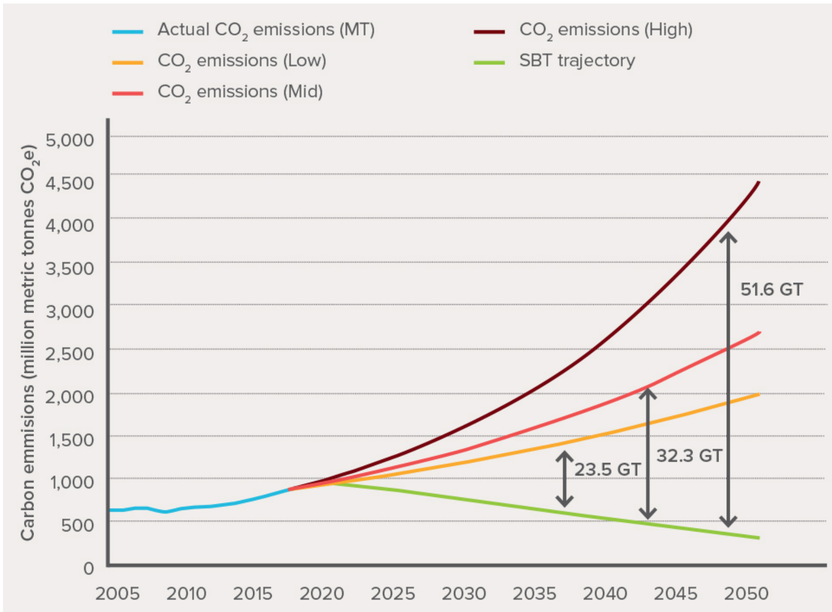
Source: The International Council on Clean Transportation 2015

Rocky Mountain Institute estimates that electric and blended-wing aircraft may save up to 7 billion tons of carbon emissions, about 50% of the RMI's moderate reduction scenario of 32.3 gigatons of abatement needed by 2050, in which aviation growth is estimated at 3.5% . **Figure 1.4.2** depicts RMI's three anticipated scenarios, the highest of which anticipates 51.6 gigatons of abatement needed based on the continuation of current emissions trends.

52 A. Klauber, "A Historic Step Toward Sustainable Aviation". Rocky Mountain Institute, November 7 2016

53 https://theicct.org/sites/default/files/publications/ICCT_Aircraft-FE-Trends_20150902.pdf

Figure 1.4.2 Aviation Carbon Emissions Scenarios

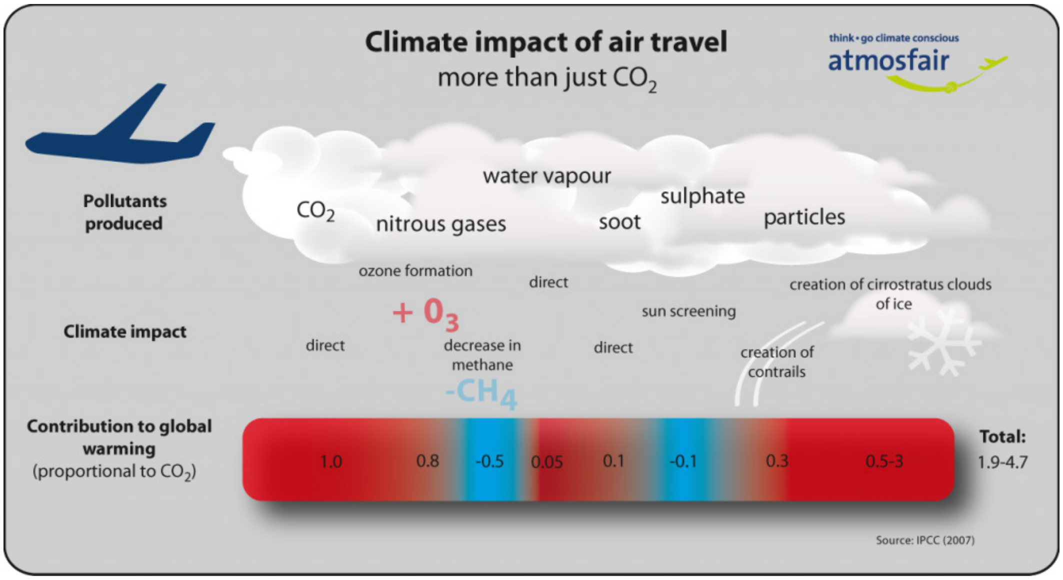


Source: Rocky Mountain Institute 2019

Globally, the International Civil Aviation Organization (ICAO) is leading an international emissions pact, CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation). CORSIA requires international airlines to report annual carbon emissions and offset any that arise from international flights. While an encouraging benchmark, CORSIA would only encompass 7% of global flights due to exemptions for domestic flights and travel from landlocked nations dependent on aviation, leaving a 5.6 gigaton gap to the industry goal of 50% emissions reductions by 2050[54]. In the absence of Federal guidelines, airlines will voluntarily determine their observance of CORSIA standards. **Figure 1.4.3** depicts aircraft impacts to the environment beyond CO_2 emissions.

54 "Fact Sheet: CORSIA". International Air Transport Association

Figure 1.4.3 Climate Impacts of Air Travel[55]



Source: Environmental and Energy Study Institute 2019

Washington has a series of State Implementation Plans (SIPs) that ensure it is adhering to National Ambient Air Quality Standards (NAAQS) in both attainment areas, which do not meet air quality standards due to specific pollution, and maintenance areas, which currently comply with standards[56]. A component of these plans are transportation implementation plans, which ensure that transportation investments do not result in new or more severe air quality violations. Electric aircraft and supporting infrastructure, if paired with a renewable power source, will help achieve these goals. Washington also recently approved a Zero Emissions Vehicle Standard comparable to that of California, which took effect on June 11, 2020.

Electric aircraft are targeted to impact smaller aircraft in the immediate future. While small aircraft tend to have higher emissions per passenger due to their low capacity and their focus on shorter trips, the total emissions reduction will depend on the market penetration rate and power source renewability over time. Modal shift of regional automobile and small cargo trips to electric aircraft will help reduce vehicle emissions, which tend to be higher when resulting from low-speed city driving. It is important to note that Washington State Legislature passed Senate Bill SB 5811 that would enable Washington State to join the national Zero Emissions Vehicle (ZEV) program and HB 2515 that will require all new vehicles sold in the state to be electric by the year 2030[57]. The overall amount of reduction in CO_2 emissions will depend upon the source of energy utilized to charge electric batteries.

55 https://www.eesi.org/papers/view/fact-sheet-the-growth-in-greenhouse-gas-emissions-from-commercial-aviation

56 https://ecology.wa.gov/Regulations-Permits/Plans-policies/State-implementation-plans

57 Washington State Moves Closer to Clean Cars with Key Electric Vehicle Bills Advancing in Legislature. https://apnews.com/press-release/pr-businesswire/1b62fe8884614ad8adc505af316f4e76

Sustainable Aviation Fuel

To improve emissions of existing aircraft fleets, Sustainable Aviation Fuels (SAF) are increasingly being deployed and are incentivized or required in some jurisdictions. For example, California's Low Carbon Fuel Standards (LCFS) legislation requires a 20% reduction in emissions through the use of SAF or purchase of emissions credits. In Washington, the Port of Seattle has partnered with tenant airlines, aircraft manufacturers, and academia to develop a framework for the first airport-wide biofuel provision program. This program included consideration for a regional supply chain, and for airport and non-airport funding mechanisms to narrow the cost gap between SAF and conventional fuel[58,59]. The Port has established a goal of using at least 10% SAF by 2028 [60].

SAF is currently 2-3 times more expensive than conventional fuel – leaving airlines with the critical role of providing the market signaling to encourage an industry shift to further adopt SAF. ICAO's 2019 trends assessment notes that a 100% substitution of aviation fuel with SAF, which would require significant policy support and capital investment, could reduce the baseline CO_2 emissions from international flights by 63% by 2050."[61] The use of sustainable aviation fuel has been shown to provide significant reductions in overall CO_2 lifecycle emissions compared to fossil fuels, up to 80% in some cases.

SAF is made with renewable contents, such as oil, wooden debris, algae or municipal waste products, and is "drop-in" compatible with standard Jet-A fuel through blending[62]. Washington State University has been a leader in researching and exploring wood-based biofuel. In November 2016, the education institution partnered with Alaska Airlines and a commercial aircraft powered by jet made from woody biomass departed from Seattle-Tacoma International Airport[63]. SAF reduces emissions by recycling previously emitted CO_2, and by expelling 90% less particulate matter and 100% less Sulfur oxide (SO2) than regular fuel[64]. **Figure 1.4.4** depicts the significant mitigation of proposed emissions with SAF deployment[65].

58 https://rmi.org/wp-content/uploads/2017/07/RMI_Sustainable_Aviation_Innovative_Funding_SAF_2017.pdf

59 https://www.portseattle.org/page/sustainable-aviation-fuels

60 https://www.portseattle.org/page/sustainable-aviation-fuels

61 https://www.icao.int/environmental-protection/Documents/Sustainable%20Aviation%20Fuels%20Guide_100519.pdf, https://www.icao.int/Meetings/a40/Documents/WP/wp_054_en.pdf

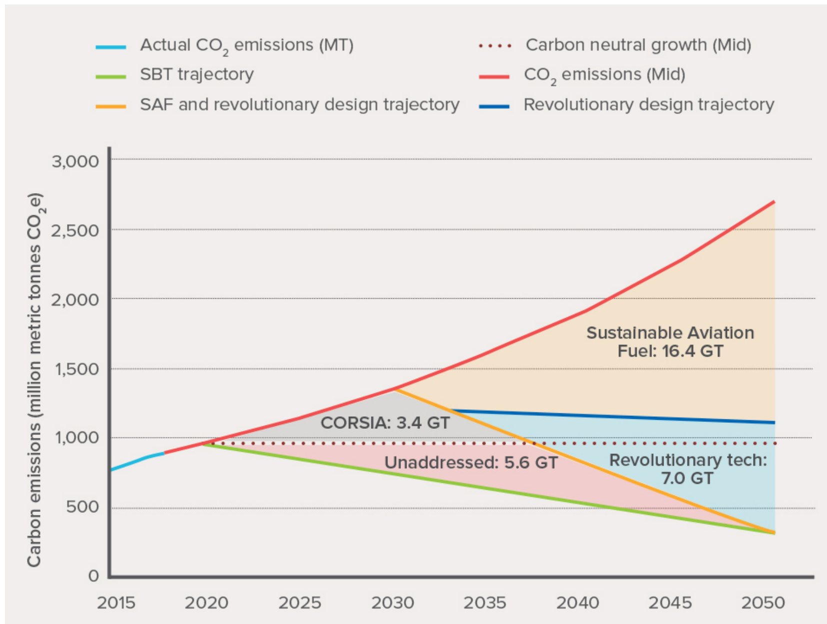
62 https://www.portseattle.org/page/sustainable-aviation-fuels#:~:text=The%20Port%20of%20Seattle%20set,SAF%20to%20SEA%20Airport%20here

63 Wood-based biofuel powers cross-country flight. https://research.wsu.edu/2016/12/20/wood-based-biofuel-powers-cross-country-flight/

64 https://skynrg.com/sustainable-aviation-fuel/saf/

65 https://rmi.org/wp-content/uploads/2019/01/wef-action-brief.pdf

Figure 1.4.4 Aviation Carbon Emissions Roadmap



Source: Rocky Mountain Institute 2019

Energy Sourcing

To fully support the reduction of carbon emissions that is associated with the deployment of electric aircraft, it is integral to ensure a renewable power source is used throughout the supply chain and charging process. For example, electric aircraft that are charged with power generated from coal combustion may not ultimately result in the net reduction of carbon emissions that is anticipated with the implementation of electric aircraft. A comprehensive lifecycle analysis of electric aircraft in Germany determined that while electric aircraft will obtain significant operational emissions reduction, emissions from the battery development phase is equivalent to the entire remainder of the production process[66].

Washington state is uniquely positioned to provide low-emissions power to electric aircraft. Hydropower accounted for 69% of the Washington state's net generation in 2018 Washington state, over 25% of the nation's hydroelectric generation[67]. The remaining prominent sources included nuclear power (8%), wind power (8%), and coal power (under 5%). However, the Centralia coal plant's two units are scheduled to retire in 2020 and

66 https://www.bauhaus-luftfahrt.net/en/research/alternative-fuels/environmental-life-cycle-assessment-of-universally-electric-aircraft/

67 https://www.eia.gov/state/analysis.php?sid=WA#:~:text=Hydroelectric%20power%20typically%20accounts%20for,of%20the%20state's%20net%20generation.

2025, respectively, with natural gas or renewable production offsetting the emissions of coal generation until then. In addition, the Washington Department of Commerce is working with utility companies and multiple stakeholders to implement the Clean Energy Transformation Act (CETA) which commits Washington State to an electricity supply that is free of GHG emissions by year 2045[68].

With a predominately renewable power grid, Washington state is well poised to capitalize on the emissions reduction potential of electric aircraft. Many airports are implementing or evaluating the use of solar panels, taking advantage of their large unobstructed areas such as unused land or atop parking garages, office buildings or rental car centers. These implementations are key to airports' zero net-energy goals. Several airports, beginning with India's Cochin International in 2015, and now including South Africa's George Airport, Seymour Airport in the Galapagos and Chattanooga Airport in Tennessee, have operated entirely on solar power since 2015. Utility providers have been enticed to install solar panels at airports, at their own cost or by offering subsidies and rebates to the airport, as they are able to recoup their capital outlay by reverting surplus energy to the grid[69].

To ensure electric aircraft have a reliable power source, airports are evaluating alternate technologies to generate or isolate power on campus. One key source is microgrids, which can "island" themselves from the broader electrical grid if needed. This could preclude the use of expensive backup generators or operational shutdowns, such as that resulting from a fire at Atlanta's Hartsfield-Jackson International in 2017, which caused an 11-hour ground stop of all flights. Microgrid companies are already working in the State of Washington to provide microgrid solutions to facilitate renewable energy integration[70].

Utility companies in Burlington, Vermont and Pittsburgh, noticing the benefits of an airport installation to the local grid, are installing microgrids at the airport[71]. In fact, a port district can become a public utility and can generate electricity. In addition to cooperating with utilities for mutual gain, airports are realizing the revenue potential of electric vehicle parking and charging. Similar self-contained power sources under consideration at airports include fuel cells, co-generation and self-generation, which require less hardware and software than microgrids.

68 https://www.commerce.wa.gov/growing-the-economy/energy/ceta/

69 A. Kandt and R. Romero, "Implementing Solar Technologies at Airports", National Renewable Energy Laboratory. July 2014.

70 https://selinc.com/engineering-services/microgrids/

71 C. Shine, "How DFW Airport became North America's first carbon neutral airport. The Dallas Morning News, October 11 2016.

Current Electrification Initiatives

Electric Ground Support Equipment (eGSE), such as shuttle buses and baggage tugs, offer ideal opportunities to begin implementing electric technology on airport grounds. The electrification of GSE might encourage electric aircraft implementation due to cost synergies between them and GSE—for example, charging infrastructure under 80 kW would be applicable to both. GSE are seen to be a natural entry point to airport electrification, which will advance the business case for additional electric conversion on campus.

At SeaTac, biomethane is currently being implemented to power the bus fleet[72]. At JFK International in New York, JetBlue, the Port Authority of New York and New Jersey and NYPA (the utility) jointly invested in the electrification of 118 GSE at one terminal to align with their organizational sustainability goals, including the development of a solar plant to send 10Mw of energy to neighboring communities[73].

In piston aircraft, which are poised for early conversion to electric aircraft, lead emissions from 100LL avgas will be reduced. Piston aircraft are the largest remaining source of lead emissions to air in the United States[74]. Batteries present another potential source of environmental impact and should be carefully observed for battery chemistry fluid leaks. That is, if batteries are utilized for electric energy storage, they should be carefully observed for degradation during primary use, reuse and disposal related to potential environmental impacts. Turboprop aircraft, some of which may use avgas rather than jet fuel, are also well positioned for conversion.

For conventional aircraft, electric green taxiing (EGTS) technology, such as Safran Honeywell's pushback unit and WheelTug's nose wheel motors, are under development. However, these units may increase in-flight emissions due to added weight (about 660 lbs. for the Safran Honeywell unit)[75].

Noise Mitigation

Electric aircraft are anticipated to mitigate noise exposure, despite a growth of air traffic, due to the lack of a combustion engine. This will further reduce the exposure of the population living near existing high-decibel aviation corridors in the US. However, while overall noise is reduced, some people may be exposed to increased aviation noise since electric aircraft are likely to increase operations at many smaller airports.

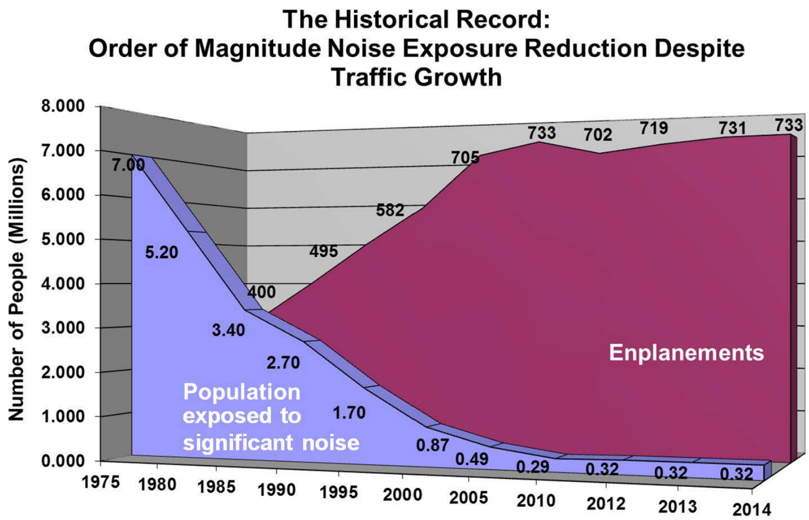
72 https://www.seattletimes.com/business/boeing-aerospace/port-of-seattle-set-to-meet-emissions-reduction-target-10-years-early/

73 PANYNJ reference

74 https://www.epa.gov/regulations-emissions-vehicles-and-engines/regulations-lead-emissions-aircraft

75 A. Basu, "Electric Taxiing Systems: Past, Present and the Possible Future". Avionics International, May 1 2019.

Figure 1.4.5 Evolution of the Population Living within 65 dB DNL Contours in the US[76]



Source: Federal Aviation Administration 2016

Early electric aircraft developers are incorporating noise reduction into their product design. The Pipistrel Alpha Electro is being used to enable flight schools to operate in urban areas with low impact, and the Uber Elevate project is aiming at a 15 dB noise reduction compared to helicopters of comparable weight[77].

Pipistrel's Velis Electro is designed for a noise output of 60 dB[78], the quietest of any existing aircraft worldwide. A study of a single-engine Cessna 172 and twin-engine Piper Seminole determined an average cabin noise of 86 dB[79], within the FAA's estimated noise range of 70-90 dB for a small aircraft cockpit. FAA and OSHA have guidelines on ear protection and maximum duration of exposure for individuals in proximity to noise levels above 85-90 dB[80], as a ramp employee in proximity to a jet engine may be exposed to 130-160 dB[81].

While the FAA's current noise pollution standard is 65 dB, some cities have set lower benchmarks. In Seattle, the noise limits in areas with residential zoning are 55 dB during daylight and 45 dB at night[82].

76 https://www.faa.gov/airports/southwest/airports_news_events/2016_workshop/media/03-national-perspective.pdf

77 https://www.icao.int/environmental-protection/Documents/EnvironmentalReports/2019/ENVReport2019_pg124-130.pdf

78 https://www.planeandpilotmag.com/news/the-latest/2020/06/12/pipistrel-gets-easa-okay-for-electric-plane/

79 https://ohsonline.com/articles/2010/07/12/interior-sound-levels-in-general-aviation-aircraft.aspx

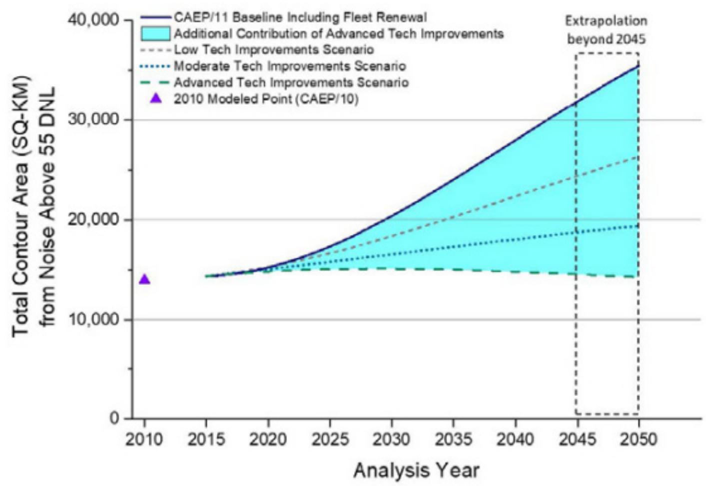
80 https://www.faa.gov/pilots/safety/pilotsafetybrochures/media/hearing.pdf

81 Hearing and Noise in Aviation. Federal Aviation Administration. https://www.faa.gov/pilots/safety/pilotsafetybrochures/media/hearing.pdf

82 https://library.municode.com/wa/seattle/codes/municipal_code?nodeId=TIT25ENPRHIPR_CH25.08NOCO_SUBCHAPTER_IIIENSOLE

Electric aircraft are likely to have less engine noise, but could have more aerodynamic noise generated from propeller rotation. Additionally, increased noise is possible if electric aircraft are heavier than anticipated or are unable to reduce battery weigh[83]. **Figure 1.4.6** shows the projected expansion of high-decibel corridors without technology interventions, and the subsequent reduction that would occur with improvements

Figure 1.4.6 Total Aircraft Noise Contour Area above 55 Db DNL for 315 Airports[84]



Source: ICAO

Stakeholder Priorities

Electric Aircraft Working Group Stakeholders (EAWG) have emphasized the need to develop battery cluster and electrical engineering capabilities in Washington state, with state incentives if needed. An existing operator of air passenger service participating in the EAWG strongly emphasized the value expanding the amount of quiet, low emissions technology to passenger travel within the state.

Quantifying Environmental Benefits

Reducing emissions and noise impacts is clearly a benefit to the public. Quantifying the value of the reductions due to electric aircraft is highly complex. First, the environmental benefit must be estimated. Key factors include the adoption rate of electric aircraft, the routes utilized, the extent to which electric aircraft encourage mode shift away from fossil fuel air and ground travel versus encouraging new travel, and the relative reduction

83 Pereda Albarrán, M.Y., Kreimeier, M., Enders, W. et al. Noise evaluation of battery powered small aircraft. CEAS Aeronaut J 11, 125–135 (2020). https://doi.org/10.1007/s13272-019-00404-2

84 https://www.icao.int/environmental-protection/Pages/Noise_Trends.aspx

in emissions and noise from electric aircraft compared to other alternatives. Once the environmental benefits are computed, they must be quantified. This requires developing the value of the social benefit of each metric ton of emissions reduced and for each decibel of noise eliminated. A value of $50 to $75 per ton have been posited[85]. Finally, the monetary cost of implementing the shift to electric aircraft must be considered, including developing the infrastructure to operate and maintain the aircraft and the power generation required. This cost, in turn, would be compared to the cost to continue providing fuel for existing aircraft being replaced by electric aircraft.

Section 5: Airport Revenue Impacts

The shift to electric aircraft will impact airport revenue since fuel is a direct and indirect source of funds. Fuel flowage fees, in which airports charge a few cents per gallon of fuel loaded onto aircraft, are an important source of revenue for general aviation airports, in particular (commercial aircraft typically do not pay fuel flowage fees). The income from these fees will be reduced as electric aircraft enter the market.

Airports also generate revenue from leasing property and structures to fixed-base operators (FBOs), which service aircraft by providing fueling, maintenance, ground handling, and other services. Fueling is a key source of revenue for most FBOs, with 25-40% of revenue typically derived from fuel sales[86]—though many FBOs continue to bundle other services into the price of fuel[87]. If FBO business is reduced due to the lower maintenance requirements of electric aircraft and reduced fueling, the value of the FBO leaseholds will likewise shrink. Moreover, some airports directly operate their FBO, meaning any reduction in revenue will directly impact airport income.

In addition to replacing lost fuel-related revenue, airports will need recoup investment in charging infrastructure for electric aircraft. Airports can replace airport revenue reduced by electric aircraft by increasing existing fees and/or creating new charges.

- General aviation aircraft under 12,500 pounds generally do not pay landing fees to the airport (unlike commercial service aircraft). Airports could apply a landing fee to electric aircraft, or to all GA aircraft. However, airports should expect resistance from aviation associations (Aircraft Owners and Pilots Association, Experimental Aircraft Association, etc.) that will likely push back on any charges to small aircraft.
- FBOs or airports could charge ramp and parking fees on electric aircraft
- Battery recharge or exchange fees can offset lost fuel flowage revenues
- Enhancing non-aeronautical revenues through increasing parking and ground transport fees, concession and retail charges, and/or cargo fees.

85 https://www.imf.org/external/pubs/ft/fandd/2019/12/the-true-cost-of-reducing-greenhouse-gas-emissions-gillingham.htm

86 https://www.avbuyer.com/articles/jet-maintenance/fbo-market-analysis-and-trends-69601

87 https://www.aviationpros.com/fbos-tenants/article/12413495/should-us-fbos-adopt-a-european-model

A key challenge will be finding an equitable balance between encouraging electric aircraft for the transportation connectivity and environmental benefits and ensuring electric aircraft pay their fair share of costs. This mirrors issues faced in surface transportation, where federal, state, and local governments have seen revenue from gasoline and diesel fuel taxes decline as vehicles become more fuel efficient and the share of hybrid or electric vehicles increases. For this reason, at least eight states, including California, which has the largest share of electric cars, have added registration fees to electric vehicles[88]. In fact, as of October 2019, hybrid-vehicle owners in Washington state are required to pay an annual $75 car-tab fee to finance electric vehicle infrastructure, as part of House Bill 2042[89].

Section 6: Electric Aircraft Funding Opportunities

Funding and Financing Mechanisms for Electric Aircraft Industry

Substantial investment will be required to deliver the power and equipment needed to charge electric aircraft to airports around the state. A comprehensive plan to fund infrastructure development will be needed to support the implementation of electric aircraft. The funding plan will require investment by airports, municipalities, state, and private entities. Governmental support will be critical to incentivizing investment at each of these levels.

As a developing industry necessitating significant investment in physical infrastructure and business operations, the electric aircraft industry could benefit from several existing public funding and financing mechanisms at the local, state and federal levels. The funding programs presented below illustrate the availability of financial support for commercial businesses related to the electric aircraft industry, including airport operations, parts and vehicle manufacturing, transportation infrastructure and freight logistics. A number of state and federal agencies provide discretionary grant and formula funding for projects supporting commercial development and transportation infrastructure. Additional options include debt financing based on business revenues, tax credits and exemptions, subsidized loan financing and property levies. While several of the funding programs described below are oriented towards promoting regional economic development across all industries, the programs may specifically support projects only indirectly related to supporting the electric aircraft industry in Washington state.

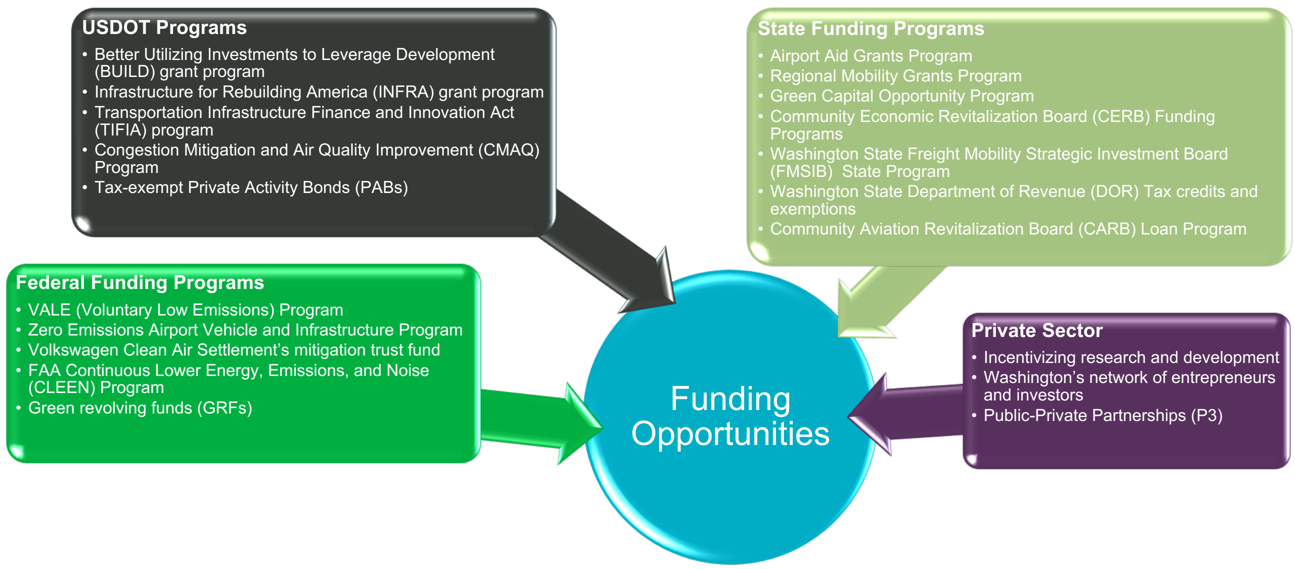
While some of the funding options may not be directly applicable to airport infrastructure, there may be instances in the future in which public transportation and advanced air mobility infrastructure and facilities, for example, may be combined. Hence, a range of funding opportunities that may be applicable now or in the future are provided for consideration.

88 https://www.usnews.com/news/best-states/articles/2019-12-30/states-hike-fees-for-electric-vehicle-owners-in-2020#:~:text=These%20states%20are%20Alabama%2C%20California,relies%20heavily%20on%20gas%20taxes

89 https://www.greencarreports.com/news/1125362_washington-state-is-charging-hybrid-owners-75-to-incentivize-electric-cars

Incentivizing growth in the electric aircraft industry will require participation from public and private entities. Collaboration across stakeholders, including energy providers and distributers, the transport industry, airports, the environmental community, universities, all levels of government, and the general public, will facilitate growth. Creativity in utilizing current funding programs and collaboration in creating new ones will be essential. The figure summarizes existing funding and financing opportunities that serves as a starting point for planning investment in electric aircraft. These opportunities are detailed below.

Figure 1.6.1 Electric Aircraft Funding Opportunities



Federal Funding Programs

The federal funding programs supporting the infrastructure and business investments related to the electric aircraft industry in Washington state fall under two general categories: the programs managed by the Federal Aviation Administration (FAA) for airport-specific investments and the program managed by the U.S. Department of Transportation (USDOT) for transportation infrastructure supporting economic vitality in the greater community.

Other Federal Opportunities include funding from the U.S. Department of Energy (DOE) through the Advanced Research Projects Agency-Energy (ARPA-E) which are actively funding advanced Air Mobility efforts within the industry and developing the Clean Cities coalitions that create networks of local stakeholders to advance energy efficient mobility systems and emerging transportation technologies[90]. The U.S. DOE's ARPA-E announced in December 2019 up to $55 million in funding to support low-cost electric aviation engine technology and powertrain systems' development[91].

90 https://cleancities.energy.gov/about/

91 https://www.energy.gov/articles/department-energy-announces-55-million-funding-electric-aviation-

Federal Aviation Administration

The Federal Aviation Administration manages the budget for capital expenditures authorized by Congress under the FAA Airport Improvement Program; the funding under the program supports the planning and development of public-use airports, including most airfield capital improvements or rehabilitation projects and in some specific situations, for terminals, hangars, and non-aviation development. In fiscal year 2020, over $1.2 billion in appropriated funds were disbursed by the program to applicants across the country, with an average award value of $3.2 million. AIP funds are provided to airports as entitlements based on passengers and operations and as competitive discretionary fund according to a national prioritization formula.

In 2004, the FAA founded the VALE (Voluntary Low Emissions) program to assist airports located in located in designated ozone and carbon monoxide air quality nonattainment and maintenance areas with Clean Air Act quality requirements[92]. VALE grants have funded projects such as electric shuttle buses, gate electrification power and air units, eGSE ground service charging equipment, and solar panels. Airports are assigned emissions reduction credits for VALE work under the Vision-100 measure[93]. For example, FAA VALE and Energy Efficiency grants funded solar installations at Chattanooga (2.64 Mw) and 95% of expenses at Manchester-Boston Regional Airport in New Hampshire[94].

The Zero Emissions Airport Vehicle and Infrastructure Program, established in 2011 as pilot program and made permanent in 2014, enables FAA to aware AIP grants to acquire and operate ZEVs. AIP funds can be used for 50% of zero emission vehicles and support systems, with greater consideration given to airports in "non-attainment" areas with higher pollution[95]. The Volkswagen Clean Air Settlement's mitigation trust fund has also been used to fund investments such as GSE electrification.

Another FAA funding program is CLEEN, which launched in its first phase in 2010 and second in 2015. This program provides matching funds to aircraft and technology manufacturers to advance alternative fuels, in alignment with FAA's NextGen strategy to stabilize emissions and support continued aviation growth[96]. The program has clearly defined emissions and noise reduction goals, and has supported the quantification of the benefits of deploying "drop-in" sustainable aviation fuels (SAF).

---

programs

92 T. Cuddy, "Airport Sustainability Planning". ICAO Seminar on Green Airports. Presentation in Montreal, Canada, November 29-30, 2017.

93 "Voluntary Airport Low Emissions Program". Federal Aviation Administration, October 9 2019.

94 A. Kandt and R. Romero, "Implementing Solar Technologies at Airports", National Renewable Energy Laboratory. July 2014.

95 T. Cuddy, "Airport Sustainability Planning". ICAO Seminar on Green Airports. Presentation in Montreal, Canada, November 29-30, 2017.

96 https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=22534

Sustainability investments may be a lower priority at some airports due to their unknown impacts on cost efficiency and revenue enhancement. Green revolving funds (GRFs) have been introduced to encourage institutions to establish dedicated funding streams for sustainability. By tracking investments and results from sustainability measures and dedicating cost savings to sustainability projects, airports can create a protected funding stream that emphasizes its dedication to emissions reduction.

GRFs, also utilized by state governments and universities, are ideal for medium and large airports that can commit resources over a year into the future, and is ideal for airports that have a compensatory rate structure and bear the financial risks of operation. The ability to scale the program from the start is also critical – airports with an annual utility cost under $200,000 may be unable to effectively scale the program[97]. Atlanta's Hartsfield-Jackson was the first airport to establish a GRF in 2016, and a collection of smaller airports in Virginia that would not find it feasible to start their own GRF created the Airports Revolving Fund, enabling them to collectively obtain attractive financing options in this space[98].

USDOT Programs

The U.S. Department of Transportation manages the budget and selection process for several discretionary grant programs using funds appropriated by Congress to support vital freight capacity and encourage economic vitality in our communities. The Better Utilizing Investments to Leverage Development (BUILD) grant program evaluates road, rail, transit and port projects promising to achieve national objectives and have a significant local and regional impact. In 2019, the program awarded approximately $888 million in funds to projects across the country with an average amount of $16 million. Similar to BUILD, the Infrastructure for Rebuilding America (INFRA) grant program provides funding for strategic freight infrastructure projects, including major highways, ports, bridges and railroads, while leveraging funding and financing from the private sector. In 2020, the program awarded approximately $906 million in funds to projects across the country with an average amount of $45 million. While these programs do not specifically support the airport operations and manufacturing sectors, they could significantly benefit from a regional infrastructure improvement project while supporting the narrative as a strategic transportation solution promoting regional economic development. Additionally, while the BUILD grant program was established as part of the American Recovery and Reinvestment Act of 2009, the INFRA grant program was authorized and funded through the 2015 FAST Act, which is slated to expire at the end of September 2020 without a defined replacement currently under consideration.

97 http://www.trb.org/Publications/Blurbs/179614.aspx

98 http://www.trb.org/Publications/Blurbs/179614.aspx

In addition to its discretionary grant funding programs, the U.S. Department of Transportation provides credit assistance through the Transportation Infrastructure Finance and Innovation Act (TIFIA) program for qualified large-scale surface transportation projects of regional and national significance, including highway, transit, railroad, intermodal freight, and port access projects. The TIFIA credit program is designed to fill market gaps and leverage substantial private co-investment by providing supplemental and subordinate capital to public entities and private firms. Since being enacted into law in 1998, the TIFIA program has provided over $31 billion in loans to support transportation infrastructure projects with an average award of approximately $400 million. Similar to the USDOT discretionary grant programs described previously, the TIFIA program may not specifically identify support for airport operations and related businesses, but they do support the regional infrastructure projects directly beneficial to them. Currently, a nexus to surface transportation is required for TIFIA eligibility, but pending legislation in Congress would enhance airports' ability to access TIFIA.

Under the Federal Highway Administration (FHWA) within the US Department of Transportation, the Congestion Mitigation and Air Quality Improvement (CMAQ) Program provides funding to states on a formula basis to support surface transportation projects contributing to air quality improvements and congestion relief. In 2020, the total funding for the CMAQ program amounted to $2.5 billion, of which Washington state received $36 million. Funds may be used for a transportation project or program that is likely to contribute to the attainment or maintenance of a national ambient air quality standard, with a high level of effectiveness in reducing air pollution; specifically related to the electric aircraft industry, eligible activities include projects for non-road vehicles and electric vehicle infrastructure. In addition to projects specifically supporting the electric aircraft industry, the investments enabled by the CMAQ funding in the region may indirectly benefit the industry's production facilities and airport operations.

As an alternative to the discretionary grant funds, credit assistance and formula funds available for supporting transportation infrastructure projects, the federal government leverages the private equity markets by enabling local and state governments to issue tax-exempt Private Activity Bonds (PABs) for public infrastructure projects. The PABs provide lucrative investment terms to investors in the equity market and to private businesses making investments in infrastructure beneficial to the public, including airports, port facilities, surface transportation projects and manufacturing facilities. The total value of PABs eligible to be secured by state governments on an annual basis is restricted by the federal government; in 2020, the total bond allocation cap for Washington state is approximately $800 million with the allocation for "Small Issue" industrial development projects at $200 million.

State Funding Programs

At the state level, several programs administered by various state agencies provide grant funding, loan financing and tax incentives for projects supporting the electric aircraft industry in Washington state. The Washington State Department of Transportation (WSDOT) administers programs supporting regional transportation infrastructure projects by discretionary grant funding. Additionally, WSDOT Aviation administers Community the Aviation Revitalization Board (CARB) loan program. The Washington State Department of Commerce (DOC) administers the Community Economic Revitalization Board (CERB), which provides funding for public infrastructure supporting private business growth and expansion. The Washington State Freight Mobility Strategic Investment Board (FMSIB) manages a comprehensive and coordinated state program to facilitate freight movement between and among local, national and international markets and provides grant funding for projects. Lastly, the Washington State Department of Revenue (DOR) provides several tax credits and exemptions to eligible manufacturing and retail businesses and airport facilities.

The Washington State Department of Transportation administers three grant programs for funding regional infrastructure projects with potential impacts on the electric aircraft industry: The Airport Aid Grants program, the Regional Mobility Grants program and the Green Capital Opportunity Grant Opportunity program.

The Airport Aid Grants program supports any municipality and federally recognized tribe who owns a public-use airport by providing grant funding for projects related to pavement, safety, and maintenance, operations, and planning capabilities. These funds would be useful for the installation of electric charger stations, procuring electronic equipment, runway improvements or airport planning activities to support electric aircraft operations at airports. In 2019, the agency provided $1.4 million in grant funding with an average award amount of $750,000.

The Regional Mobility Grants program supports local efforts to improve connectivity between counties and regional population centers and reduce transportation delay. Eligible applicants include cities, counties, ports and transit agencies in Washington state with projects aligned with local, regional and state transportation plans; previously funded projects included park and ride facilities, transportation demand management, inter-county connectivity services and capital projects improving the efficiency and connectivity of the transportation system. As part of the proposal for improving regional connectivity for freight and personal travel, electric aircraft operations would be eligible as part of a regional transportation solution. For the 2019-2021 biennium, the Regional Mobility Grants program provided approximately $105 million in funding with the average award amounting $2.2 million.

The Green Transportation Capital Grant Opportunity program provides funding to any transit authority for cost-effective capital projects to reduce the carbon intensity of the Washington transportation system. Eligible projects include the electrification of vehicle fleets, the modification or replacement of capital facilities to facilitate fleet electrification, necessary upgrades to electrical transmission and distribution systems and the construction of charging stations. The Green Transportation Capital Grant Opportunity program is currently set to award $12 million for the 2021-2023 biennium.

The Community Aviation Revitalization Board (CARB) Loan Program supports revenue-producing capital projects to support public-use general aviation airports become more self-sustainable. The program provides loans up to $750,000 at 2% interest for airports that have less than 75,000 annual commercial enplanements. Eligible projects can include revenue-generating or cost-cutting developments such as hangars or passenger amenities and would be well suited for electric aircraft related funding as it is a revenue generating activity.

The Washington State Department of Commerce (DOC) administers the Community Economic Revitalization Board (CERB), which provides funding for public infrastructure supporting private business growth and expansion throughout Washington State. The CERB manages four funding programs: the Planning Program, the Committed Private Partner Program, the Prospective Development Program, and the Rural Broadband Program. The Planning Program provides limited grant funding for studies to evaluate high-priority economic development projects; eligible activities include studies related to economic feasibility, capital facilities, site planning and marketing. The Committed Private Partner Program provides loans and grants for construction of public infrastructure necessary for private business expansion, with the requirement of a private business commitment; eligible activities include the planning, construction or improvement of port facilities, surface transportation facilities, utilities and structures. The Prospective Development Program provides funding for projects if an economic feasibility study has been conducted and demonstrates that private business development is likely to occur as a result of the public improvements; eligible activities include the planning, construction or improvement of port facilities, surface transportation facilities, utilities and structures. The Rural Broadband Program provides funding for construction and planning for broadband projects in rural counties and rural communities. In 2019, CERB awarded over $11 million in loans and grants with an average grant award of $193,000 and an average loan award of $907,000.

The Washington State Freight Mobility Strategic Investment Board (FMSIB) manages a comprehensive and coordinated state program to facilitate freight movement between and among local, national and international markets and provides grant funding for projects.

The state program includes projects related to the construction and improvement of surface transportation facilities and rail infrastructure to best facilitate freight movements throughout the region, which would directly benefit the aerospace manufacturing industry and multimodal freight networks involving electric aircraft. In 2019, the FMSIB awarded a total of $82 million in grant funds to projects with an average award amount of $3.7 million.

In addition to loan and grant awards, the Washington State Department of Revenue (DOR) provides a number of tax credits and exemptions to eligible manufacturing and retail businesses and airport facilities. By reducing the tax liability of business operations and the sale of goods and services, manufacturing and retail businesses related to the electric aircraft industry reduce their operating costs and exposure to market risk as they're given the opportunity to mature into commercial production. The tax credits and exemptions include the following:

- Business & Occupation (B&O) tax credit for preproduction development expenditures;
- Business & Occupation (B&O) tax credit for property/leasehold taxes paid on aerospace business facilities;
- Sales and use tax exemption for construction of new facilities used for airplane repair and maintenance; and,
- Sales & use tax exemption for aerospace businesses for computer hardware/software/peripherals

Private Sector

Engaging private sector funding for electric aircraft infrastructure development is essential for success. This may include incentivizing research and development such as for battery pack development, raising the visibility of the opportunity to Washington's network of entrepreneurs and investors, and utilizing public-private partnerships (P3) to share the costs, risks, and upside of investment.

An example is Sea-Tac Airport will be among one of the first airports in the world to offer a reliable supply of biofuels to its customers. The partnership between the Port of Seattle, Boeing, and Alaska Airlines on aviation biofuels infrastructure feasibility is part of a larger continued effort in the state to reduce transportation emissions and meet the growing demand for a sustainable future. A study determined that it would be feasible to develop a biofuels infrastructure to serve the main fuel supply system at the airport, with the goal of producing a blended fuel of 20 percent biofuel and 80 percent petroleum. One of the primary lessons was the value of education. Many of the groups who has limited or no experience with biojet fuel were initially hesitant to consider this option. After an education period, many groups were more open to the idea of biojet or SAF to be included as an option.

Another example of collaboration with the private sector is the U.S. Energy Service Company (ESCO) industry delivering cost-effective energy savings in the public sector. These companies provide energy savings performance contracts (ESPCs) for federal agencies and implement energy conservation measures which result in significant annual energy savings. The DOE establishes a qualified list of ESCOs as part of the Federal Energy Management Program (FEMP) which currently includes about 100 firms.

Section 7: Recommendations

The research on environmental and economic benefits of electric aircraft in Washington state identified several actions to facilitate adoption. The recommendations for policy makers and for airports are summarized below:

Policymakers	Airports
Build partnerships with stakeholders to advance electric aircraft integration within the state and consult with the Department of Energy for funding opportunities to support low-cost electric aviation engine technology	Develop electric aircraft infrastructure and evaluating alternate technologies to generate or isolate power such as coordinating with utility companies to install microgrids or self-contained power sources such as fuel cells
Coordinate among federal, state, and private funding agencies to help fund electric aircraft infrastructure and operations and provide competitive flying rates for a successful market entry for passenger service	Examine replacing airport fuel revenues by adjusting existing fees and/or creating new charges related to electric aircraft operations (battery recharges, landing fees, ramp parking, etc.)
Promote public acceptance by communicating the benefits of electric aircraft for economic growth and sustainability through emission reduction, noise mitigation, and economic impact benefits including direct and indirect job creation across sectors, labor income, and total business revenues.	Educate airport users, tenants, and community stakeholders regarding electric aircraft benefits and impacts
Develop incentives to support battery cluster and electrical engineering capabilities within Washington state	Continue developing partnerships with local universities to promote sustainable technologies such as WSU – Alaska Airlines woody biomass fuel partnership and seek collaboration with the U.S. Energy Service Company (ESCO) industry

Policymakers	Airports
Establish electric aircraft regional transportation routes along the state's congested corridors	Develop relationships with e-commerce providers (Amazon) and major manufacturers (Boeing) to establish electric aircraft air cargo activity through capital improvement projects
Promote the benefit of electric aircraft to all constituencies (e.g., faster, lower cost deliveries to rural areas, congestion relief in urban areas)	
Sponsor additional research that will help refine this analysis, focusing on infrastructure needs and funding requirements	
Develop policies and regulation regarding revenue generation and safety/security for urban UAS operations	

Chapter 2:

Transportation Network Assessment

A New Era of Connectivity

The innate drive to travel beyond one's immediate surroundings is one of the defining characteristics of humankind. We are driven not only by the need to find new resources and expand our social networks, but by an innate curiosity. This need to explore has taken men and women to the most remote and extreme environments we can reach, including the tallest peaks; deepest abysses; and driest, coldest, hottest, and generally inhospitable places on Earth and beyond. Humans continue to push the boundaries of exploration—an edge that is limited only by the technologies that let us keep moving.

Just as importantly, our desire to move beyond our immediate surroundings has been one of the keystones to modern, industrialized societies. Ideas, goods, and knowledge are transported along roads and railways, over water, and through the air. New levels of economic vitality and prosperity arise as people and communities gain increased access to mobility and transportation options. Indeed, societies today—just as in our earliest histories—develop, expand, and flourish, in part, based on transportation networks that facilitate the movement of goods and people between markets.

Electric aircraft represent the expansion of air travel and potentially a new mode of transportation that combines the speed and comfort of air travel with the low cost typically associated with ground transportation options. When considering the future of electric aircraft in Washington, it is important to evaluate the technology in terms of its role within the existing multimodal network. Further, electric aircraft has the potential to fill gaps within or otherwise address current issues facing the state's existing transportation system. Electric aircraft are anticipated to create new or fill latent demand as passengers realize the benefits of intra- and interstate travel via electric aircraft. As such, this section first places electric aircraft within the context of Washington's broader multimodal network and then looks more specifically at its potential role in the National Airspace System (NAS). These interrelated analyses are organized as follows:

- Existing Intermodal Network
- Existing Air Connectivity Analysis
- Travel Time Cost Analysis

It is important to note that this study generally focuses on those airports that have been preliminarily identified by the Washington State Department of Transportation Aviation Division (WSDOT Aviation) as capable of supporting electric aircraft. Airports were identified based on having a 3,000-foot-long runway, which WSDOT Aviation has determined as the minimum criteria for supporting electric aircraft. Airports capable of supporting electric aircraft are listed in **Table 2.i.1** and illustrated in **Figure 2.i.1**.

Table 2.i.1 Airports Capable of Supporting Electric Aircraft

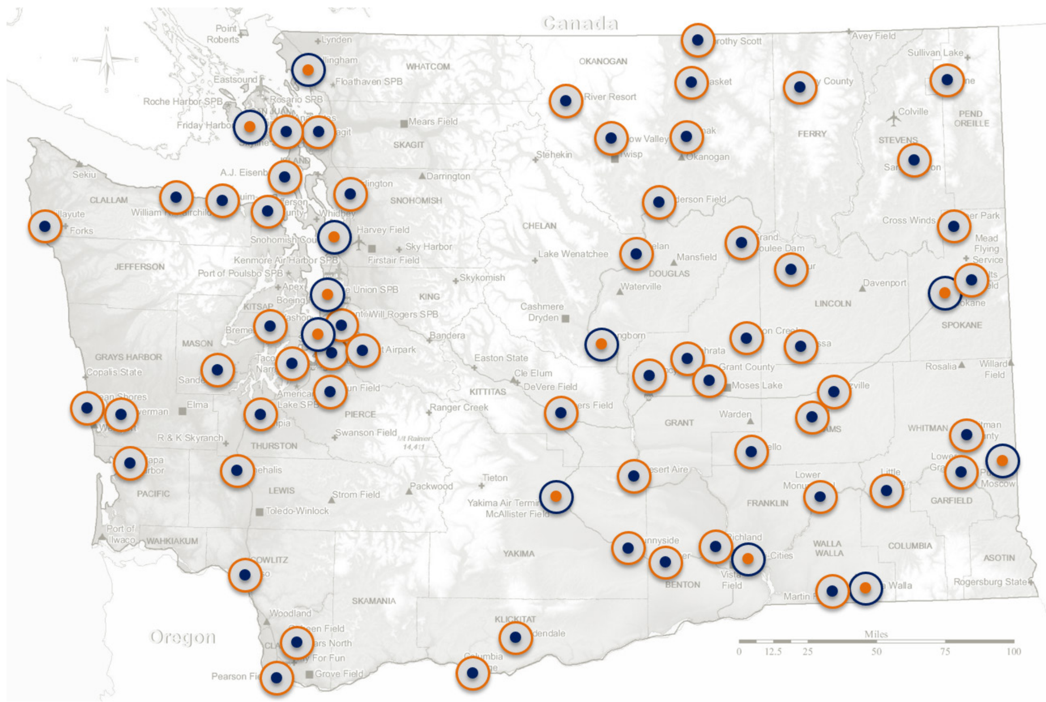
Associated City	FAA ID	Airport Name	Airport Classification	Longest RW (Feet)
Commercial Service				
Bellingham	BLI	Bellingham International	Major	6,700
Pasco	PSC	Tri-Cities	Major	7,711
Seattle	BFI	Boeing Field/King County International	Major	10,007
Seattle	SEA	Seattle-Tacoma International	Major	11,900
Spokane	GEG	Spokane International (Geiger Field)	Major	11,002
Walla Walla	ALW	Walla Walla Regional	Major	6,527
Wenatchee	EAT	Pangborn Memorial	Major	7,000
Yakima	YKM	Yakima Air Terminal (McAllister Field)	Major	7,604
Friday Harbor	FHR	Friday Harbor	Regional	3,402
Pullman/Moscow	PUW	Pullman/Moscow Regional	Regional	7,101
General Aviation				
Everett*	PAE	Snohomish County (Paine Field)	Major	9,010
Moses Lake	MWH	Grant County International	Major	13,503
Arlington	AWO	Arlington Municipal	Regional	5,332
Bremerton	PWT	Bremerton National	Regional	6,000
Burlington/Mount Vernon	BVS	Skagit Regional	Regional	5,478
Chehalis	CLS	Chehalis-Centralia	Regional	5,000
Deer Park	DEW	Deer Park Municipal	Regional	6,100
Ellensburg	ELN	Bowers Field	Regional	5,590
Ephrata	EPH	Ephrata Municipal	Regional	5,500
Hoquiam	HQM	Bowerman Field	Regional	5,000
Olympia	OLM	Olympia Regional	Regional	5,500
Port Angeles	CLM	William R Fairchild International	Regional	6,347
Puyallup	PLU	Pierce County - Thun Field	Regional	3,651
Renton	RNT	Renton Municipal	Regional	5,382

Associated City	FAA ID	Airport Name	Airport Classification	Longest RW (Feet)
Richland	RLD	Richland	Regional	4,009
Shelton	SHN	Sanderson Field	Regional	5,005
Spokane	SFF	Felts Field	Regional	6,000
Tacoma	TIW	Tacoma Narrows	Regional	5,002
Vancouver	VUO	Pearson Field	Regional	3,275
Anacortes	74S	Anacortes	Community	3,015
Auburn	S50	Auburn Municipal	Community	3,400
Brewster	S97	Anderson Field	Community	4,000
Chelan	S10	Lake Chelan	Community	3,506
Colfax	S94	Port of Whitman Business Air Center	Community	3,209
College Place	S95	Martin Field	Community	3,819
Kelso	KLS	Southwest Washington Regional	Community	4,391
Kent	S36	Norman Grier Field (Crest Airpark)	Community	3,288
Oak Harbor	OKH	AJ Eisenberg	Community	3,265
Oroville	0S7	Dorothy Scott	Community	4,017
Port Townsend	0S9	Jefferson County International	Community	3,000
Prosser	S40	Prosser	Community	3,452
Sequim	W28	Sequim Valley	Community	3,508
The Dalles	DLS	Columbia Gorge Regional / The Dalles Municipal	Community	5,097
Toledo	TDO	South Lewis County (Ed Carlson Memorial Field)	Community	4,479
Tonasket	W01	Tonasket Municipal	Community	3,053
Wilbur	2S8	Wilbur Municipal	Community	3,851
Chewelah	1S9	Sand Canyon	Local	3,446
Electric City	3W7	Grand Coulee Dam	Local	4,203
Goldendale	S20	Goldendale Municipal	Local	3,491
Ione	S23	Ione Municipal	Local	3,643
Lind	0S0	Lind Municipal	Local	3,197
Mattawa	M94	Desert Aire	Local	3,665
Ocean Shores	W04	Ocean Shores Municipal	Local	8,001
Odessa	43D	Odessa Municipal	Local	3,124
Omak	OMK	Omak Municipal	Local	4,667
Othello	S70	Othello Municipal	Local	4,000

Associated City	FAA ID	Airport Name	Airport Classification	Longest RW (Feet)
Quillayute	UIL	Quillayute	Local	4,210
Quincy	80T	Quincy Municipal	Local	3,660
Republic	R49	Ferry County	Local	3,498
Ritzville	33S	Pru Field	Local	3,433
South Bend/Raymond	2S9	Willapa Harbor	Local	3,005
Sunnyside	1S5	Sunnyside Municipal	Local	3,423
Wilson Creek	5W1	Wilson Creek	Local	3,851
Winthrop	S52	Methow Valley State	Local	5,049
Anacortes	21H	Skyline SPB	General Use	5,000
Bellingham	0W7	Floathaven SPB	General Use	10,000
Clayton	C72	Cross Winds	General Use	3,800
Colfax	00W	Lower Granite State	General Use	3,400
Copalis	S16	Copalis State	General Use	3,560
Friday Harbor	W33	Friday Harbor SPB	General Use	10,000
Kahlotus	W09	Lower Monumental State	General Use	3,300
Kenmore	S60	Kenmore Air Harbor Inc	General Use	10,000
Mazama	W12	Lost River Resort	General Use	3,150
Poulsbo	83Q	Port of Poulsbo Marina SPB	General Use	12,000
Renton	W36	Will Rogers Wiley Post Memorial SPB	General Use	5,000
Roche Harbor	W39	Roche Harbor SPB	General Use	5,000
Rosario	W49	Rosario SPB	General Use	10,000
Seattle	W55	Kenmore Air Harbor	General Use	5,000
Seattle	0W0	Seattle Seaplanes SPB	General Use	9,500
Starbuck	16W	Little Goose Lock and Dam State	General Use	3,400
Tacoma	W37	American Lake SPB	General Use	5,500
Vancouver	W56	Fly for Fun	General Use	3,275

**Note: Paine Field (PAE) began scheduled commercial service in March 2019. However, the airport is classified as a GA facility by the FAA's current National Plan of Integrated Airport Systems (NPIAS) Report (2019-2023). Sources: FAA NFDC (accessed August 2020), WASP 2017*

Figure 2.i.1 Airports Potentially Capable of Supporting Electric Aircraft



Source: WSDOT Aviation 2020

Section 1: Existing Intermodal Network

In Washington, WSDOT and the Washington State Transportation Commission (WSTC) are jointly responsible for statewide transportation planning.[99] The WSTC defines the overall policy objectives for the state's transportation system, while WSDOT is responsible for implementing this overarching policy via the statewide multimodal transportation plan. The WSTC's latest state transportation policy plan, known as the *Washington Transportation Policy Plan—2040 and Beyond* (Transportation Policy Plan) defines the following vision for Washington:

> *Washington's transportation system safely connects people and communities —fostering commerce and economic opportunity for all, operating seamlessly across boundaries, and providing travel options to achieve an environmentally and financially sustainable system.*[100]

99 https://www.wsdot.wa.gov/planning/default.htm

100 https://www.wtp2040andbeyond.com/vision/statewide-transportation-goals

To implement this vision, the Transportation Policy Plan defined six statewide goals in accordance with the Revised Code of Washington (RCW) 47.04.280 as follows:

- **Economic vitality:** Make the best use of existing infrastructure, service, and resources to foster commerce and economic opportunity for all
- **Preservation:** Support local and regional land use objectives and optimize existing infrastructure
- **Safety:** Increases safety and efficiency while keeping lifecycle costs as low as possible
- **Mobility:** Increases travel choices and system reliability and operates seamless between jurisdictional boundaries and between modes
- **Environment and health:** Reduce environmental and social impacts and uses public resources wisely in order to generate maximum benefit
- **Stewardship:** Continuously improves the quality, effectiveness, and efficiency of the transportation system

The vision and goals of the Transportation Policy Plan serve as the overarching framework for statewide, regional, and local transportation planning as implemented by WSDOT, the state's 18 Regional Transportation Planning Organizations and 12 Metropolitan Planning Organizations, and local comprehensive plans. Because these entities are responsible for transportation planning at state, regional, and local levels, the widespread adaptation of electric aircraft will necessitate communication and coordination at a broad and multi-tiered scale. It is noteworthy that electric aircraft promote and advance each of the six Washington statewide transportation goals listed above.

Implementing the Policy Plan at the state level occurs via the *Washington Transportation Plan – Phase 2 Implementation 2017—2040* (WTP Phase 2). Based on an extensive community outreach process involving the public, government agencies (federal, tribal, state, and local), organizations, and other transportation interests, WTP Phase 2 identified four major themes (referred to as focus issues) and associated action items.[101] These focus areas represent the most critical "unresolved" statewide policy issues that are most critical for achieving the statewide transportation vision. The connection between Washington's statewide transportation focus areas and associated action items with the electric aircraft use cases highlighted in this study are summarized in **Table 2.1.1**. The aircraft symbol (✈) indicates specific eA uses cases with significant potential to advance the existing transportation network action items. As highlighted, the integration of electric aircraft into Washington's existing multimodal transportation network has the potential to significantly advance all of the focus areas and associated action items identified by the WTP Phase 2 plan.

101 WSDOT (2018). *Washington Transportation Plan – Phase 2 Implementation 2017 – 2040*. Page 13. Available online at https://washtransplan.com/wp-content/uploads/2018/05/WTPPhase2-2017-web-PlanAndAppendicies-1.pdf (accessed May 2020).

Table 2.1.1 Relationship Between WTP Phase 2 Focus Issues/Action Items and Electric Aircraft

Transportation Focus Area and Action Items	Air Cargo	Pilot Training	Regional PAX Service (≤5)	Regional PAX Service (≤12)	Personal/ Business Use	Other EA Applications
Maintain and preserve assets						
MP1. Maintain, preserve, and operate assets and manage demand to meet desired performance on multimodal transportation systems before funding expansion projects	✈		✈	✈		✈
MP2. Support ways to help jurisdictions, transportation asset owners, and transportation service providers prepare for, respond to, and become resilient to emergencies and disasters						✈
Manage growth and traffic congestion						
MG1. Promote transportation-efficient communities by coordinating and providing state agency technical assistance to emphasize the link between land use and transportation at all levels of government, the private sector, and other organizations	✈					✈
MG2. Prioritize access for people and goods instead of throughput for vehicles to improve multimodal options, livable communities, and economic vitality for people and businesses	✈	✈	✈	✈	✈	✈
MG3. Research, evaluate, adapt to, and deploy technologies and innovations in all modes; share best practices	✈	✈	✈	✈	✈	✈
Enhance multimodal connections and choices						
EC1. Work to achieve better travel time reliability and door to door multimodal connections for people of all backgrounds and abilities through continued application of practical solutions	✈		✈	✈		✈
EC2. Provide transportation facilities and services to support the needs of all communities, with a focus on equity for populations with specialized needs, those in rural areas, and those who are traditionally underserved	✈		✈	✈		
EC3. Adopt metrics for all modes to align with performance objectives	✈	✈	✈	✈	✈	✈
Align funding structure with multimodal vision						
FS1. Support funding flexibility to reduce barriers to creating an integrated multimodal system that achieves performance objectives	✈		✈	✈		✈
FS2. Work to diversify and strengthen transportation revenue sources to hedge against inflation and economic downturns	✈	✈	✈	✈	✈	✈
FS3. Address the constraints and opportunities for public-private partnership programs	✈	✈	✈	✈	✈	✈

Note: PAX = passengers. Source: WSDOT 2018

Mode-Specific Overviews

As electric aircraft enter the market for commercial and recreational purposes, this technology will form a new branch of a complex and multifaceted statewide multimodal system. Modes in Washington considered by the WTP Phase 2 plan and with their own specific plan include active transportation (bicycle and pedestrian), aviation, ferries, freight, highway system plan, public transportation, and rail. An overview of each of these modes, as well as any key findings or recommendations offered by mode-specific planning documents, are provided in the section below.

Active Transportation

With a breathtaking natural landscape, moderate climate, and extensive public transit network, Washington offers a robust network of active transportation facilities. Two-hundred and eighty-one cities; 39 counties; Tribal government, state agencies including the Department of Natural Resources, Department of Fish and Wildlife, and state parks; and federal agencies including the National Parks Service, Bureau of Land Management, and US Forest Service all own or manage some portion of Washington active transportation facilities. Washington's state-interest facilities and services include streets, bike lands, share-use paths, trails, and public roads. WSDOT is currently conducting the Active Transportation Plan (scheduled for completion in 2020). This plan will provide recommendations for future policy decisions, investments, and improvements associated with Washington's active transportation facilities.

Airports

The Washington aviation system comprises 134 publicly- and privately-owned, public-use airports. One hundred and four airports are publicly owned (78 percent) and 30 airports (22 percent) are privately-owned. Sixty-four airports (48 percent) are included in the Federal Aviation Administration's National Plan of Integrated Airport Systems (NPIAS), while 70 are not (52 percent). Airports included in the NPIAS are eligible for federal funding through Airport Improvement Program (AIP), as well as state funding through the Airport Aid Grant Program and local matches. Non-NPIAS airports are only eligible for state and potentially local funding (depending on the local jurisdiction's ability and willingness to fund airports, either publicly or privately-owned). As noted previously, 60 of these airports have at least a 3,000-foot-long runway and thus preliminarily identified as capable of supporting electric aircraft.

The 2017 *Washington Aviation System Plan* (WASP) serves as the strategic, long-term planning document for the Washington aviation system. This study developed a series of aviation-specific goals in consultation with the then-current Transportation Policy Plan

(*Washington Transportation Plan 2035 Policy Plan*) and 2009 *Long-term Air Transportation System Plan* (LATS Plan). As one of the final outcomes of the WASP, 30 actionable policy recommendations were established to address the priority needs of the system and to more fully develop its economic and community potential. **Table 2.1.2** highlights the goal categories and policy recommendations with a specific connection to the integration of electric aircraft into the NAS.

Table 2.1.2 2017 WASP Goal Categories and Policy Recommendations Associated with Electric Aircraft

WASP Goal	Policy Recommendations Associated with EA
Aeronautical and Airport Safety	• Reconsider the aviation system definition and expand it to include heliports and future 'droneports'.
Economic Development and Vitality	• Partner with government agencies (state, regional, airports) and industry freight representatives regarding air cargo data and needs to better understand demands, issues, and opportunities related to ground transportation, economic development, and financial investment. • Building from WTP direction, collaborate with the Department of Commerce, the Washington Tourism Alliance and smaller commercial service airports to explore the feasibility of maintaining or expanding flight offerings between smaller commercial service airports to "hub" airports and promote aviation industries including maintenance, passenger service, and cargo activities throughout the State. • Support implementation of strategic aviation system investments that leverage the value of the aerospace industry and commercial travel to the State's economy.
Education, Outreach, and Community Engagement	• Identify collaborative, systematic approaches to enhance airport participation in local, regional and statewide transportation planning activities to recognize multimodal opportunities and needs that support airport activities. • Continue educational outreach programs that facilitate information sharing across the state with pilots, airports, agencies, and organizations regarding aviation subjects ranging from airspace to land use, unmanned aircraft systems/drones, and future topics arising from emerging issues.
Infrastructure Improvement, Preservation, and Capacity	• Support aviation capacity as a resource from the Legislature and WSDOT by preserving, protecting and enhancing capacity through strategies focusing on airport operations, technology, safety, and land use. • Emphasize as a priority and continue partnering with the FAA, Washington State Transportation Commission, and others to develop viable solutions to provide adequate future capacity to accommodate documented growth in commercial service demand.
Aviation Innovation	• Seek opportunities to develop and continue partnerships to sustain and grow Washington's prominence in leading aviation innovation, fostering strategies that support education, training, maintenance, and development of innovative technologies in all areas including aerospace manufacturing. • Continue engaging at the national level on unmanned aircraft systems (UAS)/drones policy and regulation to understand the safety, integration, privacy, and community impacts and provide the best possible integration for Washington citizens, airports, and the overall aviation system. • Work with partners and stakeholders to determine whether government should establish policy for zones where UAS activity should be prohibited or regulated. • Host working groups to explore possible future infrastructure needs associated with aircraft innovation.

WASP Goal	Policy Recommendations Associated with EA
Modal Mobility, Capacity, and Accessibility	• Increase multimodal coordination, communication, and partnerships between airports and other modal representatives (state, regional, local transportation planning entities) that strengthens connectivity between modal planning and results in identification of policies that support multimodal needs. • Identify signage, access roads, and ground transportation options that can be improved to support airport accessibility. • Pursue a statewide NextGen study that will address challenging airspace issues.
Stewardship	• -Support development of airport plans and municipal codes that reflect airport needs, implement land use controls for protection from encroachment, and include business planning and evaluation of revenue opportunities to promote land use compatibility and financial diversification. • Partner with government, communities, academia, and industry to develop aerospace/aviation awareness, networking, and mentoring opportunities. • Continue to grow partnerships and programs to promote general aviation growth.
Sustainability	• Promote sustainable best practices identified on the state and national level that lead to financially and environmentally sustainable development. • Support investment in aviation technologies, including NextGen and biofuels development, to meet future aviation needs and reduce greenhouse gas emissions.

Source: WSDOT Aviation 2017

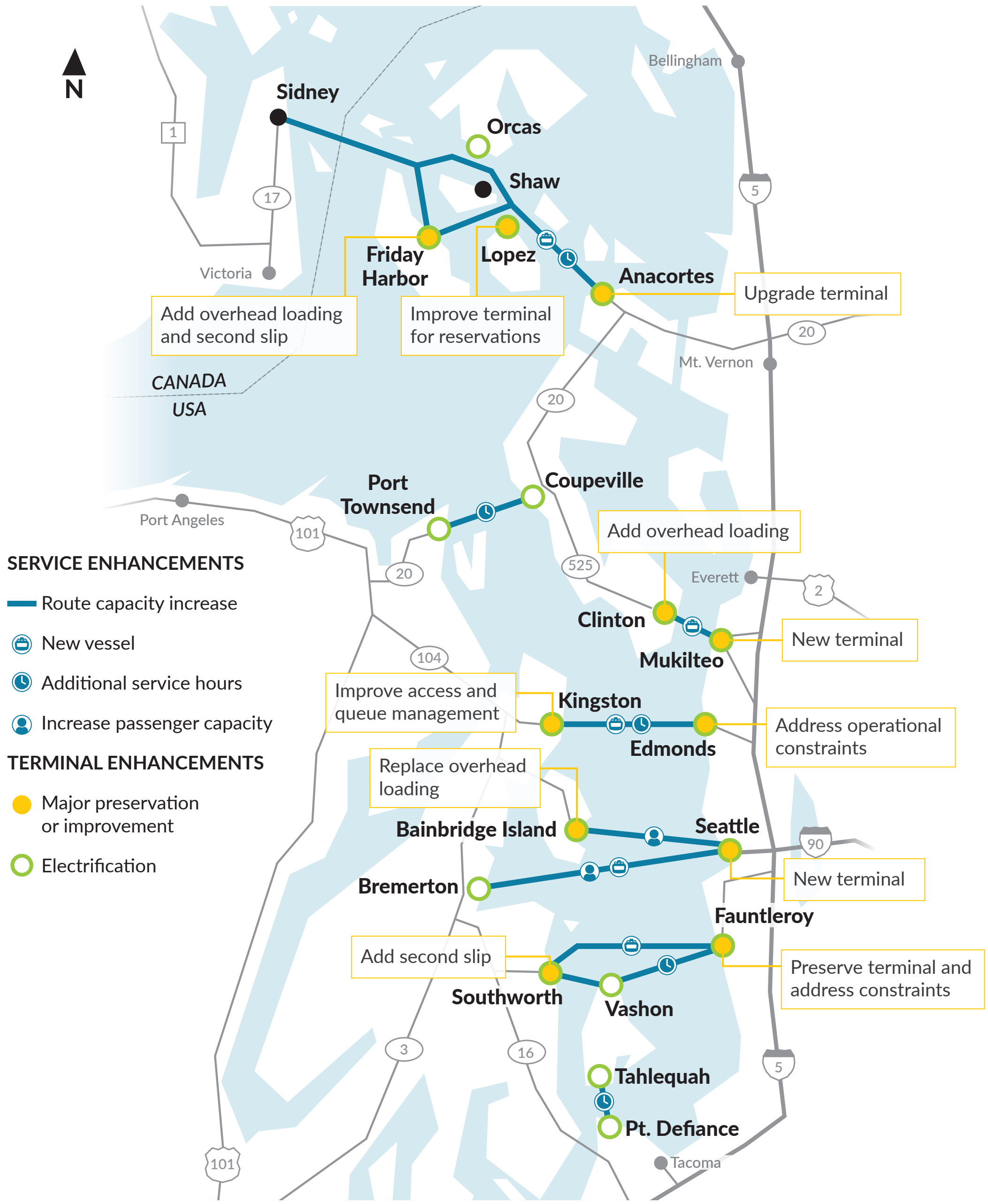
Ferries

Washington State Ferries (WSF) operates the largest ferry system in the U.S. along 10 routes and 20 terminals. The WSF provides service to communities on both sides of Puget Sound with the San Juan Islands and internationally to Sidney, British Columbia. Similar to the aviation system, Washington's ferries provide mobility and access to remote communities in and around Puget Sound, connect businesses, and attract visitors. In some communities, ferries provide the only access to medical and other emergency services.

In January 2019, WSDOT released the *WSF 2040 Long Range Plan* (Long Range Plan), which identified a number of key challenges facing the system over the next 20 years. In 2017, the ferry system carried 24.5 million passengers. By 2040, ridership is anticipated to grow to 32.5 million. Walk-on passenger ridership is expected to increase by 45 percent, and vehicle ridership is expected to increase by 21 percent. In addition to demand growth, 13 of WSDOT's 23 ferries will need to be replaced; and the system could also benefit from an increased number of relief or "standby" vessels to ensure reliable service and adequate maintenance time for vessels. By 2040, the WSF fleet would grow to 26 service vessels. Terminal enhancements are also needed throughout the network.

To address these and other challenges, the Long Range Plan offers a series of recommendations falling within the four themes of study: reliable service, customer experience, manage growth, and sustainability and resilience. The service and terminal enhancements identified by the plan are illustrated in **Figure 2.1.1**. In some cases, there is clear connection with the services and benefits of electric aviation. Demand for ferry service, for example, could decrease should air service become more viable in terms of scheduling and costs. This could be particularly beneficial for walk-on riders who either depend on public transit or do not require ground transportation at their destinations.

Figure 2.1.1 WSF 2040 Long Range Plan Terminal and Service Enhancements



Source: WSF 2040

Table 2.1.3 highlights the connections between the themes and policy recommendations of the WSF's Long Range Plan and electric aircraft. Not all recommendations associated with increasing capacity have been included, as these issues could be affected should air service be enhanced or otherwise modified in these communities. Additionally, future increases in air service to Puget Sound communities could provide an additional level of resiliency and emergency preparedness, as aviation provides the only alternative mode of transportation to these remote areas.

Table 2.1.3 2017 WASP Goal Categories and Policy Recommendations Associated with Electric Aircraft

WSF Theme	Policy Recommendations Associated with EA
Reliable Service	**Vessels** • Extend the open contract for Olympic Class vessels to build five new electric hybrid vessels: two to stabilize the fleet and three to replace vessels due to retire—the first five in a total of 16 new vessels. • Examine the 60-year life expectancy for vessels in the fleet that have not had the maintenance and preservation time required to meet this high life-expectancy goal. • Allow for 12 weeks of annual out-of-service maintenance and preservation time for every vessel in the fleet to achieve the 60-year life expectancy goal. • Invest in 11 additional new vessels after the first five Olympic Class ferries to replace retiring vessels and support fleet maintenance needs, for a total construction of 16 new vessels. • Streamline the fleet composition to realize enhanced efficiencies and redundancy. **Terminals** • Plan for reliable terminal infrastructure with seismic upgrade planning, a new terminal building in Anacortes, queuing space to accommodate reservations on Lopez Island, and the addition of a second slip at Southworth to support partnership with regional passenger-only service. • Program terminal preservation projects to support reliable service, such as projects to maintain operating efficiencies at Fauntleroy, Edmonds, Coupeville, Kingston and overhead loading facilities at Bainbridge Island and Friday Harbor. • Invest in the Eagle Harbor maintenance facility to serve system needs through 2040.
Customer Experience	• Increase accessibility and wayfinding in and around the vessels and terminals to improve access and multimodal connections. • Enhance mobility by improving pedestrian, bike and transit connections to and from terminals. • Plan vessels and terminals to be flexible and adaptable to emerging technologies and new transportation options. • Enhance parking opportunities for customers that encourage walk-on ridership and carpooling.
Manage Growth	• Refine existing metrics and define new metrics to monitor data for system planning and that prioritize the movement of people while improving the customer experience. • Maximize utilization of system capacity through adaptive management strategies such as an expanded reservation system, an improved fare structure and fare collection methods, and others that increase efficiency, spread out demand, and prioritize walk-on and bicycle customers. • Increase system capacity with additional service hours and by leveraging new vessel construction, terminal improvements and modifications to facilities.

WSF Theme	Policy Recommendations Associated with EA
Sustainability and Resilience	**Sustainability** • Promote mode shift through investments in technology and infrastructure that promote walk-on and bike-on passengers and improve multimodal connections. • Design future vessels and terminals to be more environmentally friendly and flexible in design to accommodate new technology, changing transportation modes and increased passenger ridership. • Reduce vehicle emissions by optimizing terminal operational efficiencies and employing adaptive management strategies that spread out peak demand and minimize wait times. • Highlight sustainability through organizational structure, decision-making, and reporting. **Resilience** • Develop an emergency response plan to enhance preparedness and aid in response and recovery efforts and develop a prioritization of terminal capital projects for emergency response. • Prioritize terminal maintenance needs with the most seismic risk, vulnerability to sea level rise, and "lifeline routes" that provide access to major population centers or critical facilities. • Increase the number of spare vessels to support regional emergency response and consider designing new vessels with emergency side-loading capabilities.

Source: WSF 2019

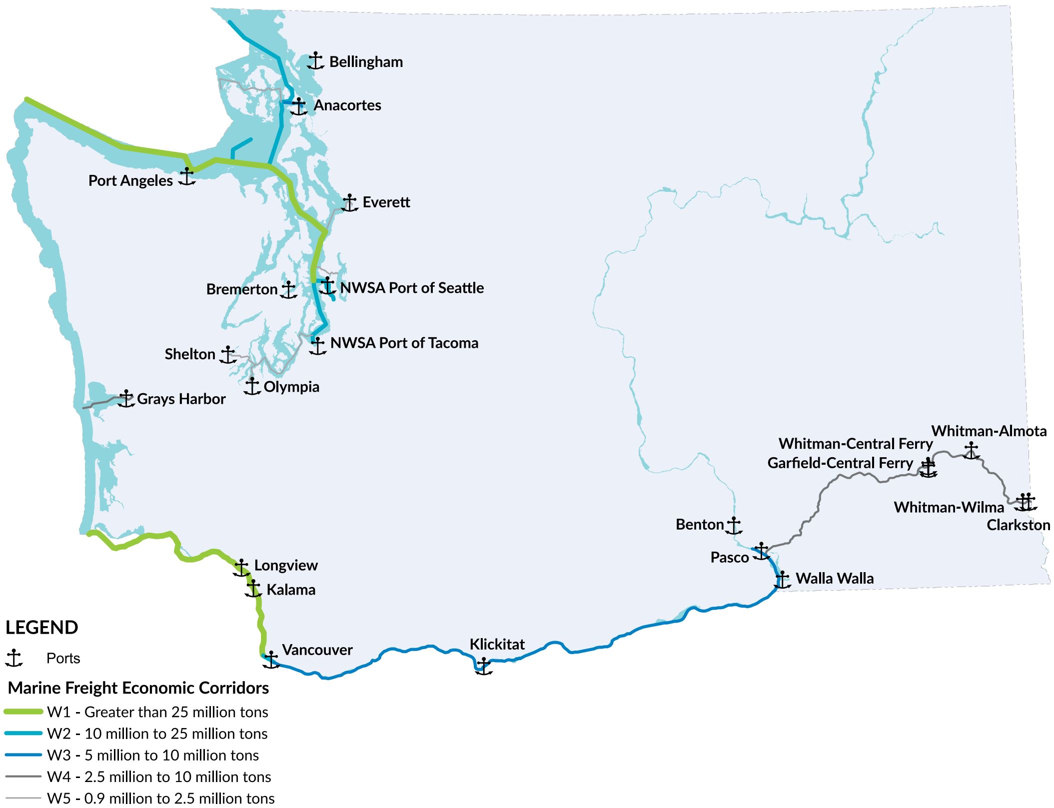
Marine Freight and Ports

Washington hosts 22 marine ports owned by port districts on the Columbia River, Snake River, Puget Sound, and the Pacific Ocean, including 16 deep draft ports. These ports are critical to Washington's economy: in fact, Washington was the second most trade-dependent state in the US in 2016.[102] The 2017 *Washington State Marine Ports and Navigation Plan* reports that most of the trade flowing through the state supports the aviation industry, followed by agricultural products. Ports rely on multimodal connectivity to transport goods from waterways to their next destinations inland—either by truck, rail, or—in some cases—air. The economic vitality of ports is driven by the ability of quickly and efficiently move goods from the ship to shore, and then off to their final destinations. A map of waterway freight economic corridors is shown in **Figure 2.1.2**. The Freight Economic Corridor system is used to identify and map supply chains, identify system condition and capacity issues, and develop performance measures to improve freight mobility.[103]

102 WSDOT (2017). 2017 Washington State Marine Ports and Navigation Plan. Page 2. Available online at www.wsdot.wa.gov/sites/default/files/2007/12/20/Freight-Plan-AppendixB-MarinePortsNavigationPlan.pdf (accessed May 2020).

103 Ibid. Page 7

Figure 2.1.2 Washington Marine Freight Economic Corridors



Source: WSDOT 2017

In many cases, these ports are either co-located with airports and/or operated by the same port district (serving as the airport sponsor). These cases include (but are not limited to) the Port of Bellingham (Bellingham International Airport), Port of Anacortes (Anacortes Airport), Port of Grays Harbor (Bowerman Airport), Port of Angeles (William R Fairchild International and Seiku airports), Walla Walla (Walla Walla International Airport), and Port of Vancouver (Pearson Field Airport). There is potential to more closely consider these airports to serve as the beta test sites for the air cargo electric aircraft use case. These airports may have existing infrastructure that could either be expanded or repurposed as air cargo handling facilities; already serve as key links in Washington's export/import supply chains; and established connections between freight operators/forwarders, mode operators/managers, and port authorities.

Highway System Plan

The Washington State Highway System Plan (HSP) serves as WSDOT's "blueprint for preserving, maintaining, improving, and operating state highways"[104] The HSP serves as the basis for the six-year highway program and the two-year biennial budget request to the State Legislature. The HSP is currently being updated (anticipated for delivery in 2021); the previous plan was delivered in December 2007. It is recommended that the 2021 HSP be reviewed by WSDOT Aviation to identify areas of alignment between the HPS and electric aircraft, as well as areas where electric aircraft could benefit (e.g., reduce demand on) the state highway system.

Electric aircraft are anticipated to be particularly beneficial in their abilities to ease congestion along highly trafficked routes, especially as Urban Air Mobility (UAM) solutions become commercially available. WSDOT's "2019 Update to the Project Delivery Plan" notes that the WSDOT Traffic Program is currently investing in traffic mitigation projects along I-5, I-205, and I-90.[105] Additionally, WSDOT has invested $1.5 billion to reduce congestion along I-405/State Route (SR) 167—the only high-capacity north/south route on the east side of Lake Washington. Not only are traffic delays frustrating, time-consuming, and wasteful for commuters, but the corridor is also an important freight route. As WSDOT notes, "as a vital link in our regional transportation network, a highly congested I-405 is a deterrent to economic growth."[106] To mitigate the issue, the ongoing I-405/SR 167 Program is delivering a blended approach to transportation that incorporates transit, roadway, non-motorized, and environmental investments. This includes the I-405 Bus Rapid Transit (BRT) system, which will connect communities along I-405 and SR 518 from Lynnwood to Burien by 2024.[107]

In total, WSDOT is currently conducting approximately 150 improvements along the state highway system. As shown in **Figure 2.1.3**, multiple projects are underway along all of WSDOT major corridors including I-5 (running north/south from Portland, Oregon into western Canada), west/east along I-90 from Seattle through Moses Lake to Spokane, and southwest/northeast along US Highway 395 between Kennewick and Spokane. An interactive map of all WSDOT ongoing projects is available online at www.transinfo.state.wa.us/projects/gis/mapping/interactivemap.asp.

---

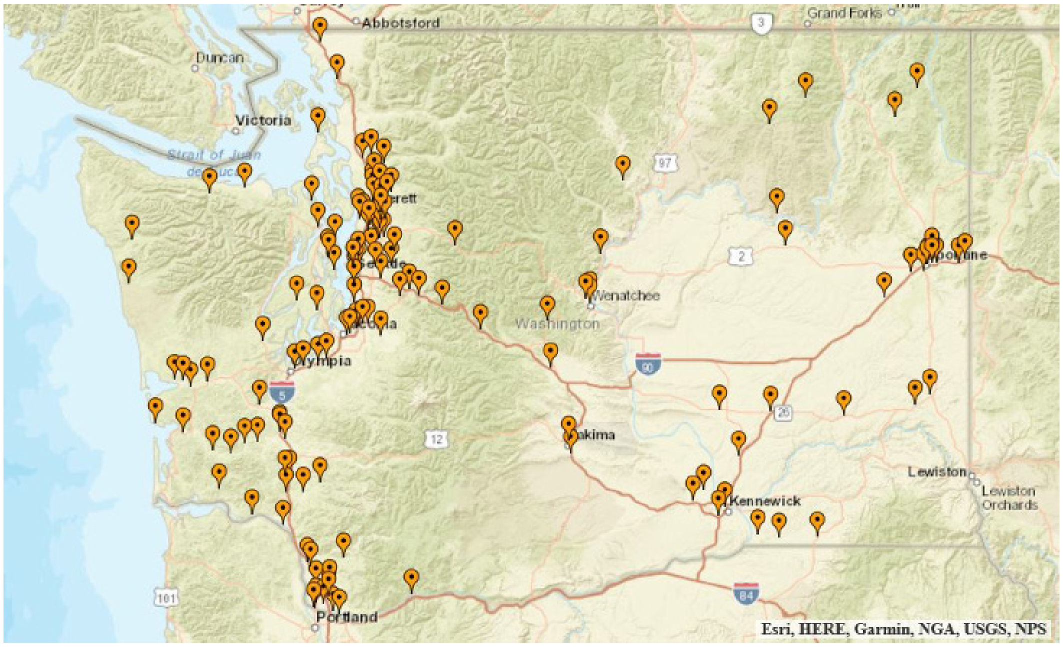
104 WSDOT (2019). *2021 Highway System Plan Update*. Available online at wsdot.wa.gov/sites/default/files/2020/03/04/Highway-System-Plan-update-folio-statewide-planning-office.pdf (accessed May 2020).

105 https://www.wsdot.wa.gov/sites/default/files/2019/09/30/2019-Highway-Construction-Project-Delivery-Plan-Assumptions-and-Concepts.pdf

106 https://www.wsdot.wa.gov/Projects/I405/corridor/faq.htm

107 https://www.wsdot.wa.gov/Projects/I405/default.htm

Figure 2.1.3 Active WSDOT Projects (May 2020)



Source: WSDOT 2020

Public Transportation

To support transportation system integration and multimodal transportation, WSDOT's Public Transportation Division publishes the *Washington State Public Transportation Plan* (Public Transportation Plan, 2016). This plan defines public transportation as a diverse set of modes and systems that "do not involve a single person in a motorized vehicle."[108] Examples of public transportation include transit services (e.g., bus, light/commuter rail, park and ride lots), shared mobility (e.g., carpool, carshare), demand management (e.g., trip reduction strategies, congestion pricing, transit priority traffic signals), active transportation (e.g., bicycle lanes, sidewalks, trails), on-request (e.g., paratransit, transportation network companies [TNCs]), and intercity services (e.g., airplanes, passenger rails, and bus). To provide a robust public transportation network, the plan notes that a broad array of partners much collaborate including 32 public transit providers; MPOs; RPOs; and hundreds of local communities, nonprofits, employers, and private-sector transportation providers.

108 WSDOT (2016). Washington State Public Transportation Plan. Page 19. Available online at https://www.wsdot.com/sites/default/files/2019/10/15/PT-Report-WashingtonStatePublicTransportationPlan-2016.pdf (accessed May 2020)

The Public Transportation Plan recognizes four key public transportation challenges in Washington, each of which either applies to or could be mitigated by the integration of electric aircraft into the NAS:

- The demand for access to jobs, schools, services and community is growing, but public transportation providers' ability to meet this demand has never been more constrained
- Congestion is hurting our economy and quality of life, and we must find ways to move more people with even greater efficiency
- Traditional methods for funding transportation are increasingly unsustainable
- Emerging technologies and business models are redefining how people communicate, work and conduct trade

As a potentially new mode of public transit, WSDOT should carefully consider how electric aircraft advance the state's multimodal goals, as its integration with and advancement of broader policy initiatives could bolster legislative support at the statewide level. Further, the information and strategies presented in the Public Transportation Plan could provide a draft framework in terms of collaborative engagement, developing actionable next steps, and defining WSDOT Aviation's role in advancing this emerging technology.

As an additional note regarding public transportation planning, WSDOT's Public Transportation Division is currently updating the Statewide Human Service Transportation Plan (anticipated 2021). When complete, this study will identify transportation service gaps, develop strategies to address transportation gaps for populations with special transportation needs, further best practices, highlight emerging trends, and inform the next cycle of locally coordinated human services transportation plans.[109] Similar to the Public Transportation Plan, the findings and recommendations of this study may pertain to the future electric aircraft in the state.

Railways

Washington's railway network composes a core element of the state's multimodal network integral to the movement of passengers and freight. As shown in **Figure 2.1.4**, rail system in Washington includes two Class I railroads (annual operating revenue in excess of $489.9 million) and 27 Class III (short-line) railways (annual operating revenues of less than $39.2 million) that operate on approximately 3,200 route miles[110].

109 https://www.wsdot.wa.gov/transit/2021-human-services-transportation-plan (accessed May 2020)

110 WSDOT (August 2020). Washington State Rail Plan 2019 – 2040. Page 11. Available online at https://wsdot.wa.gov/sites/default/files/2020/08/27/2019-2040-State-Rail-Plan.pdf (accessed November 2020)

Figure 2.1.4 Washington Railway System by Owner

Source: WSDOT 2020

WSDOT released the public review draft of the *Washington State Rail Plan 2019 - 2040* in August 2020. In addition to addressing the issue related to the 2017 derailment of the Amtrack Cascades, the plan specifically looks at the near- and long-term challenges. These issues include meeting the increasing demand for passenger and freight rail services, developing more efficient and effective connections between rail and other modes of transportation, and ensuring the sustainability of the railroads in terms of infrastructure investment needs and preservation.[111] While many of the recommendations are highly specific to railways, there are several recommendations that overlap with the role and benefits of electric aircraft in the transportation system, as summarized in **Table 2.1.4**. In general, there is overlap between the challenges and opportunities affecting the railway system with those of the aviation system. Coordinated efforts between railway and

111 WSDOT (August 2020). *Washington State Rail Plan 2019 – 2040*. Page 1. Available online at https://wsdot.wa.gov/sites/default/files/2020/08/27/2019-2040-State-Rail-Plan.pdf (accessed November 2020

aviation planners could prove mutually beneficial, as the gaps and/or deficiencies affecting one mode could be addressed or mitigated by the other (and vice versa).

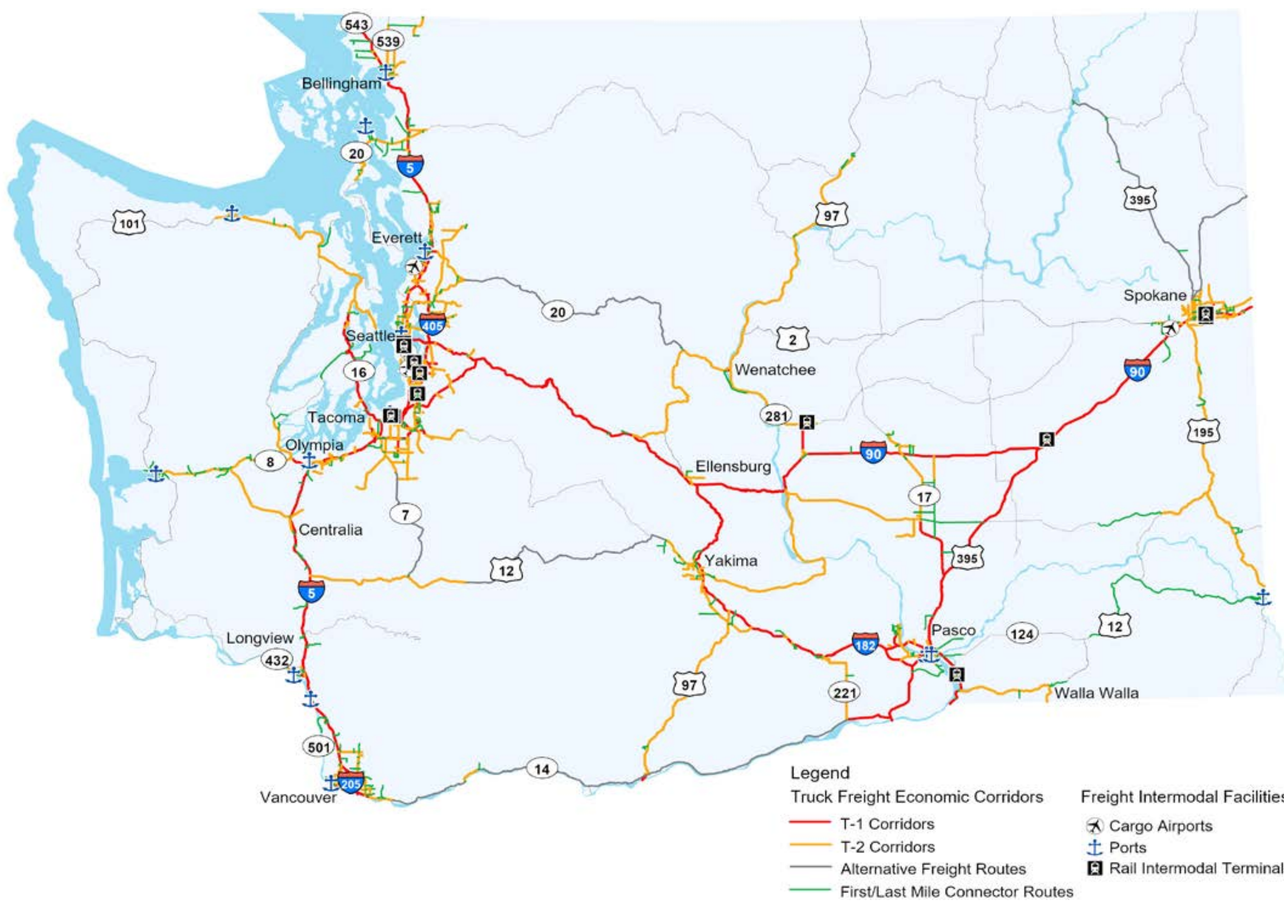
Table 2.1.4 2019 Rail System Plan Draft Recommendations Associated with Electric Aircraft

Rail Plan Recommendation	Draft Policy Recommendations Potentially Associated with Electric Aircraft
Freight rail strategies	**Managing capacity to meet future demand** • Railroads can use a variety of strategies to deal with freight volume growth • Increase east-west capacity • Washington's participation in corridor partnerships can advance shared interests
Passenger rail	**Planning for future demand** • WSDOT can prepare a Service Development Plan to define future Amtrak Cascades improvements • The Legislature can consider establishing east-west intercity rail service • WSDOT can prepare for long-term needs by continuing to plan for an Ultra-High-Speed Ground Transportation system **Commuter rails** • Sound Transit can make modifications to allow for longer trains • Sound Transit can implement station access improvements to accommodate more riders • Extending the route could improve rider access to Sounder • Sound Transit can negotiate with BNSF to add more trips
Integrated rail system strategies	**Multimodal connectively for freight rails** • Ports and railroads can invest in improvements that make operations more efficient • Public agencies can coordinate planning to ensure freight can easily move to and from rail terminals • Northwest Seaport Alliance can continue exploring the viability of an inland seaport **First/last mile connectors** • WSDOT and other agencies can use the Freight and Goods Transportation System to focus on freight connectively investments • Regional and local planning agencies can include intermodal freight connections in their planning activities • Railroads and public agencies can continue to improve intermodal connector routes **Multimodal connectivity for passenger rail** • WSDOT can work with local jurisdictions and transit agencies to improve connectivity at Amtrak Cascades stations • WSDOT can consider access to Amtrak stations when planning additional Travel Washington intercity bus routes • Sound Transit could continue to invest in station access improvements at Sounder stations • Passenger rail operators can use technology to improve the connectivity experience for passengers **Planning coordination** • Agencies can coordinate planning activities

Source: WSF 2020

The recommendation regarding first/last mile connectivity noted in the table above is particularly germane to the role of electric aircraft in the transportation network. Similar to seaports, rails rely on first/last mile connections between rail facilities and farms, industrial centers, ports, freight corridors, and the rest of the transportation system. As rail cargo often travels by truck for first/last-mile deliveries and further, the Rail Plan observes, "As the use and volume of freight rail increases, these [roadway] connectors are at risk of becoming overwhelmed. Increased truck traffic could cause congestion and wear out pavement faster."[112] UAS could becoming an increasingly viable and feasible option to replace trucks for the first/last-mile connections and mitigate some of the issues recognized by the State Rail Plan. **Figure 2.1.5** depicts the truck freight economic corridors in Washington that include local connections to freight-intensive land uses and intermodal facilities critical to the state's supply chains. This information could be a consideration during the selection of the beta test site for the electric aircraft air cargo beta test site.

Figure 2.1.5 Truck Freight Economic Corridors in Washington



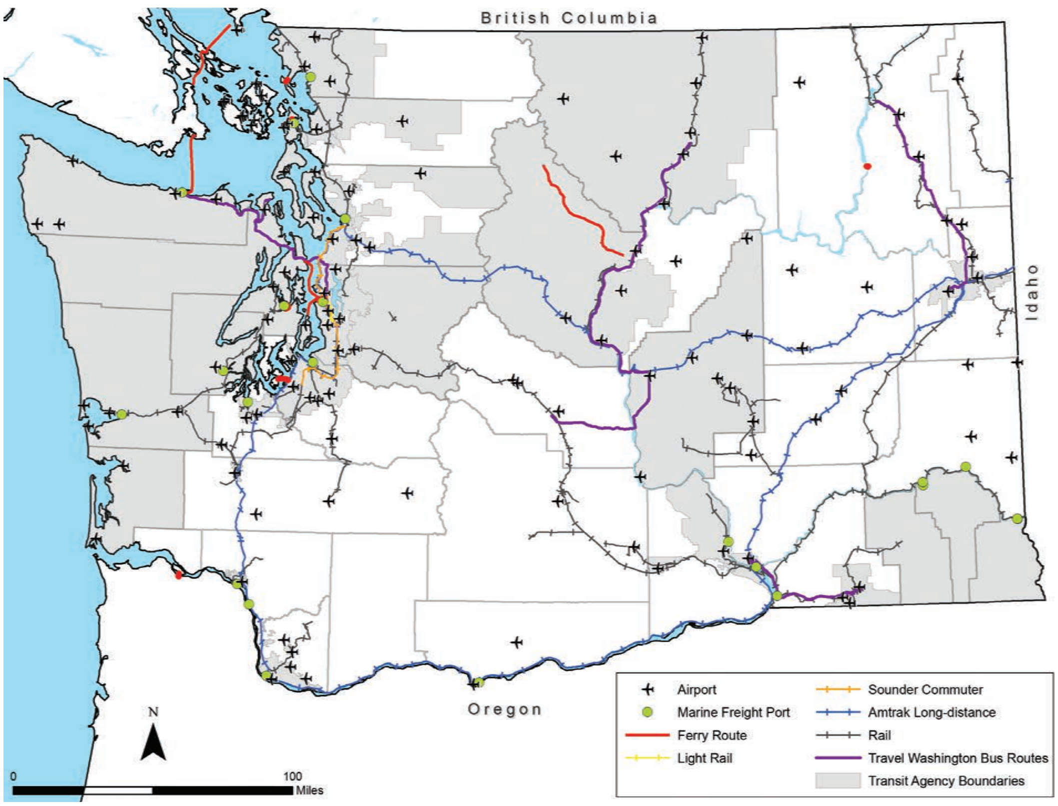
Source: WSDOT 2019

112 WSDOT (August 2020). *Washington State Rail Plan 2019 – 2040 (Public Review Draft).* Page 68

Summary

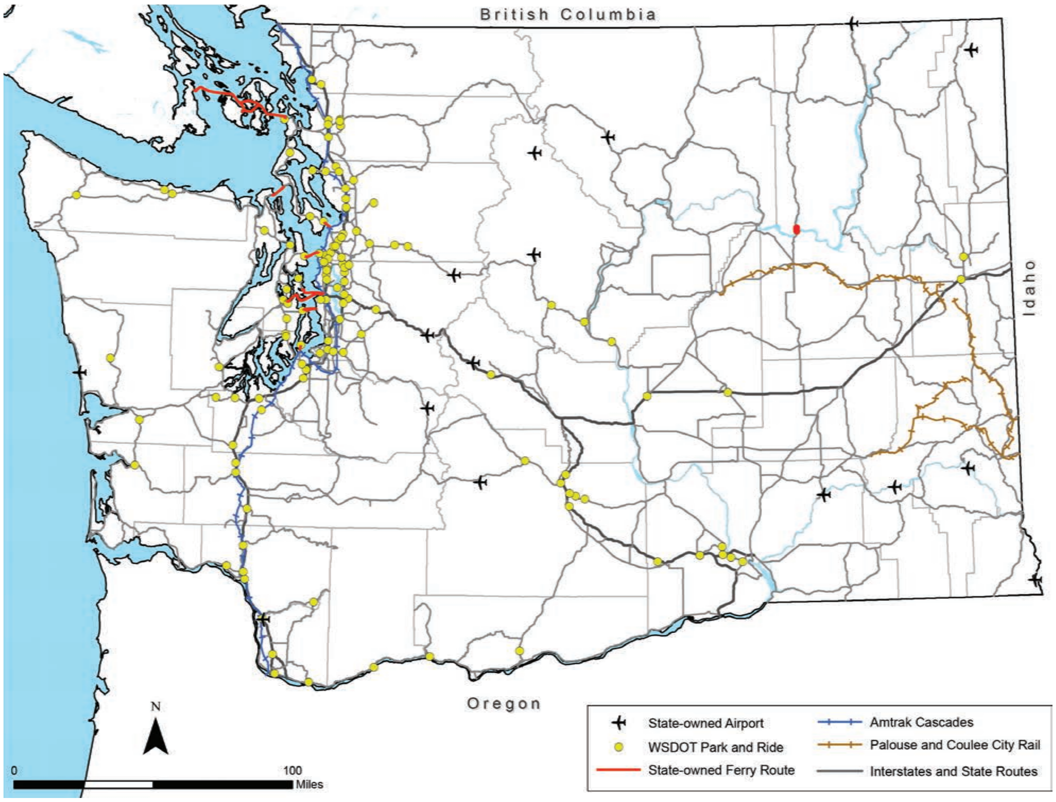
Figure 2.1.6 depicts the state-interest facilities and services owned and managed by private companies, public agencies, and Tribal governments. The following **Figure 2.1.7** depicts the transportation facilities and services owned by the State of Washington.

Figure 2.1.6 Washington State Interest Facilities and Services



Note: Not all facilities and services shown due to scale. Source: WSDOT WTP 2018

Figure 2.1.7. Transportation Facilities and Services Owned by the State of Washington



Note: Not all facilities and services shown due to scale. Source: WSDOT WTP 2017

Section 2: Existing Air Connectivity Analysis

Washington currently has 10 Primary commercial service airports as defined by the FAA latest *NPIAS Report (2019 – 2023)*. Additionally, Snohomish County (Paine Field, PAE) began scheduled commercial air service in 2019. These airports offer access to destinations within Washington, across the US, and/or worldwide. **Table 2.2.1** lists the non-stop destinations in the US and western Canada served by Washington's commercial service airports. In total, these airports provide non-stop access to over 100 destinations in these regions. It is important to note that many general aviation airports provide scheduled and unscheduled air taxi/commuter flights to destinations within the state, Pacific Northwest Region, and beyond.

Table 2.2.1 Non-stop Destinations Served by Washington's Commercial Service Airports (May 2020)

Associated City	Airport	FAA ID	Air Carriers	Non-stop Destinations (Domestic and Western Canada)
Bellingham	Bellingham International	BLI	Alaska Airlines, Allegiant Air, San Juan Airlines	Seattle/Tacoma, Las Vegas, Los Angeles, Oakland, Palm Springs, Phoenix/Mesa, San Diego, Anchorage, Tucson, Eastsound, Friday Harbor, Lopez Island, Point Roberts
Friday Harbor	Friday Harbor	FHR		Seattle, Bellingham, Anacortes
Everett	Snohomish County (Paine Field)	PAE	Alaska Airlines, United Express	Denver, Las Vegas, Los Angeles, Orange County, Palm Springs, Phoenix, Portland (OR), San Diego, San Francisco, San Jose (CA), Spokane
Pasco	Tri-Cities	PSC	Alaska Airlines, Allegiant Air, Delta Connection, United Express	Chicago-O'Hare, Denver, Las Vegas, Minneapolis/St. Paul, Salt Lake City, San Francisco, Seattle/Tacoma, Los Angeles
Seattle	Boeing Field/ King County International	BFI	United Express	Chicago–O'Hare, Denver, San Francisco
Seattle	Seattle-Tacoma International	SEA	Air Canada Express, Alaska Airlines, American Airlines, American Eagle, Delta Air Lines, Frontier Airlines, Hawaiian Airlines, JetBlue, Southwest Airlines, Spirit Airlines, Sun Country Airlines, United Airlines, United Express	Albuquerque, Anchorage, Atlanta, Austin, Baltimore, Bellingham, Billings, Boise, Boston, Bozeman, Burbank, Calgary, Charleston (SC), Charlotte, Chicago–Midway, Chicago–O'Hare, Cincinnati, Cleveland, Columbus–Glenn, Dallas/Fort Worth, Dallas–Love, Denver, Detroit, Edmonton, El Paso, Eugene, Fairbanks, Fort Lauderdale, Fresno, Great Falls, Helena, Honolulu, Houston–Intercontinental, Houston–Hobby, Indianapolis, Juneau, Kahului, Kailua–Kona, Kalispell, Kansas City, Kelowna, Ketchikan, Las Vegas, Lihue, Long Beach, Los Angeles, Los Angeles, Madison, Medford, Miami, Milwaukee, Minneapolis/St. Paul, Missoula, Nashville, New Orleans, New York–JFK, Newark, Oakland, Oklahoma City, Omaha, Ontario, Orange County, Orlando, Osaka–Kansai, Palm Springs, Philadelphia, Phoenix–Sky Harbor, Pittsburgh, Portland (OR), Puerto Vallarta, Pullman, Raleigh/Durham, Redmond/Bend, Reno/Tahoe, Sacramento, Salt Lake City, San Francisco, St. Louis, Sun Valley, Tampa, Tri-Cities (WA), Tucson, Vancouver, Victoria, Walla Walla, Washington–Dulles, Washington–National, Wenatchee, Wichita, Yakima
Spokane	Spokane International (Geiger Field)	GEG	Alaska Airlines, American Airlines, Delta Air Lines, Delta Connection, Frontier Airlines, Southwest Airlines, United Airlines, United Express	Boise, Everett, Los Angeles, Portland (OR), San Diego, San Francisco, Seattle/Tacoma, Dallas/Fort Worth, Phoenix–Sky Harbor, Atlanta, Minneapolis/St. Paul, Salt Lake City, Las Vegas, Boise, Denver, Las Vegas, Oakland, Sacramento, San Jose (CA), Chicago–O'Hare, San Francisco, Houston–Intercontinental
Walla Walla	Walla Walla Regional	ALW	Alaska Airlines	Seattle/Tacoma
Wenatchee	Pangborn Memorial	EAT	Alaska Airlines	Seattle/Tacoma, Yakima
Yakima	Yakima Air Terminal (McAllister Field)	YKM	Alaska Airlines	Seattle/Tacoma, Wenatchee

Source: Airport-specific websites (accessed May 2020)

To obtain a more nuanced understand of where Washington passengers are flying to and from, the Department of Transportation Statistics (BTS) Original and Destination (O&D) Survey was queried. O&D Survey data represents a 10 percent sample of airline tickets from reporting carriers as collected by the Office of Airline Information. These data only represents domestic itineraries and indicates itinerary details of passengers transported. It does not provide specific flight details. Data is accessible quarterly; this sample represents the first quarter (Q1) of 2019. It is assumed that this time period is generally reflective of the origins and destinations of passengers flying into and out of the state.

Table 2.2.2 shows the domestic routes less than 1,000 miles either originating from or destinated for a location in Washington state. All destination cities within 1,000 miles of a Washington airport are depicted in **Figure 2.2.1**. According to the O&D Survey data, the shortest route traveled by air in the first quarter of 2019 was between Snohomish County (Paine Field, PAE) and Seattle-Tacoma International (SEA) for a distance of 32 miles. The farthest route within the 1,000-mile study radius was between Palm Springs International Airport (PSP) and SEA for a distance of 987 miles. The most common origins and/or destinations for passengers utilizing a Washington airport are as follows:Portland International

- Boise Air Terminal
- San Francisco International
- Salt Lake City International
- Norman Y. Mineta San Jose International
- McCarran International
- Los Angeles International

Figure 2.2.1 Domestic Air Traveler Origins/Destinations within 1,000 miles of a Washington Airport

Source: BTS O&D Survey (Q1) 2019

Table 2.2.2 Domestic Air Passenger Origin and Destinations (>1,000 miles)

Route	Miles
Everett, WA: Snohomish County; Seattle, WA: Seattle/Tacoma International	32
Pasco/Kennewick/Richland, WA: Tri Cities; Walla Walla, WA: Walla Walla Regional	42
Pullman, WA: Pullman Moscow Regional; Spokane, WA: Spokane International	64
Pasco/Kennewick/Richland, WA: Tri Cities; Yakima, WA: Yakima Air Terminal/McAllister Field	71
Lewiston, ID: Lewiston Nez Perce County; Spokane, WA: Spokane International	89
Bellingham, WA: Bellingham International; Seattle, WA: Seattle/Tacoma International	93
Seattle, WA: Seattle/Tacoma International; Bellingham, WA: Bellingham International	93

Route	Miles
Pasco/Kennewick/Richland, WA: Tri Cities; Wenatchee, WA: Pangborn Memorial	94
Pasco/Kennewick/Richland, WA: Tri Cities; Lewiston, ID: Lewiston Nez Perce County	101
Pasco/Kennewick/Richland, WA: Tri Cities; Spokane, WA: Spokane International	120
Portland, OR: Portland International; Yakima, WA: Yakima Air Terminal/McAllister Field	120
Portland, OR: Portland International; Seattle, WA: Seattle/Tacoma International	129
Pullman, WA: Pullman Moscow Regional; Wenatchee, WA: Pangborn Memorial	153
Kalispell, MT: Glacier Park International; Spokane, WA: Spokane International	159
Everett, WA: Snohomish County; Portland, OR: Portland International	161
Portland, OR: Portland International; Everett, WA: Snohomish County	161
Missoula, MT: Missoula International; Spokane, WA: Spokane International	169
Pasco/Kennewick/Richland, WA: Tri Cities; Seattle, WA: Seattle/Tacoma International	172
Portland, OR: Portland International; Pasco/Kennewick/Richland, WA: Tri Cities	174
Pasco/Kennewick/Richland, WA: Tri Cities; Portland, OR: Portland International	174
Portland, OR: Portland International; Bellingham, WA: Bellingham International	221
Bend/Redmond, OR: Roberts Field; Seattle, WA: Seattle/Tacoma International	228
Seattle, WA: Seattle/Tacoma International; Bend/Redmond, OR: Roberts Field	228
Eugene, OR: Mahlon Sweet Field; Seattle, WA: Seattle/Tacoma International	234
Boise, ID: Boise Air Terminal; Pasco/Kennewick/Richland, WA: Tri Cities	234
Pasco/Kennewick/Richland, WA: Tri Cities; Boise, ID: Boise Air Terminal	234
Pullman, WA: Pullman Moscow Regional; Seattle, WA: Seattle/Tacoma International	250
Lewiston, ID: Lewiston Nez Perce County; Seattle, WA: Seattle/Tacoma International	261
Pasco/Kennewick/Richland, WA: Tri Cities; Kalispell, MT: Glacier Park International	269
Pullman, WA: Pullman Moscow Regional; Portland, OR: Portland International	275
Portland, OR: Portland International; Spokane, WA: Spokane International	279
Boise, ID: Boise Air Terminal; Spokane, WA: Spokane International	287
Bend/Redmond, OR: Roberts Field; Spokane, WA: Spokane International	290
Missoula, MT: Missoula International; Yakima, WA: Yakima Air Terminal/McAllister Field	307
Bend/Redmond, OR: Roberts Field; Bellingham, WA: Bellingham International	320
Helena, MT: Helena Regional; Pasco/Kennewick/Richland, WA: Tri Cities	341
Medford, OR: Rogue Valley International - Medford; Seattle, WA: Seattle/Tacoma International	352
Kalispell, MT: Glacier Park International; Seattle, WA: Seattle/Tacoma International	379
Idaho Falls, ID: Idaho Falls Regional; Spokane, WA: Spokane International	388
Missoula, MT: Missoula International; Seattle, WA: Seattle/Tacoma International	389
Idaho Falls, ID: Idaho Falls Regional; Pasco/Kennewick/Richland, WA: Tri Cities	395
Boise, ID: Boise Air Terminal; Seattle, WA: Seattle/Tacoma International	399
Seattle, WA: Seattle/Tacoma International; Boise, ID: Boise Air Terminal	399
Billings, MT: Billings Logan International; Spokane, WA: Spokane International	445
Helena, MT: Helena Regional; Seattle, WA: Seattle/Tacoma International	491
Great Falls, MT: Great Falls International; Seattle, WA: Seattle/Tacoma International	512
Salt Lake City, UT: Salt Lake City International; Pasco/Kennewick/Richland, WA: Tri Cities	521
Pasco/Kennewick/Richland, WA: Tri Cities; Salt Lake City, UT: Salt Lake City International	521

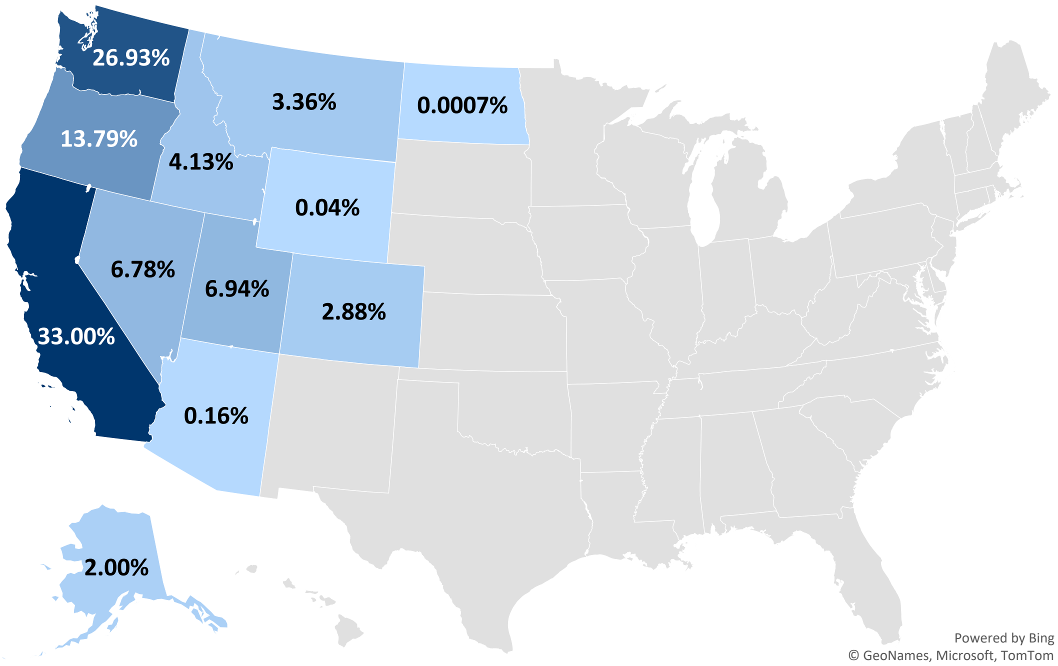
Route	Miles
Pasco/Kennewick/Richland, WA: Tri Cities; Sacramento, CA: Sacramento International	537
Bozeman, MT: Bozeman Yellowstone International; Seattle, WA: Seattle/Tacoma International	543
Seattle, WA: Seattle/Tacoma International; Bozeman, MT: Bozeman Yellowstone International	543
Salt Lake City, UT: Salt Lake City International; Spokane, WA: Spokane International	546
Reno, NV: Reno/Tahoe International; Seattle, WA: Seattle/Tacoma International	564
Reno, NV: Reno/Tahoe International; Spokane, WA: Spokane International	572
Sacramento, CA: Sacramento International; Seattle, WA: Seattle/Tacoma International	605
Santa Rosa, CA: Charles M. Schulz - Sonoma County; Seattle, WA: Seattle/Tacoma International	618
Pasco/Kennewick/Richland, WA: Tri Cities; San Francisco, CA: San Francisco International	620
San Francisco, CA: San Francisco International; Pasco/Kennewick/Richland, WA: Tri Cities	620
Jackson, WY: Jackson Hole; Seattle, WA: Seattle/Tacoma International	621
Sacramento, CA: Sacramento International; Spokane, WA: Spokane International	649
Seattle, WA: Seattle/Tacoma International; Billings, MT: Billings Logan International	664
Billings, MT: Billings Logan International; Seattle, WA: Seattle/Tacoma International	664
Oakland, CA: Metropolitan Oakland International; Seattle, WA: Seattle/Tacoma International	672
San Francisco, CA: San Francisco International; Seattle, WA: Seattle/Tacoma International	679
Ketchikan, AK: Ketchikan International; Seattle, WA: Seattle/Tacoma International	680
Salt Lake City, UT: Salt Lake City International; Seattle, WA: Seattle/Tacoma International	689
San Jose, CA: Norman Y. Mineta San Jose International; Seattle, WA: Seattle/Tacoma International	696
San Francisco, CA: San Francisco International; Everett, WA: Snohomish County	710
Everett, WA: Snohomish County; San Francisco, CA: San Francisco International	710
Oakland, CA: Metropolitan Oakland International; Spokane, WA: Spokane International	723
San Jose, CA: Norman Y. Mineta San Jose International; Everett, WA: Snohomish County	728
Pasco/Kennewick/Richland, WA: Tri Cities; Las Vegas, NV: McCarran International	732
Las Vegas, NV: McCarran International; Pasco/Kennewick/Richland, WA: Tri Cities	732
San Francisco, CA: San Francisco International; Spokane, WA: Spokane International	733
San Jose, CA: Norman Y. Mineta San Jose International; Spokane, WA: Spokane International	742
Fresno, CA: Fresno Yosemite International; Seattle, WA: Seattle/Tacoma International	748
Monterey, CA: Monterey Regional; Seattle, WA: Seattle/Tacoma International	750
Oakland, CA: Metropolitan Oakland International; Bellingham, WA: Bellingham International	764
Bellingham, WA: Bellingham International; Oakland, CA: Metropolitan Oakland International	764
Bellingham, WA: Bellingham International; San Francisco, CA: San Francisco International	771
Petersburg, AK: Petersburg James A Johnson; Seattle, WA: Seattle/Tacoma International	787
Las Vegas, NV: McCarran International; Spokane, WA: Spokane International	806
Denver, CO: Denver International; Spokane, WA: Spokane International	836
San Luis Obispo, CA: San Luis County Regional; Seattle, WA: Seattle/Tacoma International	847
Los Angeles, CA: Los Angeles International; Pasco/Kennewick/Richland, WA: Tri Cities	851
Pasco/Kennewick/Richland, WA: Tri Cities; Los Angeles, CA: Los Angeles International	851
Denver, CO: Denver International; Pasco/Kennewick/Richland, WA: Tri Cities	852
Pasco/Kennewick/Richland, WA: Tri Cities; Denver, CO: Denver International	852
Las Vegas, NV: McCarran International; Seattle, WA: Seattle/Tacoma International	867

Route	Miles
Hayden, CO: Yampa Valley; Seattle, WA: Seattle/Tacoma International	891
Las Vegas, NV: McCarran International; Everett, WA: Snohomish County	894
Santa Barbara, CA: Santa Barbara Municipal; Seattle, WA: Seattle/Tacoma International	908
Juneau, AK: Juneau International; Seattle, WA: Seattle/Tacoma International	909
Burbank, CA: Bob Hope; Spokane, WA: Spokane International	927
Ontario, CA: Ontario International; Spokane, WA: Spokane International	936
Burbank, CA: Bob Hope; Seattle, WA: Seattle/Tacoma International	937
Seattle, WA: Seattle/Tacoma International; Burbank, CA: Bob Hope	937
Eagle, CO: Eagle County Regional; Seattle, WA: Seattle/Tacoma International	940
Los Angeles, CA: Los Angeles International; Spokane, WA: Spokane International	945
Long Beach, CA: Long Beach Airport; Spokane, WA: Spokane International	953
Los Angeles, CA: Los Angeles International; Seattle, WA: Seattle/Tacoma International	954
Bellingham, WA: Bellingham International; Las Vegas, NV: McCarran International	954
Las Vegas, NV: McCarran International; Bellingham, WA: Bellingham International	954
Ontario, CA: Ontario International; Seattle, WA: Seattle/Tacoma International	956
Seattle, WA: Seattle/Tacoma International; Aspen, CO: Aspen Pitkin County Sardy Field	961
Santa Ana, CA: John Wayne Airport-Orange County; Spokane, WA: Spokane International	962
Pasco/Kennewick/Richland, WA: Tri Cities; Phoenix, AZ: Phoenix Sky Harbor International	962
Long Beach, CA: Long Beach Airport; Seattle, WA: Seattle/Tacoma International	965
Pasco/Kennewick/Richland, WA: Tri Cities; Phoenix, AZ: Phoenix - Mesa Gateway	977
Phoenix, AZ: Phoenix - Mesa Gateway; Pasco/Kennewick/Richland, WA: Tri Cities	977
Santa Ana, CA: John Wayne Airport-Orange County; Seattle, WA: Seattle/Tacoma International	978
Los Angeles, CA: Los Angeles International; Everett, WA: Snohomish County	984
Everett, WA: Snohomish County; Los Angeles, CA: Los Angeles International	984
Palm Springs, CA: Palm Springs International; Seattle, WA: Seattle/Tacoma International	987

Source: BTS Origin and Destination Survey (Q1) 2019

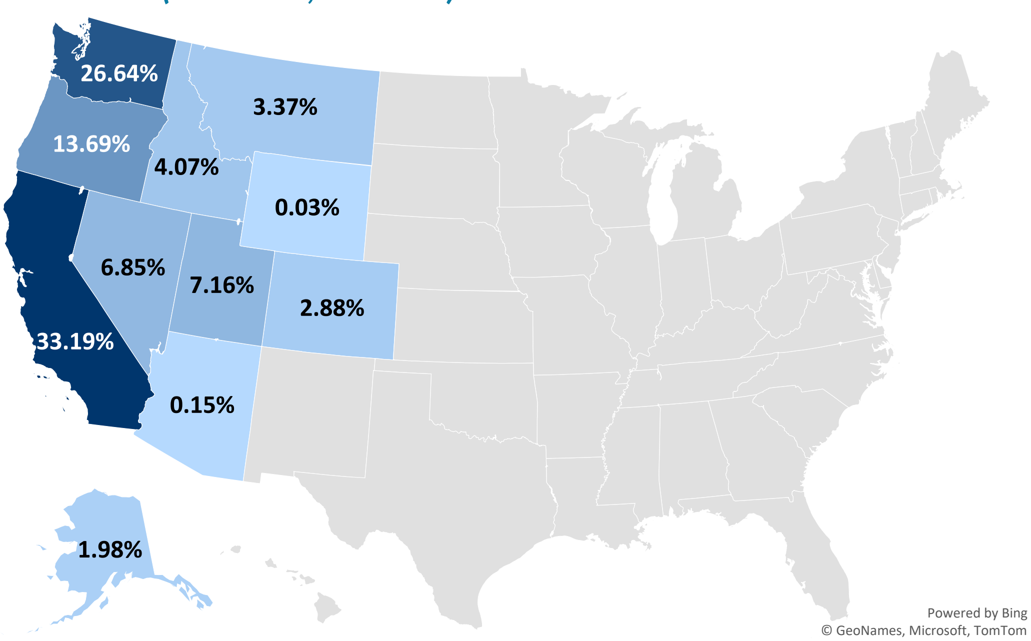
The following **Figure 2.2.2** and **Figure 2.2.3** show the percent of travelers by state either destined for or originating from a Washington airport along routes less than 1,000 miles. As travelers generally fly round-trip, the percent of travelers by state is nearly identical between these figures. Approximately one-quarter of air travelers are traveling within the state. Approximately one-third of passengers are traveling to or from an airport in California, and 14 percent of travelers are originated from/destined for an Oregon airport. Seven percent of air travelers are originated from/destined for an airport in either Utah or Nevada. The remaining passengers are traveling to or from Idaho (four percent), Montana (three percent), Colorado (three percent), Alaska (two percent), and Arizona and Wyoming (less than one percent). Note that the figure is only looking at trips less than 1,000 miles, so these percentages do not reflect the actual number of passengers originating from/ destined for these states. This information is important because it provides some data regarding potential routes that could be served by electric aircraft in the mid-term (as commercial flights reaching 1,000 miles become feasible).

Figure 2.2.2 Destinations of Passengers Originated at a Washington Airport by Percent Total (Routes >1,000 miles)



Source: BTS Origin and Destination Survey (Q1) 2019

Figure 2.2.3 Origins of Passengers Destined for a Washington Airport by Percent Total (Routes >1,000 miles)



Source: BTS Origin and Destination Survey (Q1) 2019

Section 3: Travel Time Cost Analysis

Travelers weigh a variety of factors when deciding which mode(s) of travel to use between destinations including cost, time, comfort, accessibility, and prestige of travel. Factors such as comfort and accessibility are difficult to quantify. The cost of travel is quantified both in terms of ticket costs as well as productivity and/or leisure time spent during transit. At this time, the cost of traveling by electric aircraft would necessitate several assumptions—while anticipated to be lower due to lower fuel and maintenance costs—the cost of an airline ticket will be based on current market conditions. Further, electric aircraft are more likely to replace travelers who are currently driving between destinations, particularly in the short-term with more limited travel ranges. As such, this analysis focuses on the value of travel time saved between destinations within Washington, as well as Primary airports in neighboring states. Because congestion at Sea-Tac is one of the primary issues affecting the aviation system in Washington, transiting passengers to hub airports in neighboring state may become necessary. This analysis is one of the first steps in moving towards such a solution.

This analysis is based on the FAA's guidance on the treatment of the value of time saved or lost as a result of investments in transportation facilities or regulatory actions. Because time is a valuable economic resource, changes in travel time must be "monetized within a regulatory or investment analysis."[113] These valuations are based on the US median household income in 2015 ($56,516) divided by 2,080 to yield and hourly income. This figure is then adjusted by 1.2 percent as recommended by the FAA to reflect real changes in median household income over time. **Table 2.3.1** shows the FAA's hourly values for aviation passenger time by user type.

Table 2.3.1 Hourly Values of Travel Time Savings ($US per person-hour)

Travel Purpose	Local Travel*	Intercity Travel
Personal	$16.32	$43.32
Business	$30.48	$75.84
All purpose	$16.92	$56.52

**Note: Local is defined as distances of 50 miles or less. Source: FAA 2016*

Table 2.3.2 presents the average value of travel time savings for destinations within Washington and in neighboring states. Note that flight times were estimated based on the use of a light jet, which offers specifications that most closely align with those of the most

113 FAA. (2016). *Economic Values for Evaluation of FAA investment and Regulatory Decisions*. Section 1: Treatment of Time. Available online at https://www.faa.gov/regulations_policies/policy_guidance/benefit_cost/ (accessed May 2020).

commercially viable electric aircraft in the regional commuter category in the market today. Drive times were estimated on an average weekday; peak travel times (e.g., morning and evening commutes) could increase this time significantly—particularly along Washington's most congested urban corridors. It is important to note that these travel times do not take into consideration ground travel time to reach an airport prior to boarding nor time needed to reach one's final destination (via ground transportation). Such an analysis would require numerous assumptions including but not limited to the type of aircraft operation (impacting Transportation Security Administration [TSA] screening requirements), available ground transportation options and associated parking needs, and time of day. These factors should be considered when evaluating travel time savings of specific use cases at a more granular/airport-specific level.

In addition to the travel time savings presented below, electric aircraft may offer increased schedule flexibility with "Uber-style" on-demand flights, scheduled routes between multiple airports, and the ability to quickly and cost-effectively travel to mid-range destinations that are too far by car and cost-prohibitive by traditional aircraft. The increased access and mobility provided by electric aircraft will create new opportunities for commercial partnerships, increase access to commercial centers for rural communities, and create new on-airport jobs to meet passenger needs. Advancements in Urban Air Mobility (UAM) may be particularly beneficial in streamlining travel to and from airports and further bolster the advantages of travel via electric aircraft.

In the following table, the value of travel time saved was calculated for 35 destinations within 1,000 miles of Sea-Tac, Spokane International, or both using this same methodology (see **Table 2.3.3**). These airports were identified using the travel distances reported in the BTS' O&D Survey discussed above. Again, this analysis does not take into consideration the cost of an airline ticket nor costs associated with driving including gas, wear and tear on one's vehicle, insurance, and food and lodging (as necessary depending on trip length) due to the number and extent of the assumptions that would be required to conduct such an analysis.

Table 2.3.4 shows the flight times (minutes) and nautical miles between Washington's 10 Major airports as classified by the 2017 WASP. This provides an indication of potential routes that may be feasible in the near-term given the existing state of electric aircraft technologies.

Table 2.3.2 Average Trip Savings Between Washington Destinations – Flying versus Driving

			Destination Airport									
Associated City	**Airport**	**FAA ID**	**Seattle Tacoma International (SEA)**		**Spokane International (GEG)**		**Boise Air Terminal (BOI)**		**Salt Lake City International (SLC)**		**Portland International (PDX)**	
Burlington/ Mount Vernon	Skagit Regional	BVS	Existing CS flight availability	No	Existing CS flight availability	No	Existing CS flight availability	No	Existing CS flight availability	No	Existing CS flight availability	No
			Flight time	32	Flight time	44	Flight time	76	Flight time	107	Flight time	49
			Nautical miles	61	Nautical miles	203	Nautical miles	392	Nautical miles	641	Nautical miles	173
			Drive time	82	Drive time:	312	Drive time	523	Drive time	811	Drive time	229
			Savings (minutes)	50	Savings (minutes)	268	Savings (minutes)	447	Savings (minutes)	704	Savings (minutes)	180
			Savings - Personal ($)	$36.10	Savings - Personal ($)	$193.50	Savings - Personal ($)	$322.73	Savings - Personal ($)	$508.29	Savings - Personal ($)	$129.96
			Savings - Business ($)	$63.20	Savings - Business ($)	$338.75	Savings - Business ($)	$565.01	Savings - Business ($)	$889.86	Savings - Business ($)	$227.52
			Saving - All Purpose ($)	$47.10	Saving - All Purpose ($)	$252.46	Saving - All Purpose ($)	$421.07	Saving - All Purpose ($)	$663.17	Saving - All Purpose ($)	$169.56
Hoquiam	Bowerman Field	HQM	Existing CS flight availability	No	Existing CS flight availability	No	Existing CS flight availability	No	Existing CS flight availability	No	Existing CS flight availability	No
			Flight time	19	Flight time	42	Flight time	62	Flight time	95	Flight time	27
			Nautical miles	72	Nautical miles	263	Nautical miles	385	Nautical miles	636	Nautical miles	100
			Drive time	115	Drive time:	360	Drive time	544	Drive time	832	Drive time	158
			Savings (minutes)	96	Savings (minutes)	318	Savings (minutes)	482	Savings (minutes)	737	Savings (minutes)	131
			Savings - Personal ($)	$69.31	Savings - Personal ($)	$229.60	Savings - Personal ($)	$348.00	Savings - Personal ($)	$532.11	Savings - Personal ($)	$94.58
			Savings - Business ($)	$121.34	Savings - Business ($)	$401.95	Savings - Business ($)	$609.25	Savings - Business ($)	$931.57	Savings - Business ($)	$165.58
			Saving - All Purpose ($)	$90.43	Saving - All Purpose ($)	$299.56	Saving - All Purpose ($)	$454.04	Saving - All Purpose ($)	$694.25	Saving - All Purpose ($)	$123.40
Moses Lake	Grant County International	MWH	Existing CS flight availability	No	Existing CS flight availability	No	Existing CS flight availability	No	Existing CS flight availability	No	Existing CS flight availability	No
			Flight time	23	Flight time	20	Flight time	41	Flight time	75	Flight time	31
			Nautical miles	123	Nautical miles	77	Nautical miles	255	Nautical miles	499	Nautical miles	167
			Drive time	185	Drive time	107	Drive time	354	Drive time	642	Drive time	283
			Savings (minutes)	162	Savings (minutes)	87	Savings (minutes)	313	Savings (minutes)	567	Savings (minutes)	252
			Savings - Personal ($)	$116.96	Savings - Personal ($)	$62.81	Savings - Personal ($)	$225.99	Savings - Personal ($)	$409.37	Savings - Personal ($)	$181.94
			Savings - Business ($)	$204.77	Savings - Business ($)	$109.97	Savings - Business ($)	$395.63	Savings - Business ($)	$716.69	Savings - Business ($)	$318.53
			Saving - All Purpose ($)	$152.60	Saving - All Purpose ($)	$81.95	Saving - All Purpose ($)	$294.85	Saving - All Purpose ($)	$534.11	Saving - All Purpose ($)	$237.38
Omak	Omak Municipal	OMK	Existing CS flight availability	No	Existing CS flight availability	No	Existing CS flight availability	No	Existing CS flight availability	No	Existing CS flight availability	No
			Flight time	24	Flight time	25	Flight time	52	Flight time	84	Flight time	34
			Nautical miles	128	Nautical miles	94	Nautical miles	325	Nautical miles	562	Nautical miles	214
			Drive time	254	Drive time	161	Drive time	474	Drive time	762	Drive time	385
			Savings - Personal ($)	$183.39	Savings - Personal ($)	$116.24	Savings - Personal ($)	$342.23	Savings - Personal ($)	$550.16	Savings - Personal ($)	$277.97
			Savings - Business ($)	$321.06	Savings - Business ($)	$203.50	Savings - Business ($)	$599.14	Savings - Business ($)	$963.17	Savings - Business ($)	$486.64
			Saving - All Purpose ($)	$239.27	Saving - All Purpose ($)	$151.66	Saving - All Purpose ($)	$446.51	Saving - All Purpose ($)	$717.80	Saving - All Purpose ($)	$362.67
			Saving - All Purpose ($)	$47.10	Saving - All Purpose ($)	$252.46	Saving - All Purpose ($)	$421.07	Saving - All Purpose ($)	$663.17	Saving - All Purpose ($)	$169.56
Port Angeles	William R Fairchild International	CLM	Existing CS flight availability	No	Existing CS flight availability	No	Existing CS flight availability	No	Existing CS flight availability	No	Existing CS flight availability	No
			Flight time	17	Flight time	39	Flight time	61	Flight time	99	Flight time	29
			Nautical miles	63	Nautical miles	242	Nautical miles	409	Nautical miles	660	Nautical miles	156
			Drive time:	148	Drive time	394	Drive time	600	Drive time	888	Drive time	251
			Savings (minutes):	131	Savings (minutes):	355	Savings (minutes):	539	Savings (minutes)	789	Savings (minutes)	222
			Savings - Personal ($)	$94.58	Savings - Personal ($)	$256.31	Savings - Personal ($)	$389.16	Savings - Personal ($)	$569.66	Savings - Personal ($)	$160.28
			Savings - Business ($)	$165.58	Savings - Business ($)	$448.72	Savings - Business ($)	$681.30	Savings - Business ($)	$997.30	Savings - Business ($)	$280.61
			Saving - All Purpose ($)	$123.40	Saving - All Purpose ($)	$334.41	Saving - All Purpose ($)	$507.74	Saving - All Purpose ($)	$743.24	Saving - All Purpose ($)	$209.12

			Destination Airport									
Associated City	**Airport**	**FAA ID**	**Seattle Tacoma International (SEA)**		**Spokane International (GEG)**		**Boise Air Terminal (BOI)**		**Salt Lake City International (SLC)**		**Portland International (PDX)**	
Seattle	Boeing Field/King County International	BFI	Existing CS flight availability	No	Existing CS flight availability	No	Existing CS flight availability	No	Existing CS flight availability	No	Existing CS flight availability	No
			Flight time	2	Flight time	36	Flight time	56	Flight time	90	Flight time	22
			Nautical miles	5	Nautical miles	193	Nautical miles	349	Nautical miles	600	Nautical miles	117
			Drive time	13	Drive time	263	Drive time	469	Drive time	757	Drive time	160
			Savings (minutes)	11	Savings (minutes)	227	Savings (minutes)	413	Savings (minutes)	667	Savings (minutes)	138
			Savings - Personal ($)	$2.99	Savings - Personal ($)	$163.89	Savings - Personal ($)	$298.19	Savings - Personal ($)	$481.57	Savings - Personal ($)	$99.64
			Savings - Business ($)	$5.59	Savings - Business ($)	$286.93	Savings - Business ($)	$522.03	Savings - Business ($)	$843.09	Savings - Business ($)	$174.43
			Saving - All Purpose ($)	$3.10	Saving - All Purpose ($)	$213.83	Saving - All Purpose ($)	$389.05	Saving - All Purpose ($)	$628.31	Saving - All Purpose ($)	$130.00
Spokane	Spokane International (Geiger Field)	GEG	Existing CS flight availability	Yes	Existing CS flight availability	N/A	Existing CS flight availability	Yes	Existing CS flight availability	Yes	Existing CS flight availability	No
			Flight time	36	Flight time	N/A	Flight time	40	Flight time	71	Flight time	39
			Nautical miles	194	Nautical miles	N/A	Nautical miles	250	Nautical miles	474	Nautical miles	242
			Drive time	263	Drive time	N/A	Drive time	396	Drive time	641	Drive time	325
			Savings (minutes)	227	Savings (minutes)	N/A	Savings (minutes)	356	Savings (minutes)	570	Savings (minutes)	286
			Savings - Personal ($):	$163.89	Savings - Personal ($):	N/A	Savings - Personal ($):	$257.03	Savings - Personal ($):	$411.54	Savings - Personal ($):	$206.49
			Savings - Business ($)	$286.93	Savings - Business ($)	N/A	Savings - Business ($)	$449.98	Savings - Business ($)	$720.48	Savings - Business ($)	$361.50
			Saving - All Purpose ($)	$213.83	Saving - All Purpose ($)	N/A	Saving - All Purpose ($)	$335.35	Saving - All Purpose ($)	$536.94	Saving - All Purpose ($)	$269.41
Vancouver	Pearson Field	VUO	Existing CS flight availability	No	Existing CS flight availability	No	Existing CS flight availability	No	Existing CS flight availability	No	Existing CS flight availability	N/A
			Flight time	20	Flight time	39	Flight time	48	Flight time	82	Flight time	N/A
			Nautical miles	111	Nautical miles	243	Nautical miles	301	Nautical miles	549	Nautical miles	N/A
			Drive time	149	Drive time	334	Drive time	403	Drive time	691	Drive time	N/A
			Savings (minutes)	129	Savings (minutes)	295	Savings (minutes)	355	Savings (minutes)	609	Savings (minutes)	N/A
			Savings - Personal ($)	$82.39	Savings - Personal ($)	$188.41	Savings - Personal ($)	$226.73	Savings - Personal ($)	$388.95	Savings - Personal ($)	N/A
			Savings - Business ($)	$144.22	Savings - Business ($)	$329.81	Savings - Business ($)	$396.89	Savings - Business ($)	$680.86	Savings - Business ($)	N/A
			Saving - All Purpose ($)	$107.48	Saving - All Purpose ($)	$245.78	Saving - All Purpose ($)	$295.77	Saving - All Purpose ($)	$507.40	Saving - All Purpose ($)	N/A
Walla Walla	Walla Walla Regional	ALW	Existing CS flight availability	Yes	Existing CS flight availability	No	Existing CS flight availability	No	Existing CS flight availability	No	Existing CS flight availability	No
			Flight time	34	Flight time	26	Flight time	32	Flight time	63	Flight time	34
			Nautical miles	184	Nautical miles	97	Nautical miles	176	Nautical miles	421	Nautical miles	183
			Drive time	266	Drive time	166	Drive time	255	Drive time	543	Drive time	232
			Savings (minutes)	232	Savings (minutes)	140	Savings (minutes)	223	Savings (minutes)	480	Savings (minutes)	198
			Savings - Personal ($)	$167.50	Savings - Personal ($)	$101.08	Savings - Personal ($)	$161.01	Savings - Personal ($)	$346.56	Savings - Personal ($)	$142.96
			Savings - Business ($)	$293.25	Savings - Business ($)	$176.96	Savings - Business ($)	$281.87	Savings - Business ($)	$606.72	Savings - Business ($)	$250.27
			Saving - All Purpose ($)	$218.54	Saving - All Purpose ($)	$131.88	Saving - All Purpose ($)	$210.07	Saving - All Purpose ($)	$452.16	Saving - All Purpose ($)	$186.52
Yakima	Yakima Air Terminal (McAllister Field)	YKM	Existing CS flight availability	Yes	Existing CS flight availability	No	Existing CS flight availability	No	Existing CS flight availability	No	Existing CS flight availability	No
			Flight time	24	Flight time	26	Flight time	41	Flight time	76	Flight time	19
			Nautical miles	90	Nautical miles	138	Nautical miles	257	Nautical miles	508	Nautical miles	104
			Drive time	151	Drive time	194	Drive time	334	Drive time	622	Drive time	186
			Savings (minutes)	127	Savings (minutes)	168	Savings (minutes)	293	Savings (minutes)	546	Savings (minutes)	167
			Savings - Personal ($):	$91.69	Savings - Personal ($):	$121.30	Savings - Personal ($):	$211.55	Savings - Personal ($):	$394.21	Savings - Personal ($):	$120.57
			Savings - Business ($)	$160.53	Savings - Business ($)	$212.35	Savings - Business ($)	$370.35	Savings - Business ($)	$690.14	Savings - Business ($)	$211.09
			Saving - All Purpose ($)	$119.63	Saving - All Purpose ($)	$158.26	Saving - All Purpose ($)	$276.01	Saving - All Purpose ($)	$514.33	Saving - All Purpose ($)	$157.31

Sources: airplanemanager.com/flightcalculator.aspx (accessed May 2020), Google Earth (accessed May 2020), Kimley-Horn 2020, FAA 2016 Guidance for Value Travel Time

Table 2.3.3 Travel Time and Cost Between Eastern and Western Washington and Select Destinations within 1,000 miles

		Western WA - Sea-Tac						Eastern WA - Spokane International (GEG)					
State	City	Miles by Air	Flying Time (minutes)	Driving Distance (miles)	Driving Time (minutes)	Time Savings (minutes)	Value of Travel Time Saved ($)	Miles by Air	Flying Time (minutes)	Driving Distance (miles)	Driving Time (minutes)	Time Savings (minutes)	Value of Travel Time Saved ($)
AK	Juneau	902	127	1,815	2,333	2,206	$2,078.05	1,017	152	1,810	2,460	2,308	$2,174.14
	Ketchikan	678	100	1,116	1,558	1,458	$1,373.44	809	127	1,221	1,687	1,560	$1,469.52
	Sitka	861	120	1,961	2,920	2,800	$2,637.60	993	149	2,067	3,084	2,935	$2,764.77
BC (CAN)	Kelowna	213	56	326	332	276	$259.99	181	52	235	296	244	$229.85
	Vancouver	130	46	153	157	111	$104.56	284	64	412	384	320	$301.44
	Victoria	83	40	155	271	231	$217.60	280	64	422	514	450	$423.90
CA	Burbank	939	124	1,115	1,069	945	$890.19	931	142	1,194	1,183	1,041	$980.62
	Fresno	750	99	916	900	801	$754.54	763	122	991	944	822	$774.32
	Long Beach	968	131	1,148	1,107	976	$919.39	959	145	1,226	1,155	1,010	$951.42
	Los Angeles	948	129	1,125	1,079	950	$894.90	940	143	1,203	1,130	987	$929.75
	Oakland	666	99	791	780	681	$641.50	723	107	869	836	729	$686.72
	Ontario	955	129	1,159	1,114	985	$927.87	938	143	1,197	1,134	991	$933.52
	Orange County	975	135	1,159	1,120	985	$927.87	961	145	1,409	1,236	1,091	$1,027.72
	Palm Springs	987	134	1,229	1,185	1,051	$990.04	955	145	1,248	1,179	1,034	$974.03
	Reno/Tahoe	561	76	696	683	607	$571.79	574	99	788	722	623	$586.87
	Sacramento	613	85	741	726	641	$603.82	659	109	820	789	680	$640.56
	San Francisco	668	101	798	742	641	$603.82	728	110	875	842	732	$689.54
	San Jose (CA)	698	104	826	815	711	$669.76	748	110	909	868	758	$714.04
	San Luis Obispo	844	131	1,010	915	784	$738.53	870	134	1,088	1,108	974	$917.51
	Santa Barbara	909	120	1,102	1,091	971	$914.68	921	141	1,182	1,207	1,066	$1,004.17
	Santa Rosa	622	105	809	746	641	$603.82	690	113	852	863	750	$706.50
ID	Boise	396	54	499	460	406	$382.45	285	44	419	391	347	$326.87
	Sun Valley	475	87	647	618	531	$500.20	311	48	478	528	480	$452.16
MT	Billings	666	110	825	737	627	$590.63	443	83	542	485	402	$378.68
	Bozeman	550	96	682	618	522	$491.72	333	70	399	365	295	$277.89
	Great Falls	515	92	648	600	508	$478.54	286	64	364	351	287	$270.35
	Helena	489	89	593	546	457	$430.49	265	62	310	293	231	$217.60
	Kalispell	376	75	520	491	416	$391.87	149	48	237	238	190	$178.98
	Missoula	394	77	481	444	367	$345.71	170	50	198	190	140	$131.88
NV	Las Vegas	861	118	1,171	1,086	968	$911.86	801	114	1,042	949	835	$786.57
OR	Eugene	238	59	274	257	198	$186.52	370	74	460	424	350	$329.70
	Medford	355	73	437	410	337	$317.45	455	85	557	566	481	$453.10
	Portland (OR)	134	36	165	157	121	$113.98	290	51	351	324	273	$257.17
	Redmond/Bend	226	57	299	338	281	$264.70	295	65	368	355	290	$273.18
UT	Salt Lake City	693	91	847	769	678	$638.68	550	75	721	624	549	$517.16

Sources: travelmath.com, FAA 2016 Guidance for Value Travel Time, BTS O&D Survey (Q1) 2019

Table 2.3.4 Flight Times and Nautical Miles Between Washington's Major Airports

			BLI		PAE		MWH		PSC		BFI		SEA		GEG		ALW		EAT		YKM	
Associated City	**Airport Name**	**FAA ID**	NM	Flight Time	NM	Flight Time	NM	Flight Time	NM	Flight Time	NM	Flight Time	NM	Flight Time	NM	Flight Time	NM	Flight Time	NM	Flight Time	NM	Flight Time
Bellingham	Bellingham International	BLI	-	-	54	14	160	30	205	33	76	20	81	22	212	34	237	38	126	23	156	29
Everett	Snohomish County (Paine Field)	PAE	54	14	-	-	127	23	163	30	23	8	27	99	192	36	196	36	89	24	107	20
Moses Lake	Grant County International	MWH	160	30	127	23	-	-	57	15	123	23	123	23	77	20	79	21	38	13	63	17
Pasco	Tri-Cities	PSC	205	33	163	30	57	15	-	-	151	28	149	28	104	19	36	12	81	22	62	16
Seattle	Boeing Field/King County International	BFI	76	20	23	8	123	23	151	28	-	-	5	2	193	36	186	34	85	23	92	25
Seattle	Seattle-Tacoma International	SEA	81	22	27	99	123	23	149	28	5	2	-	-	194	36	184	34	86	23	90	24
Spokane	Spokane International (Geiger Field)	GEG	212	34	192	36	77	20	104	19	193	36	194	36	-	-	97	26	109	20	138	26
Walla Walla	Walla Walla Regional	ALW	237	38	196	36	79	21	36	12	186	34	184	34	97	26	-	-	111	21	98	26
Wenatchee	Pangborn Memorial	EAT	126	23	89	24	38	13	81	22	85	23	86	23	109	20	111	21	-	-	52	14
Yakima	Yakima Air Terminal (McAllister Field)	YKM	156	29	107	20	63	17	62	16	92	25	90	24	138	26	98	26	52	14	-	-

Source: airplanemanager.com/flightcalculator.aspx (accessed May 2020)

Section 4: Recommendations

The following provides recommendations associated with the integration of electric aircraft into Washington's existing multimodal transportation network. Recommendations are categorized in terms of applicability to airports and policymakers.

Airports

- Identify existing modal options in the vicinity of the airport and assess how the deployment of electric aircraft could affect or interact with those modes.
- Ensure the airport has adequate ground transportation options for arriving pilots and passengers. Public transit, light rail, courtesy cars, rental cars, and other ground transportation options offer visitors the ability to leave airport property and spend money in local communities. This increases the airport's economic impact, which can lead to additional support for the airport in terms of airport-compatible land use planning and zoning and local investment. Airports without a means to leave airport property may deter pilots from choosing that facility.
- Develop a partnership with local planners, as electric aircraft may need to be incorporated into local comprehensive and transportation strategic planning efforts. Planners should be educated about electric aircraft's potential roles within and impact on the broader transportation network.
- Identify high-potential electric aircraft routes for air cargo and passenger service, and calculate the cost associated with driving versus flying between specific destinations. This information is important during air service development efforts. Additional information about air service development is provided in the Airport Self-Assessment Framework in the Demand and Deployment section of this study. Additional information about calculating the cost of driving versus flying is provided in Economic and Environmental Benefits section.

Policymakers

- Coordinate with other modal managers during all regional and statewide long-term transportation planning efforts. Electric aircraft could shift demand away from existing modes, which would reduce associated capacity enhancement needs. By managing all modes of transportation as an interrelated system, state investment could be more effectively allocated within the state.
- Consider zoning ordinances and land use regulations that may be required by future UAS and UAM applications. It is anticipated that small packages will be delivered by unmanned aerial vehicles in the near-term. This activity will occur on off-airport property. As such, UAS and UAM platforms and/or vertiports will become a new type of land use that should be regulated to ensure the safety of people and property in nearby vicinities, as well as aircraft within the approach surfaces of nearby airports.
- Include electric aircraft in long-term statewide aviation planning efforts. The WASP was last published in 2017 using 2014 baseline data. Electric aircraft may shift demands within the state and open new opportunities for airports that currently do not support passenger service. This new technology may be appropriate to include when the WASP is next updated.

Section 5: Conclusion

Electric aircraft is an evolving transportation mode that will impact Washington's entire transportation network. It could relieve some capacity pressures currently confronting the state ferry system and provide a means to transport goods from rails and marine ports to their next destinations. In the long-term, congested urban corridors could experience some relief as travelers choose to commute by air instead of along highways and arterials streets. Conversely, new demands may arise as pilots, passengers, and cargo travel to and from airports by personal vehicle, rideshare/taxi services, or truck. This may cause bottlenecks surrounding airports. Such congestion is not only frustrating but results in real economic losses in terms of time delay and operating expenses for logistics providers. Light rails and public transit providers could similarly witness an uptick in activity levels. Because many long-term plans consider a 20-year horizon, evaluating electric aircraft's relationship with other transportation modes today is an important step in facilitating their transition into Washington's intermodal network.

Chapter 3:
Workforce Development

Introduction

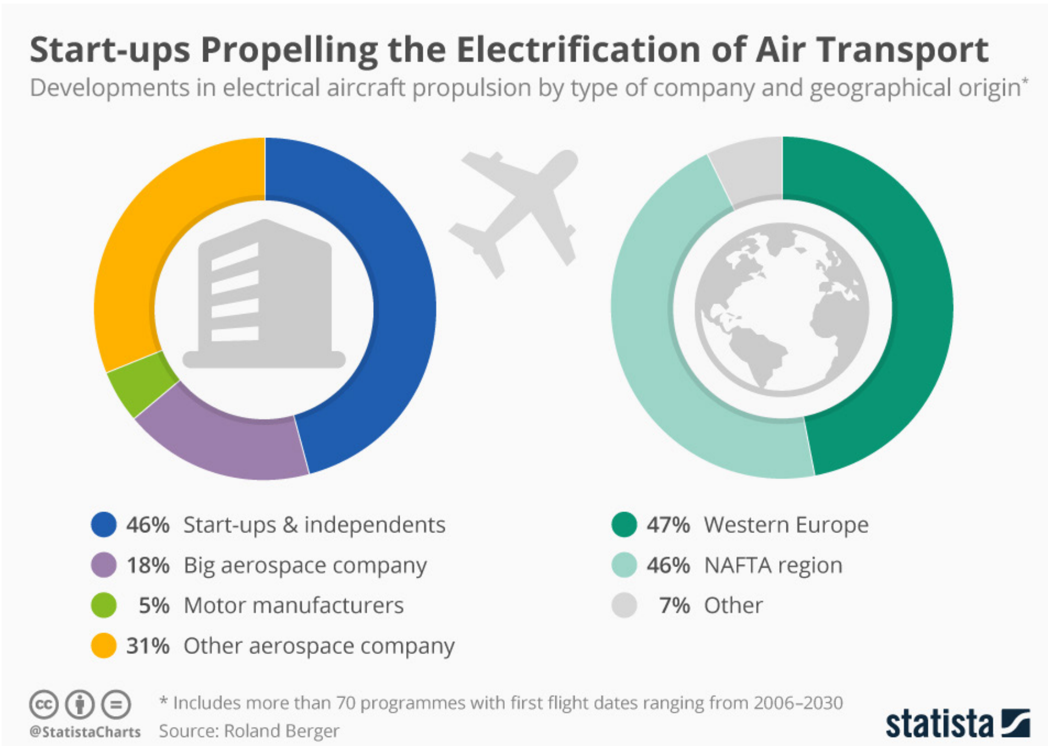
The aerospace and advanced manufacturing industries rely on a skilled workforce for the development and deployment of innovative technologies. Meeting the needs of this high-tech sector requires specialized training and skills development throughout the regional production chain. Workforce development programs leverage the experience and expertise of industry-leading firms, in concert with academic and vocational education programs, to help identify and train the next generation of production and managerial staff. This ensures a supply of skilled labor to support the sustainable growth of the conventional aerospace industry, while providing the opportunities to support innovative activities in the sector. This work paper details the ways the State of Washington can develop skilled labor required for the success of the emerging electric aircraft industry.

According to Dr. Robert Jacobs and Joshua D. Hawley, professors of Workforce Development and Education at the Ohio State University, workforce development is defined as “the coordination of public and private-sector policies and programs that provides individuals with the opportunity for a sustainable livelihood and helps organizations achieve exemplary goals, consistent with the societal context.”[114] While job training refers to an employee learning the skills necessary to perform a job on a day-to-day basis, workforce development expands to focus on long-term learning and developing capabilities beyond job skills, including management skills, personal competencies and professionalism.

Figure 3.i.1 illustrates the mix of stakeholders supporting the development of the electric aircraft industry, which includes the education and training of the labor force and leveraging resources in research and development to facilitate a commercially viable means of transportation. It is important to note that electric aircraft are bringing many new players to the industry – only 18% of developments are big aerospace companies, while nearly half are startups. This indicates that partnerships with new entities will be critical to developing the Washington state workforce.

114 https://www.stlouisfed.org/publications/bridges/spring-2010/what-is-workforce-development

Figure 3.i.1 Stakeholders Supporting the Electric Aircraft Industry



The focus on long-term learning and development recognizes the value of an education in fundamental skills and specialty technologies for an industry undergoing constant evolution. Aerospace manufacturing continues to occupy the cutting-edge of the production industries, as demonstrated by the emergence of the electric aircraft sector, and therefore requires access to a highly skilled and versatile workforce to achieve sustained growth. Through collaborations with industry firms, educational institutions, and economic development organizations, workforce development programs aim to provide skills training currently in demand by industry firms, while supporting the development of markets for emerging products and services.

The workforce development needs of the emerging electric aircraft industry will require bringing new technology into commercial production and incorporating it into the existing aerospace supply chains and infrastructure systems. Due to the unique characteristics of the propulsion and power management systems in electric aircraft, the production of the components requires employees with specialized skills training in the sophisticated design and manufacturing systems. The innovative technologies and infrastructure supporting the production and operation of electric aircraft necessitates investment by firms and public entities into expanding learning facilities at airports, developing educational curriculum in the production and maintenance of electric power systems and specialty aircraft components, and allocating financial resources for research and development at technical colleges and start-up enterprises. Furthermore, the maintenance of the systems and operation of the aircraft requires additional training for mechanics and operators. The overlap in the conceptual understanding with conventional systems illustrates the opportunity to expand the existing framework of technical colleges and apprenticeship programs with innovative course programs and skills trainings.

The viability of electric aircraft as a reliable means to transport people and cargo throughout the state relies on the development of a network of charging and operations infrastructure, including battery- charging and swapping stations, maintenance facilities, logistics nodes connected into the regional freight networks, and terminal facilities for business operations and passenger embarkment. In addition to the technological requirements for manufacturing and operations, a key challenge for making electric aircraft part of the aerospace environment will be engaging stakeholders and users to demonstrate the maturity of the technology for commercial production and the safety of the aircraft for its users and the greater public.

Aerospace Workforce Development in Washington State

In Washington state, the framework of workforce development for the aerospace industry includes a network of skills training programs managed by technical colleges,[115] a recognized Center of Excellence for Aerospace and Advanced Manufacturing,[116] apprentice programs with leading industry firms managed by the Aerospace Joint Apprenticeship Committee,[117] and a several ongoing partnerships between labor organizations, industry firms, and industry organizations. As a developing sector within the aerospace industry, the electric aircraft industry can leverage these networks for skilled laborers and attracting business investment, while contributing to the evolution of the aerospace industry throughout the region.

The geographical distribution of the aerospace industry within Washington state and the existing infrastructure networks supporting the regional economy provide opportunities for the electric aircraft sector across the state. Washington hosts over 141,000 aerospace workers from 1,400 companies, largely around the Puget Sound region and, to a lesser

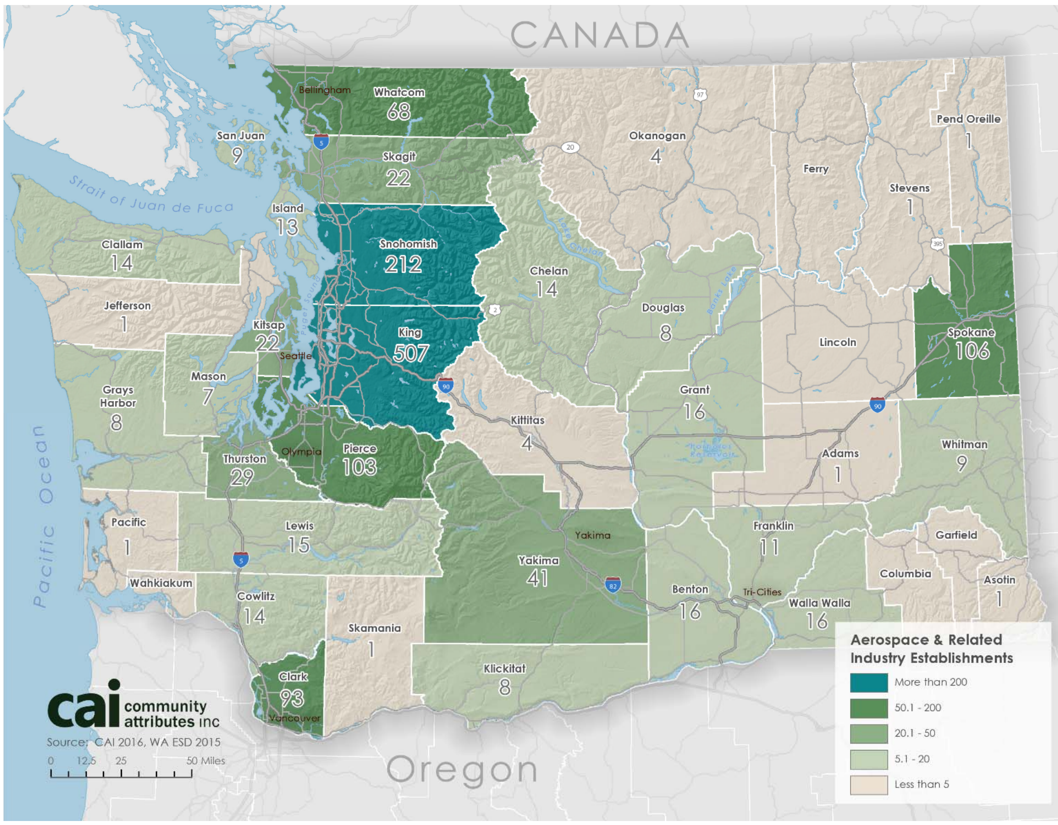
115 https://www.sbctc.edu/colleges-staff/programs-services/aerospace/default.aspx

116 https://www.coewa.com/aerospace

117 https://www.ajactraining.org/

degree, the Spokane area.[118] **Figure 3.i.2** illustrates the geographical footprint of the aerospace industry across Washington state, including the concentration of firms throughout the I-5 highway corridor.

Figure 3.i.2 Aerospace Industry in Washington State



The I-5 highway corridor connects the major population centers and greatest concentration of aerospace firms in the Puget Sound region, including Seattle, Tacoma, Renton, and Everett, providing strong regional connections for manufacturers, suppliers, and the workforce. However, the density of aerospace activity around the Puget Sound Region presents issues for other parts of the state. Firms in rural areas reportedly have a difficult time attracting and maintaining staff, while Spokane experiences challenges retaining firms in the area. Despite these constraints, the sophistication of the aerospace industry and its labor force in the Puget Sound region and the high level of connectivity to regional and global markets present a prime environment for the electric aircraft sector to achieve maturity in commercial production and service operations.

118 https://www.pnaa.net/the-cluster

As shown in **Table 3.i.1**, the workforce for the electric aircraft industry will have different requirements than the current conventional aircraft industry. Developing modules within existing workforce development programs and creating new aviation-focused training in industries related to manufacturing and support for electric aircraft is key to support the industry.

Table 3.i.1 Electric vs. Conventional Aircraft

Electric Aircraft Industry	Conventional Aircraft Industry
Hybrid-electric and electric propulsion systems	Conventional propulsion systems
Advanced materials manufacturing	Conventional airframe manufacturing
Battery and hydrogen energy systems	Conventional fuel systems
Semiconductors and digital computer systems	Analog computational systems
Integration technologies (Internet of Things, RFID, Big Data analytics)	Analog electrical and maintenance systems
Pilot training on electric aircraft	Pilot training on conventional aircraft
Mechanic training on electric aircraft	Mechanic training on conventional aircraft
Rapid integration Industry 4.0 technologies	Slower integration of Industry 4.0

Section 1: Aviation Workforce Development Programs

Collaborative relationships between educational institutions, industry associations, production firms, and Washington State government agencies are the backbone of workforce development programs throughout the region in support of suppliers, manufacturers, and other associated entities. In the face of constraints on qualified labor due to retirements, attrition, and the lack of a new generation of workers interested in working in the aerospace industry, workforce development programs became a priority for employers and economic development officials. Several technical colleges developed training programs geared towards teaching industry job skills on an accelerated timeline to meet the increased demand by firms, while also offering comprehensive two-year degree programs in aircraft maintenance and technical production. The introduction of commercially viable electric propulsion systems into the market provides an incentive for these programs to incorporate the unique requirements of electric aircraft into their curricula. In addition to technical learning, a number of programs partner with industry firms to provide the opportunity for experiential learning through on-site facilities, internships, and apprenticeships. As partnerships between the public and private sectors, these programs represent the diversity of the regional aerospace economy through the inclusion of firms and organizations of various sizes from throughout the supply chain.

Educational Programs

The emergence of the electric aircraft sector presents a paradigm shift in the aerospace industry. Utilizing electric propulsion affects various elements of the supply chain to support component manufacturing, aircraft production, operation, and maintenance, and facility management. Several educational institutions in Washington state provide skills training through various certification and degree programs to support these functions within the industry; the programs provide training in conventional systems in addition to courses specifically related to electric aircraft components and systems. With the nascence of the electric aircraft sector, existing programs increasingly address the skills needed for the production and operation of electric propulsion systems and their vehicles while specialized programs undergo development to meet the demand for these specialized skills. In the education sector, the demand by industry firms for labor with specific skillsets and knowledge preempts the development of programs addressing shortfalls in those skillsets and knowledge, so it can be expected for new programs to emerge as the electric aircraft sectors continues towards commercial maturity. Educational institutions work together with industry organizations and government agencies to identify the demand for specialized programs and invest the resources and experience necessary to develop an effective labor force.

Workforce development programs based in high schools and technical colleges provide a pathway for students to become exposed to the skills and knowledge required in the aerospace industry or a similar manufacturing-oriented industry, while working towards a widely recognized certification, usually a two-year associates degree. For example, the School of Aerospace and Aviation at Clover Park Technical College in Lakewood provides certificate and degree programs through their campus at Thun Field, which houses a number of business operations and educational facilities affiliated with the aerospace industry[119]. The school maintains a dual credit program for high school students interested in earning credits for college-level classes, which include courses in aviation maintenance and a pilot school.[120] The blended approach of technical learning and hands-on experience helps to prepare students for deployment in the workplace, while ensuring students hold negligible debt and industry employment following graduation. While such programs provide excellent opportunities for high school and college students to learn and gain hands-on experience, there is continued demand to build relationships between firms and schools to expand the apprenticeship programs and improve the framework transitioning program candidates from high school through the community colleges into a workplace.

119 https://www.cptc.edu/south-hill

120 https://www.pc3connect.org/dualcredit/engintech.html

The Core Plus Aerospace two-year program, developed with Boeing support, helps high school students develop the technical and soft skills necessary for success in the manufacturing industry and prepares them for apprenticeships or degree programs at participating technical colleges. The program is currently available at over 40 schools and skill centers in Washington State, and continues to expand. **Table 3.1.1** below lists the educational institutions with post-secondary programs aligned with the curriculum of the Core Plus Aerospace Program to further develop the skillsets and knowledge of students for roles in the aerospace manufacturing and maintenance sectors.

Table 3.1.1 Educational Institutions with Post-Secondary Programs Aligned with the Core Plus Aerospace Program

Bates Technical College: *Tacoma, WA*	**Bellingham Technical College:** *Bellingham, WA*	**Big Bend Community College:** *Moses Lake, WA*	**Clark College:** *Vancouver, WA*	**Clover Park Technical College:** *Lakewood, WA & Puyallup, WA*	**Edmonds College:** *Edmonds, WA*
Everett Community College: *Everett, WA*	**Green River College:** *Auburn, WA*	**North Seattle, College:** *Seattle, WA*	**Olympic College:** *Bremerton, WA*	**Perry Technical Institute:** *Yakima, WA*	**Renton Technical College:** *Renton, WA*
Shoreline Community College: *Shoreline, WA*	**South Seattle College:** *Seattle, WA*	**Spokane Community College:** *Spokane, WA*	**Washington Aerospace Training and Research Center:** *Everett, WA*	**Wenatchee Valley College:** *Wenatchee, WA*	

For students entering the workforce, obtaining a certification demonstrating their competencies with industry tools and systems validates their education and training to future employers and industry associations. Four of the educational institutions listed above in **Table 3.1.1** are certified as an Aircraft Maintenance Technician School (AMTS) under the Federal Aviation Administration's CFR Part 147 program: Big Bend Community College, Clover Park Technical College, Everett Community College, South Seattle College and Spokane Community College. Moody Aviation, based in Spokane, WA, is a private teaching institute certified as an Aircraft Maintenance Technician School (AMTS) under the same program.

Leveraging workforce development programs in high schools and technical colleges through standardized curricula, technical skills training, and experiential learning has proven to be effective in developing the next generation of workers in the aerospace industry. With the emergence of the electric aircraft sector, the educational system supporting the industry continues to evolve to meet changing demands of employers and incorporating an expanded set of tools and technologies for manufacturing and maintenance activities. Courses in electronics and semiconductors, which had previously been offshored, are increasingly included in the curriculum of educational programs, similar to automation technologies, electric power systems, and sophisticated design programs. The advent of Industry 4.0, the next phase in the Industrial Revolution, brings advanced tools and technologies into the manufacturing industry with a focus on interconnectivity, machine learning, automation, and real-time data. The development of these tools and their deployment in the aerospace industry will define the expectations of how the next generation of the labor force will perform their jobs. Change in the educational system requires time and additional resources to determine the demand by employers for these specialized skills and knowledge and develop a satisfactory curriculum to best prepare the next generation of the workforce. Partnerships between educational institutions and industry firms, such as advisory boards and Centers of Excellence, leverage their cumulative experience in the industry, education, and workforce development programs to ensure the allocation of their resources results in a synergistic effect for the students and the firms in the regional aerospace economy.

Figure 3.1.1 The Technological Pillars of Industry 4.0

Pilot Training

Pilot training is another key aspect of workforce development. Currently, 24 organizations in Washington state serve as certified flight schools under the Federal Aviation Administration's CFR Part 141 program. The benefits of obtaining a certification regarded as an industry standard validates the competencies and experience of the student while indicating to employers the quality of the educational programs and the value of their qualified labor force.

It is expected that current licensed pilots may only need to go through a few hours of training to obtain certification to operate electric aircraft. However, in 2013, the FAA increased the training regulations for first officers of commercial airlines and required an Air Transport Pilot license with a minimum of 1,500 flight hours instead of requiring a commercial pilot certificate with 250 hours of flight time.[121] As a result, the industry warned of a long pilot shortage and student enrollments for pilot training in the U.S. has not been able to keep up with the national demand.[122] Electric aircraft have the potential to enhance pilot training, both to meet the expected increased demand for pilots and also since the lower cost will make flight training more affordable.

Finding ways to keep costs down is a key issue for pilot training. It can cost $30,000 to $50,000 or more to become a commercial transportation pilot.[123] A key issue for flight training is that subsidized federal education loan programs are not generally available since most flight schools are not accredited institutions. Furthermore, new pilots typically build hours by working low-paying jobs. The result of these twin factors is that economically disadvantaged students are largely excluded from pursuing a career as a pilot.

Industry initiatives

Firms in the aerospace economy rely on a robust network of workforce development programs to develop a highly skilled labor force in the region and drive innovation in the design and production of aircraft components and vehicles. As the nation's number one aerospace cluster, developing and maintaining a qualified labor force is imperative to sustained growth in the regional and national economy. By forming partnerships with state government agencies, industry associations, and educational institutions, aerospace firms leverage their resources of industry experience, advocacy networks, educational facilities, and economic development funds to establish robust workforce development programs.

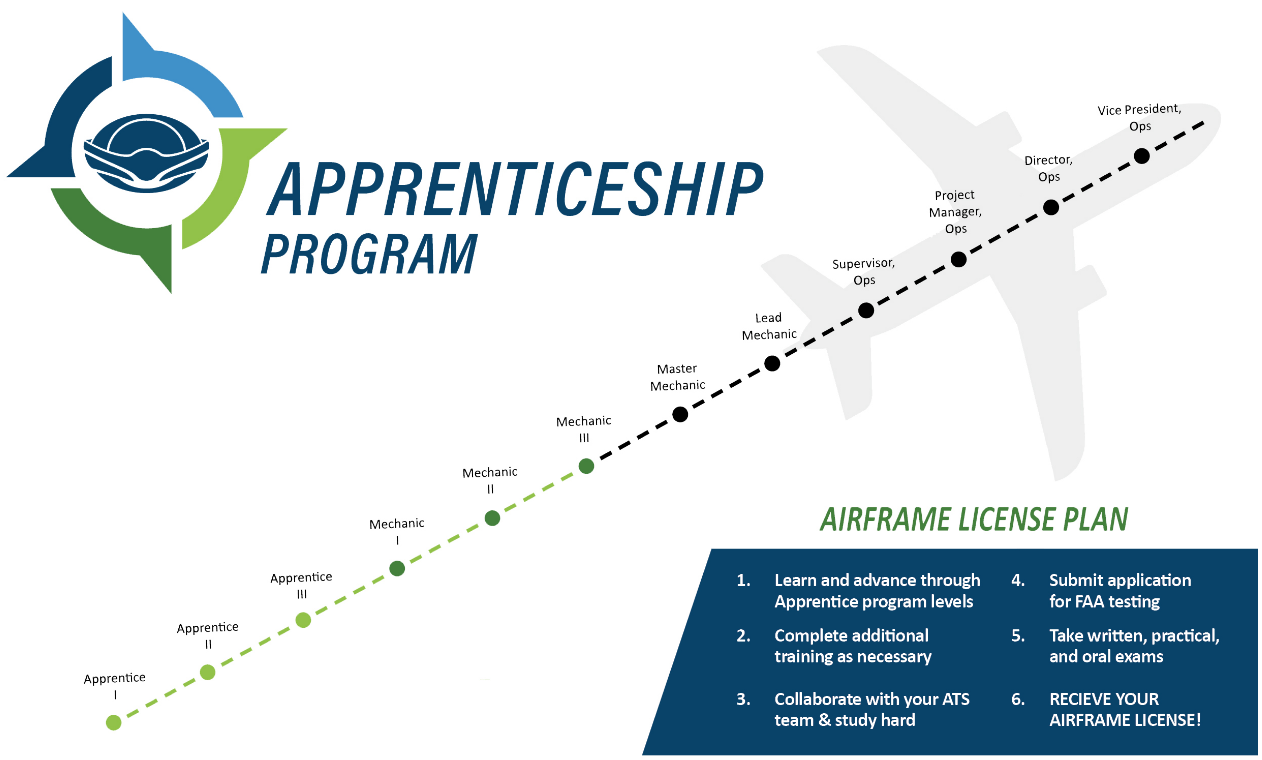
121 Press Release – FAA Boosts Aviation Safety with new Pilot Qualification Standards. https://www.faa.gov/news/press_releases/news_story.cfm?newsId=14838.

122 The Airline Pilot Shortage isn't going away, Flexair 2020. https://www.goflexair.com/the-airline-pilot-shortage-isnt-going-away/

123 https://pilotinstitute.com/pilot-license-cost/

The Centers of Excellence established between firms, state government agencies, and educational centers provide an opportunity for the industry to influence the development of educational programs meant to produce a qualified labor force. The members of the Center of Excellence leverage a process called Developing a Curriculum to identify the skills and knowledge required by students to perform in the future workplace; conducting these exercises across disciplines, such as electrical manufacturing, provide insights specifically useful for students interested in working in the electric aircraft sector. In addition to the educational programs described previously, these programs include apprenticeships, internships, industry research, business incubators, and seed investment funds to provide experiential learning opportunities and enable the growth of new sectors using innovative technologies or techniques, such as the production of electric aircraft.

Figure 3.1.2 Roadmap for Apprenticeship Program Supported by ATS, Washington State's Second Largest Maintenance Repair and Operations (MRO) Organization



Experiential learning plays a critical role for students to exercise their technical knowledge and newly learned skills, while allowing firms to train and evaluate prospective employees in a realistic work environment. The structure of the apprenticeship program mitigates the financial risk for firms of hiring inexperienced staff, while students get access to training and employment opportunities as they work and received modest compensation. Furthermore, the management of apprenticeship programs generally fall under labor organizations and industry associations, providing insurances and workplace representation for their members. The Aerospace Joint Apprenticeship Committee manages eight apprenticeship programs lasting from 18 months to five years with aerospace firms in the Puget Sound region, the Spokane area, and southeast Washington state.[124] The participating employers include large and small firms in the aerospace industry and other manufacturing sectors throughout Washington state, providing diverse opportunities and accessibility for participants of the program. Additionally, firms with properties on airports and airport owners provide opportunities for educational programs at operations facilities, which may not be an accessible learning environment in a formal school setting.

The participation of firms on advisory boards and in Centers of Excellence of educational institutions and workforce development programs ensures their input into the design and structure of those programs to align with the skill requirements of the workplace. Importantly, these programs include smaller firms, which facilitates greater investment in the development of apprentices, while ensuring the workforce needs of firms throughout the regional supply chain are being addressed.

In addition to identifying the tools and technologies required to be sufficiently productive in the workplace, the role of industry firms in these collaborative partnerships leverage their investment in product research, market analysis, and technology development to indicate trends in the industry. While these investments provide benefits to their business operations, firms contribute an understanding of the market at the ground level to workforce development programs to ensure the labor force can be upskilled or otherwise adapt to upcoming changes. Their knowledge can be incredibly helpful in identifying effective investment choices for public agencies and educational institutions to optimize the allocation of limited resources. Business incubators and investment funds serve as examples of how industry firms can allocate their resources during the early phase of emerging research or start-up enterprises and generate long-term value for the regional economy. As the technology in electric aircraft approaches maturity, the required investment to transition into commercial production can be allocated by public agencies and investment vehicles to realize the full potential of the technological advancements.

124 https://www.ajactraining.org/

Section 2: State Government Programs

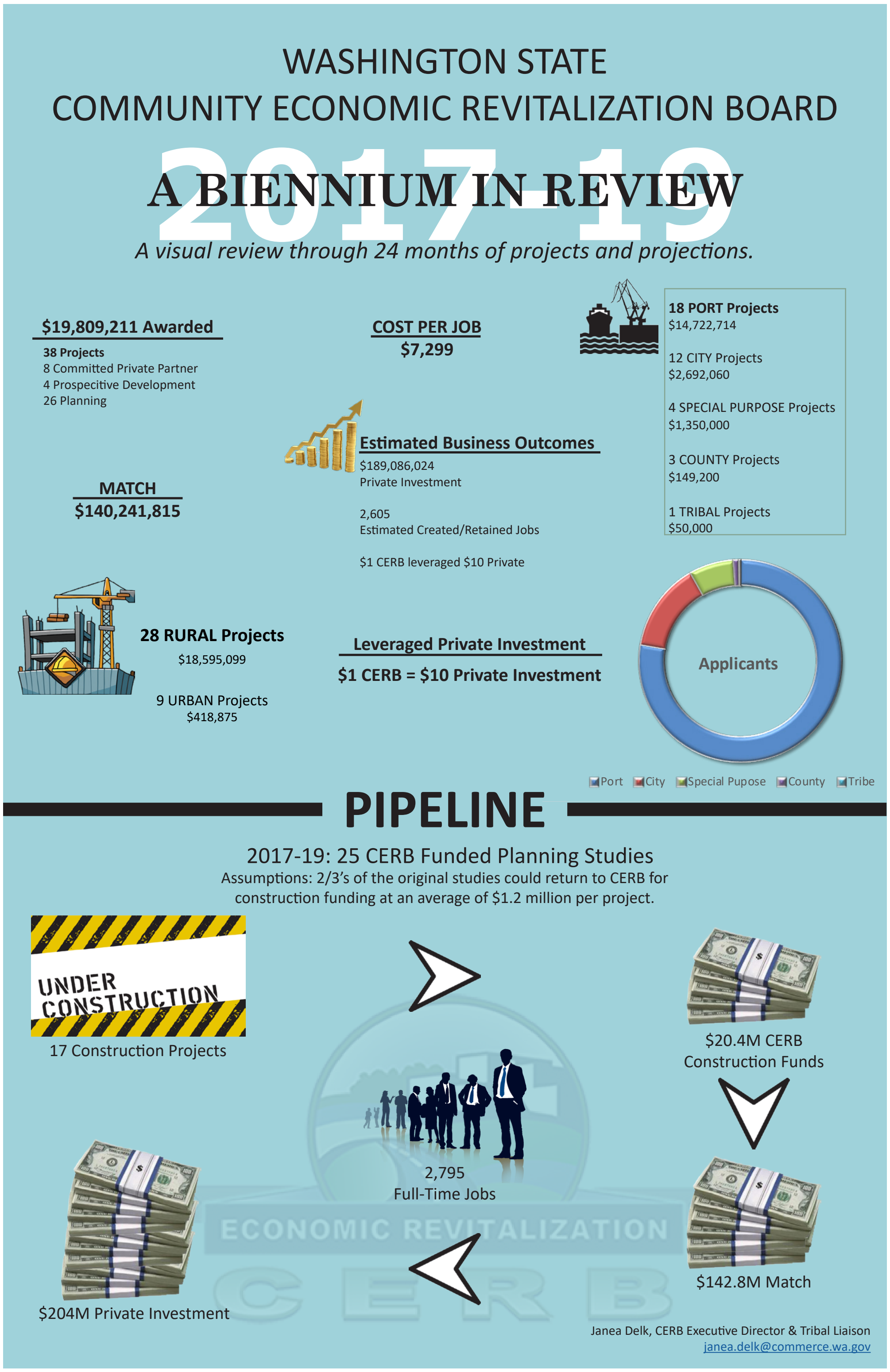
Public agencies support regional firms and the development of the labor force through funding capital investments and infrastructure or identifying and allocating resources for public use. State funding programs making investments in the aerospace industry and regional transportation networks include those under the Department of Transportation, the Department of Commerce, the Washington Freight Mobility Strategic Investment Board, and the Department of Revenue. Regional planning organizations and economic development agencies provide additional funding for business and infrastructure investments. Similar to industry firms, state and local economic development agencies provide funding for start-up enterprises and research through business incubators, research grant programs and investment funds. The Community Economic Revitalization Board, managed by the Department of Commerce, provides loan and grant funding for businesses and infrastructure projects discernibly requiring public financial assistance due to a lack of private sector investment.[125] **Figure 3.2.1** illustrates the impact of their investment activities throughout Washington state between 2017 and 2019. Such investments enable firms to find investment in rural areas or maintain continuity of operations, stabilizing the regional economy during market shocks or similar macroeconomic events.

In addition to funding business and infrastructure investments, the state government supports the regional aerospace industry by providing public educational resources, including community/technical colleges, jobs training, operations facilities, and Centers of Excellence. Technical colleges serve as invaluable conduits for workforce development programs by providing inexpensive education and job skills training to students with pathways into the aerospace industry or other manufacturing sector. As described previously, the flexibility to pursue a certificate, two-year degree or four-year degree through the state's higher education system enables students to find a pathway suitable for their goals, while knowing the skills and knowledge they acquire will be valued in the workplace. In addition to educational facilities, the state and local governments own assets, such as public-use airports and governmental facilities, to facilitate training programs with on-site business operations. Social services provide additional benefits for individuals looking for educational and employment opportunities in the aerospace industry.

The State is also preparing for the introduction of urban air mobility (UAM), which will integrate aviation into cities and towns. A groundbreaking technological change in how people and goods move through the regional transportation network requires an equally profound change in the policies and laws governing the integration of these systems.

125 https://www.commerce.wa.gov/building-infrastructure/community-economic-revitalization-board/

Figure 3.2.1 Washington State Department of Commerce CERB Biennium Review of Project Investments, 2017 to 2019



The Community Air Mobility Initiative (CAMI), based on Bainbridge Island, WA, provides resources and industry expertise to state and local governments on integrating electric aircraft into their existing transportation infrastructure. With the use cases for electric aircraft technologies becoming increasing evident as they evolve, such as electric vertical take-off and landing (eVTOL) vehicles providing taxi services, emergency medical services, and freight transportation connecting urban, suburban, and rural areas, a clearly defined governance framework provides benefits for producers, operators, and users. As these technologies are expected to become a part of our regional transportation system within the next five to ten years, the resources and expertise provided by CAMI help outline how to leverage the opportunities of these technologies in a responsible way. CAMI will be an important source of input into workforce development programs to support these new technologies.

Section 3: COVID-19 Impacts

The disruption caused to businesses, government services, and education services by the COVID-19 pandemic undoubtedly will result in long-lasting impacts to the regional economy. The recession and the restrictions on travel have been especially impactful to the aerospace industry due to the decline in demand for commercial aircraft and commercial flight services, resulting in shocks through the supply chain. Suppliers throughout the region have been temporarily closing and placing their staff on furlough. During this time, placements with firms have been delayed, training programs suspended, and on-site educational programs disrupted. With educational programs adapting to the conditions by shifting from on-site classes to virtual lessons, the greater accessibility to resources has increased their reach to a greater student population. While the long-term impacts of the restrictions implemented as a measure against the COIVD-19 pandemic cannot be determined at the moment, workforce development programs have the opportunity to adapt to the conditions by improving access to their valuable resources.

Section 4: Recommendations

Considering the structures of the regional aerospace industry and the relationships between firms, educational institutions, industry associations, and governmental agencies, a number of recommendations can be provided to enhance the workforce development programs to the benefit of the electric aircraft sector. The recommendations address actions to be taken by industry stakeholders to leverage existing capabilities and make novel investments with the goal of bringing the electric aircraft sector to technological maturity and facilitate commercial production. The actions involve identifying funding opportunities, developing job training programs, cultivating partnerships, expanding educational resources, and initiating policy changes.

The state of Washington has a robust aerospace workforce development infrastructure. Enhancing the various programs to include training to ensure skilled labor is available is essential to support the unique requirements of the electric aircraft industry. This may include the following actions:

Program Development

- Expand the capacity of apprenticeship programs and jobs skills training programs to narrow the gap between the demand for qualified labor by industry firms and the number of program graduates
- Expand course content on the tools and technologies related to the manufacture of electronics, semiconductors and electric power systems and the emergence of Industry 4.0 tools and technologies
- Develop a program of continuing education opportunities for new and journeyman staff in the aerospace industry to facilitate upskilling and continuous development as the industry continues to develop and incorporate new tools, processes and technologies into the workplace
- Identify the challenges of operating electric aircraft as a means of personal transportation and freight transportation to reduce the exposure of financial and market risk to operators and standardize operational regulations

Building Partnerships with Private Sector Entities

- Expand the institutional support for apprenticeship programs and increase the number of placements with small and medium-sized firms supporting the manufacture of components for electric aircraft
- Provide support for a position on the advisory board of the Center of Excellence representing the disciplines supporting the electric aircraft sector, including electric power systems, advanced electronics and advanced materials manufacturing
- Develop an incubator purposed to identify funding sources for research and business investment supporting the electric aircraft sector
- Develop an international marketing function between industry associations and economic development agencies to increase the market exposure of specialty producers in Washington state to the global aerospace market, especially Canada and Europe
- Develop a specialty discipline for electric aircraft within the General Aviation Manufacturers Association or similar industry association to facilitate research collaborations, business investments, governance, and economic development opportunities

Education and Research

- Define and standardize the technical terminology for the production and operation of electric aircraft
- Provide live demonstrations of the capabilities of electric aircraft to increase stakeholder education and engagement (e.g., Pipistrel Alpha trainer)
- Develop comparisons in vehicle performance and the procurement and operation costs between electric aircraft and their conventional equivalent

- Provide additional information on the sustainability of the disposal and reuse of electric vehicle batteries
- Investigate whether hydrogen fuel cells could be safely deployed as an alternative energy source
- Research the opportunities and limitations of developing and deploying hybrid fuel-electric power systems in aircraft

Policy Changes

- Research and develop policies enabling the deployment of electric aircraft at the local level as an urban mobility solution
- Determine the compatibility of the operation of electric aircraft with laws governing the conditions of land use
- Identify and integrate the infrastructure systems necessary to operate electric aircraft in the urban environment
- Investigate and identify the framework to govern the qualifications of crew operating electric aircraft
- Develop incentive programs targeted at industry firms to facilitate continuous learning related to electric aircraft systems for current employees
- Investigate the opportunities for electric aircraft to facilitate the movement of freight throughout the region and identify their strategic contribution to the regional freight transportation system

Funding Opportunities

- Leverage loan and grant funding programs administered by state government agencies providing public funds for business investments and infrastructure projects related to freight transportation, airport operations and electric vehicles
- Leverage federal grant programs administered by the Federal Aviation Administration and the U.S. Department of Transportation to fund regional infrastructure projects promoting economic vitality and freight transportation
- Identify private sector funding sources to establish an investment fund for infrastructure projects supporting the electric aircraft sector and the regional aerospace economy

Airport Recommendations

Airports can support workforce development for electric aircraft in several ways:

- Educate tenants, stakeholders, and the public about the opportunities electric aircraft will bring for increased aviation demand and new aviation-related jobs
- Encourage flight schools to integrate electric aircraft into their training and certification
- Support connections with local industries for apprenticeships
- Provide space and equipment for training
- Ensure facilities required for electric aircraft are available

Chapter 4:

Infrastructure and Battery Charging

Introduction

This assessment seeks to help inform airport planners and decision makers about the potential short and longer-term impact beyond 2030. As electric aviation becomes more prevalent, with British Airways committing to carbon-neutral operations by 2050, Qantas being certified carbon neutral since 2007, and Delta Airlines investing in carbon offsets, airlines may increasingly feel the mix of carrot and stick to shift fleet mix toward electric propulsion. Electric aircraft technology has the potential to reduce operational cost which could be passed onto the end users. This coupled with restoration and expansion of commercial service could result in growth regional and commuter aviation. Proactive airport leaders have an opportunity to weigh this potential long-term increase in passenger throughput in their long-term master-planning efforts, particularly when considering how to upgrade their facilities for greater electrical needs.

The increased electric infrastructure needs of electric aircraft will also need to be balanced with other new landside electric demands including transportation and heating and cooling (HVAC). At the same time, energy efficiency measures are also freeing up capacity for these new uses.

Since the most significant impacts will occur on the airside, this assessment focuses largely on this region of the airport, with emphasis on charging infrastructure, before highlighting affected areas of the landside and terminal. Facilities such as passenger security screening, airport retail, and landside transportation have limited impact from electric aircraft, unless an airport is adopting service for the first time or is reviving service after a period of significant reductions in service; otherwise, the scale of demand will not have a notable influence on the above mentioned considerations. **Table 4.i.1** provides a snapshot of potential adjustments, based on electric aircraft operational impacts on airport facilities and infrastructure.

In addition to the physical, operational, and infrastructure impacts of electric aviation on these three airport segments, the financial impacts that airport planners should consider including are cost of integration, source of federal funding, and economic impacts on regional GDP. Finally, this paper will discuss potential environmental impacts of electric aviation on airport operations as well as exploring potential implications for airport compliance with federal regulations.

Table 4.i.1

↑ Upward adjustment — No material adjustment ↓ Downward adjustment

	Component	Electric aircraft impacts on airport operations	Electric aircraft impacts on airport facilities
Land-side	Parking Garage	↑ Airports may expect increased passenger traffic and, as a result revenue from passenger parking. • This would result from lower ticket prices that may be enabled by the integration of electric aircraft.	↑ Higher passenger flow will require airports to increase the amount of onsite parking. ↑ Airports may decide to increase electric car charging capacity as a result of excess power capacity added to support electric aircraft. ↓ Conversely, the added load of electric aircraft charging may lead airports to remove existing electric car charging equipment to address power shortages.
Land-side	Baggage	↓ Airlines may place more stringent limitations on the per passenger baggage allowance or baggage weight limits to maximize the number of available passenger seats on aircraft with limited capacity. ↑ Airlines may increase the baggage checking fees to offset any lost revenue from a reduction in passenger load.	— Regardless of baggage limitations placed by flight service providers, airport baggage handling equipment and facilities will be capable of accommodating and no significant changes will emerge.
Land-side	Retail Outlets	↑ Increased passenger flow, resulting from more affordable flight options, will increase airport foot traffic and will likely lead to an increase in revenue from retail outlets. • A more detailed study should explore the potential mix of business vs. personal travelers	— While increased passenger foot traffic may lead to high utilization of existing retail outlet space, there will likely be no need to alter the space requirements for retail outlets.
Land-side	Passenger Management	— Electric aircraft will likely have little impact on passenger management operations at airports as vehicle designers target smooth integration with existing operations. • Electric aircraft are expected to have similar passenger capacities as conventional aircraft in each use case.	— Facility requirements will be determined by airports on an individual basis, reflecting the mix of operations hosted. However, electric aircraft will largely be capable of leveraging existing gate facilities. • Most air taxi and commute air vehicles will operate out of non-jet way gates utilizing mobile stairs. • Larger regional airliner vehicles may leverage both mobile stairs or jet-ways depending on airport capabilities.
Air-side	Aircraft Charging	↓ Electric aircraft charging requirements and limitations in charger technology may initially lead to longer aircraft turnaround times, potentially slowing operations. • Flight service providers may leverage battery swap over direct charging to decrease turnaround time. ↑ Charging services may present airports with new revenue opportunities through electricity markup and equipment fees. Charging may be a combination of electricity, hydrogen loading, diesel, etc. For hydrogen or electricity, there can be storage methods onsite.	↑ To host electric aircraft operations airports will need to install battery charging equipment and facilities. • The extent of investment required will be determined by expected traffic levels and if flight service providers will invest in private charging capabilities. ↑ Battery swap approaches will require investment in remote charging facilities by airports, flight service providers, or third-party entities.
Air-side	Electrical Grid	↑ Electric aircraft operations are expected to place significantly increased demand on airport electrical grids. • Airports unwilling or unable to expand their electrical capacity may turn to careful management of power usage and place limits on charging. • Large load demands may push airports to go directly to transmission lines.	↑ Airports planning for high levels of electric aircraft traffic may expand their electrical capacity through on-site generation or partnership with local providers. ↑ In addition to generation, airports may require investment in upgraded power distribution infrastructure to safely enable high power charging.
Air-side	Aircraft Fueling	↓ Implementation and proliferation of electric aircraft will serve to reduce the aviation fuel needs of both flight service providers and private aircraft owners, leading to a decrease in fueling revenue for airports. • As electric aircraft create a new market segment in aviation, fueling will remain constant, but as more aviation applications make the switch to electric propulsion fueling will be reduced.	— As conventionally powered aviation is expected to remain dominant during the 2025-30 period, airports will continue to require fueling facilities.
Air-side	Runway	— Assuming excess runway capacity exists at locations to be utilized, introduction of electric aircraft will have no impact on airport runway operations as aircraft under development for the examined use cases are exclusively conventional takeoff and landing designs.	↑ As electric aircraft operations spread, small rural airports may seek to host larger commuter or regional airliner operations. This may require runway or taxi-way expansions to support larger aircraft operations — This is unlikely in the timeframe examined, as the market is expected to support more aviation operations and concentrated at hub airports
Air-side	Airspace	— Electric aircraft will likely have no impact on airspace operations as they will be required to comply with the same operational standards and procedures as conventionally power aircraft. • With the economics of smaller aircraft, more frequent take offs and landings could develop in existing markets, at potentially a lower noise threshold, dependent on aircraft technology. • Longer duration, lower sustained noise.	↑ Similarly to runway facilities, small rural airports may seek to host commuter or regional airlines operations, requiring expansion of airport air traffic control facilities to manage larger aircraft and more traffic. — However, in the timeframe examined, the large electric aircraft market is expected to remain small and operations are likely to be focused at high-trafficked hubs where existing facilities will suit.

Section 1: Considerations for Charging Infrastructure for Electric Aircraft

As vehicle electrification continues to expand from light duty to heavy duty vehicles, it is also expanding to aircraft. This emerging industry is a new frontier in electric mobility and with it comes considerations for the technology and how it is deployed. While the details on how airplanes are to be electrified, the charging standards required, the support of grid infrastructure needed, and how it affects operations is different than traditional ground vehicles, many of the same barriers that light, medium, and heavy duty vehicles faced are similar to what aircraft will face. This is especially true when it comes to charging infrastructure. This section will discuss the state of this young industry and the various technologies being deployed to ensure that electric aircraft are "fueled" properly.

The first step towards understanding the charging infrastructure required for charging aircraft requires examination of ways in which an electric aircraft will charge its battery. There are three general approaches to this, much as it is in the electric vehicle (EV) industry: battery swapping technologies, existing open charging standards (such as the the CharIN standard[126]), and proprietary charging standards.

It is important for the electric aircraft industry to learn from the experiences of EVs with respect to the issues surrounding charging types and standardization. One of the critical paths to adoption is knowing that wherever you travel to (be it a town or airport), infrastructure is in place to charge your vehicle once you are there. A successful example of this is Tesla's supercharger network, where the company deployed a massive set of DC Fast charging stations that can top off a 300-mile range car in less than 1 hour throughout the nation's highway network. Other car manufacturers relied on third parties (such as Chargepoint and EVGo) to build out that infrastructure and were much less successful in deployment. Light duty EV manufacturers have not standardized charging standards, which means that car brands have a difficulty using other types of connectors. The CHAdeMO fast charging standard (used mostly by Japanese manufacturers such as Nissan) and the CCS1 combo fast charging standard (used mostly by European and US auto manufacturers) were not initially compatible with each other or with Tesla's proprietary standard. Tesla now has adapters for these, and conversely there are CCS1 to CHAdeMO adapters, but this need for adaptation for different standards has been a barrier to adoption.

For light duty non-fleet vehicles, charger compatibility issues are now mostly surmountable. People just had to know where to find chargers. As technology has progressed, and entire fleets are being electrified (including the wide-spread adoption

126 The CharIN standard is for high power commercial charging, aiming for >1MW charging speeds. It is backwards compatible with CCS plugs, which are commonly in use for battery electric bus charging.

of electric heavy-duty vehicles), various ways of charging became a sticking point for adoption. Fleet operators are worried about buying the wrong charger or the wrong vehicle and that if they buy a certain charger for a certain situation, if they buy a new vehicle, will the very expensive charger they bought still work on the new vehicle?

Technology standardization is likely to become a barrier for scalable adoption for electric aircraft deployments as well, especially since different aircraft have different needs, and those needs are often different from ground vehicles.

Section 2: Current Technologies Being Deployed

While keeping standardization in mind is extremely important, for a burgeoning industry it is important to take various use-cases into consideration and not rely on one method or technology to fit every use-case.

Battery swapping solutions

One technology solution that is currently getting more traction in the e-aircraft industry is battery swapping. This means that the aircraft is designed in such a way that the battery is easily removed from the plane when it is on the ground and rather than charging the battery on the tarmac or at a dock, a new, fully charged battery is swapped into the aircraft and the depleted battery is then taken to a charging area where it can recharge. This option currently does not have the full support of FAA, but this may be re-examined if manufacturers continue to support it.

There are several possible benefits to battery swapping:

1. **The turn-around time on an airplane can be greatly reduced.** Often, commercial planes are on the ground for approximately half an hour before their next flight.[127] This is too small of a window for current charging and battery technology standards to adequately recharge a battery for a next flight. However, with a battery swap, you could install a fully charged battery into the aircraft in about 15 minutes. The charging industry is continuing to advance faster charging standards, such as CharIN, in an effort to compete with battery swapping, but this is not available today.
2. **Demand on the grid is lower.** Even if the total energy, measured in kilowatt-hours (kWh), are the same, being able to charge a battery at a slower rate, measured in kilowatts (kW), helps prevent stress on the grid. To charge at a higher kilowatt (kW) rate, infrastructure may need to be upgraded to provide that burst of power to the site. Higher charge rates can also lead to demand charges that hurt the economic feasibility of electric vehicles since the "fueling" cost can become inflated. Battery swapping allows for a much lower kW usage but requires that the batteries be charged somewhere on the site and which could take a day to charge. As long as the operator has a fresh bank of batteries available for the next day's flights, additional electrical infrastructure upgrades may not be needed, or at least the needs could be greatly reduced.

127 Information from interview with SeaTac conducted by WSP on April 30, 2020.

3. **Better solution for small seaplanes.** We heard from industry partners that electrical upgrades to provide high power DC to an aquatic plane can be costly to upgrade and existing "shore power" technologies don't provide high enough power to fully charge a plane between flights. While in the water, it can be difficult to access battery compartments to do a battery swap on these aircraft. However, the "Beaver" type seaplane can be electrically lifted out of the water to a position to do a battery swap.[128]

However, there are also possible negatives to battery swapping:

1. **Increased/different maintenance needs.** All charging systems will require maintenance, regardless of if they are a battery swap setup or stand-alone fast chargers. However, battery swapping adds a mechanical component beyond traditional plug-in charger methods. Any time you add in mechanical components, it increases the probability of a point of failure. Battery swapping is especially prone to this, especially if each aircraft has multiple battery swaps per day. In addition to possible harm to the batteries from frequent swaps, there's the possibility of damaging the aircraft or battery during a battery swap as well. It would also increase the amount of times the lifts are used for small seaplanes every day, which could increase lift maintenance requirements as well
2. **Infrastructure differences.** Battery swapping may potentially require more space or more overall energy, even if the peak kW needed isn't as high. Instead of charging one or two batteries at a time at a high rate, the facility needs to have the space and power to slowly charge multiple batteries over the course of a night to make sure that there is enough battery capacity the next day for operations. While this does shift demand from on-peak hours to off-peak hours, it presents a set of operational challenges. In addition, airports that the aircraft may fly to would also need the same battery swapping technologies, and that can be trickier as far as who owns the actual batteries, whereas with fast charging, there's no change in ownership.

CCS1 Combo Charging Standard

The CCS1 Combo Charging standard is what most U.S. light and heavy-duty vehicles are gravitating towards. It is a robust standard that has capability to get up to a 400 kW charging rate[129]. Even 1,000 kW+ charging standards discussed by organizations such as CharIN are working on making sure that they are backwards compatible with the CCS standards to support future-proofing fleets. This means that even with a new charger, you could still charge an old vehicle using a previous CCS standard, or you could use an old CCS charger to charge a newer standard vehicle, just not at the vehicle's maximum charge rate potential.

Since the CCS combo has already been deployed widely on ground vehicles, the research and development has already been done and the troubleshooting already completed.

128 Information from interview with Kenmore Air conducted by WSP on May 19, 2020.

129 SAE Electric Vehicle and Plug in Hybrid Electric Vehicle Conductive Charge Coupler". SAE International. 2017-10-13.

The one caveat to this is that the charging mechanisms that reside on the aircraft will likely have to go through FAA certification, but this is true for any charging method, be it proprietary, battery swapping, an existing charging standard, or an all-new one.[130] Some industry partners do not believe that the CCS1 standard will meet their needs due to battery size and mission characteristics. These partners are looking to CharIN or new proprietary standards to meet their needs.

New or Proprietary Charging Standards

Many aircraft manufacturers have begun using proprietary charging connectors for early prototypes. This is beneficial as it allows the manufacturer to manage the design requirements and charging needs of the specific aircraft rather than cater the aircraft to a specific standard. However, when deployed to scale, if each manufacturer requires its own High Voltage DC Charger, it could add substantial requirements to how the grid is built and how operations function at the airport. Part of this is due to utility and code requirements that require switchgear and electrical service to be sized for maximum power draw capacity, even if not all chargers are used at the same time.

Another heavy duty charging standard that is currently restricted to use by buses is Society of Automotive Engineers (SAE) J3105.[131] This standard uses a hands free automated coupler to attach to the top of the bus. This can achieve charge speeds up to 600kW today and will increase in the future. No current electric aircraft manufacturers are using this specifically, but it may act as a template for some manufacturers.

It is recommended that aircraft manufacturers work towards a unified standard, regardless of if it is a new, electric aircraft specific standard, or an existing standard such as CCS combo standard.

130 Information from interview with Zunum Aero conducted by WSP on May 5, 2020

131 https://www.greencarcongress.com/2020/01/20200124-sae.html

Conclusions

Charging Method	Pros	Cons
Battery Swapping	• Currently faster layover times meet a better operational case for aircraft • Peak power needed could be lower • Possibly more effective for seaplanes	• Increased Maintenance Risks • Possible damage to aircraft during swapping • Infrastructure may require more space • Legal questions on battery ownership when swapping batteries at different airports • Currently lacks FAA support
CCS/Standardized Charging	• Known standard already vetted with ground EVs • Equipment more readily available and cost effective • Backwards compatible with future technologies	• Limited by standards to <400kW charging speed • High power charging may have tougher impact on the grid • Dependent on acceptance of this standard by manufacturers and use case
Proprietary Charging Standard	• Customized per aircraft to suit specific needs • Could be faster to market or allow for different charging profiles with specific battery technologies	• Not standardized so different aircraft may not use the same charger • May cause operational issues as the industry adapts to multiple proprietary methods

Section 3: Pilot Program Infrastructure Needs

The next steps toward successful electric aircraft deployments will be pilot programs. A pilot program will involve determining the electrical needs of a site and if that site can support infrastructure. Unfortunately, without specific details of what that pilot program would look like, it is impossible to provide a specific peak kW value or the surrounding infrastructure required to support such a project. However, WSP has created a flowchart of requirements to determine what those infrastructure needs are and applied a high-level example to show how infrastructure needs can be determined.

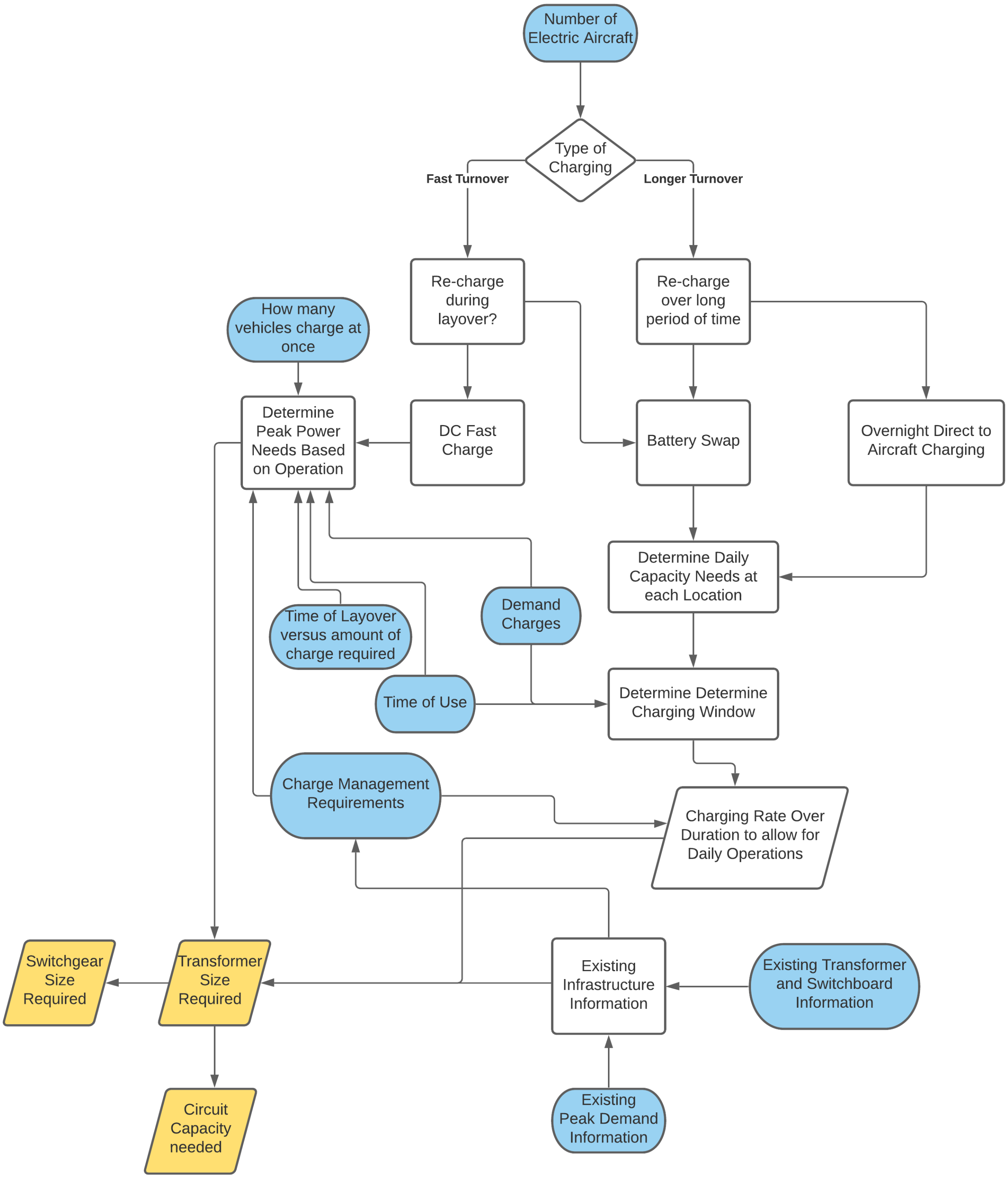
Inputs/Considerations to flowchart to determine needs:

- Number of vehicles to be electrified
- Operational needs/considerations
    - Layover time
    - Site layout
    - Charging style (battery swap, slow charge, fast charge)
    - Charging management (most critical for fast charge)
        - Peak shaving
        - Time of Use Rates
        - Demand charges
- Existing conditions
    - Existing service
        - Distribution line capacity
        - Transformer size
        - Switchboard size
        - Existing peak electric usage without pilot (from utility bills)

Results from flowchart:

- Peak kW required
- Infrastructure needs
    - Transformers
    - Switchgear
    - Number of chargers/dispensers

Figure 4.3.1 Flowchart of Infrastructure Needs Decision Matrix



Section 4: Hypothetical Scenario

Based on **Figure 4.3.1**, one can determine infrastructure needs on a possible pilot project. As an exercise, there shall be an assumed pilot of eight electric aircraft at an airport.

Assumptions:

- Eight Aircraft
- DC Fast Charge with 250 kW CCS chargers
- 200 kWh batteries
- One-hour layover
- Existing Transformer insufficient, will need new transformer/switchgear on its own metered service
- No Demand Charges or Time of Use Rates
- Four aircraft need to charge at once, maximum

Results from following the flow chart:

- Based on charger speed (250 kW) and battery size, (200 kWh), one hour of charging meets operational needs of the vehicles
- If four aircraft need to charge at once, this would produce a peak output of 1,000 kW or 1 MW of peak demand at this facility
- A new service would be required, this would likely be a 1,500 kVA transformer and associated low voltage switchgear to support four chargers.
- A new drop from a distribution line would be required to connect to this transformer, it could either be Utility owned (secondary service to the airport) or be airport owned (primary service to the airport)
- Utility coordination to ensure that 1MW peak power can be provided will be required
- Charge management could be used to add more chargers but still limit peak demand to 1MW.

Section 5: Next Steps for Infrastructure Electrification

There are three steps that need to be addressed first in order to advance the electric infrastructure front for e- aircraft:

- FAA/Regulatory involvement
- Standardization of charging technologies
- Early Department of Energy and utility engagement to help advance the technology

The FAA represents a critical path to both standardize and implement aircraft technologies. If the FAA considers technology a flight risk, such as a certain charger rate or battery swapping making an aircraft no longer air-worthy, this may narrow what solutions could be used. As far as safety is concerned, the FAA is already working with manufacturers to ensure the aircraft meet certification standards, so further regulatory oversight by WSDOT is not required at this time. The only additional regulatory needs may be incentive-based regulations to aid the electric aircraft industry and utilities that are looking to support its growth. Regulatory requirements may also be needed to address fuel tax parity with Jet A/AvGas and/or incentives to convert and recover revenues for the state. Additional legislation may be required to evaluate aeronautical/non-aeronautical uses to make charging infrastructure have a positive ROI for private vendors and potentially avoid state or Federal funding requirements.

The different charging methods are good for pilot cases and fleshing out the technologies, but eventually there needs to be scalable solutions for charging technologies that should focus around one or two standards.

Early utility engagement is very critical towards helping adoption of these projects with increased infrastructure needs. Utilities can help in many ways. First, if there is a large infrastructure upgrade required, the utility needs time and resources to help coordinate and build that infrastructure. This can take many years to orchestrate the planning, engineering, and construction required. Secondly, utilities can help with outreach and education. Many utilities, such as Avista[132] in Spokane WA, have helped sponsor “ride and drive” events to promote light duty electric vehicles and could do the same for new electric aircraft. Thirdly, utility rates and rate cases can be very critical to ensure that adoption of new technologies are still financially viable, and this takes time to get approved. Doing things like deferring demand charges, developing EV specific rate-cases, or “charge ready” infrastructure plans are all ways that early utility engagement can dramatically improve adoption of new technologies. Avista has even expressed interest in helping with pilot projects for some of these early engagement techniques. These activities usually need permission from the state regulator (Washington Utilities & Transportation Commission) to perform.

Utilities cannot perform all of the tasks needed to modernize the grid and understand cutting edge new technologies. The US Department of Energy labs, especially PNNL and NREL, have been very involved with grid modernization initiatives.[133] In addition, the University of Washington hosts the “Clean Energy Testbeds”, which helps accelerate the development, scale up, and adoption of new technologies.[134]

132 Information from interview with Avista conducted by WSP on May 22, 2020

133 https://www.energy.gov/grid-modernization-initiative

134 https://www.wcet.washington.edu/

Chapter 5:
Demand and Deployment

Section 1: Electric Aircraft Demand Assessment

The future of electric aircraft in Washington will be equally influenced by a set of factors affecting supply and a different set of factors influencing demand. The Electric Aircraft Development component of the Electric Aircraft Feasibility Study (or Feasibility Study) presented an overview of the current state of electric aircraft technologies. Primarily obtained from the stakeholder interviews conducted at the inception of the study (April 2020), this information represents the most current information publicly available about the industry's "supply" of electric aircraft. This section of the study looks at the other side of the equation: the characteristics of future markets that may influence demand for electric aircraft in the coming decades.

Because supply and demand are two sides of the same coin—comprising the very definition of a marketplace—any discussion about future demands for electric aircraft must be couched in uncertainty and scenario-based assumptions. As discussed more explicitly in the Transportation Network Assessment, electric may have the potential to generate an expansion of regional air transportation to a level where it represents a new mode of transportation. While transportation planners would study detailed historic trends and known behavior models characterizing traveler modal choices, such an assessment is neither possible nor feasible. Timeframe, cost, and performance are uncertain variables when it comes to the future of electric aircraft. If electric aircraft do drastically change the aviation environment—as many advocates believe they will—electric aircraft entry into the marketplace perhaps is most akin to the transition from horse to automobile, or when passengers first boarded slow-moving, steam-powered locomotives in the 19th century. This is true of Urban Air Mobility (UAM) applications, which will be pointedly different in terms of size, performance, and use than the commercial jets that most air travelers are familiar with. In time, electric aircraft technologies could result in new airspace "highways" and be relied upon to autonomously deliver all manners of consumer and manufacturing goods. Once electric aircraft using vertical take-off and landing capabilities (eVTOL) enter the market, the very nature of the airport's role in the transportation network could transform. It may no longer be the primary access point to the sky.

With such caveats stated, transportation planners, including WSDOT Aeronautics staff, metropolitan planning organizations, and local officials; airport managers; and other decision-makers must begin to consider electric aircraft in long-term planning efforts. This includes local, regional, and statewide transportation and comprehensive plans as well as modal-specific strategic and needs-based plans. Electric aircraft could change traveler demands associated with the state's road and rail networks, ferry system, public transit options, and other modes. At the airport level, managers should prepare long-term capital plans to potentially include airside and landside development needs in support of electric aircraft. An increase in aviation activities may also result in additional aviation economic impacts in Washington, particularly to the extent that electric aircraft enhance connectivity with markets outside of Washington. Additionally, the technology may disrupt existing industries such as trucking and existing on-airport revenue sources (i.e., fuel flowage fees). For these reasons, decision-makers, planners, and other stakeholders should have a general understanding of how aviation demands may change over the next 10 to 20 years and the impacts, assuming electric aircraft are deployed as anticipated.

As such, this section of the Electric Aircraft Feasibility Study presents three demand scenarios for the future of electric aircraft. Each scenario represents a unique future for electric aircraft in terms of date of commercial deployment, market acceptance, and projected future activity levels. The study considers how electric aircraft could replace demand for other modes of travel—which may result in the most significant new aviation demand. This latter point is notable because the scenarios focus on new demand for air travel associated with electric aircraft. Demand increases when new pilots, passengers, and businesses increase air travel/transport because of the benefits of electric aircraft. Replacing a conventional aircraft with an electric aircraft would change the overall fleet composition but not inherently impact demand.

As further discussed in the Executive Summary and Introduction, this study assumes that electric aircraft may increase existing activity levels. To create a "baseline" scenario, is important to first look at existing aviation activities in the state and other available forecasts of future demand that did not necessarily address changes associated with deployment of electric aircraft. In 2017, WSDOT published the Washington Aviation System Plan (WASP) to comprehensively assess the ability of Washington's 134 public-use airports to meet current and future 20-year demands. While the Federal Aviation Administration (FAA) does publish annual aviation forecasts, the WASP presents the most current state-specific information through 2034. As such, the aviation forecasts included in the WASP are briefly summarized in the section that follows. After presenting the electric aircraft scenario forecasts, the chapter concludes by offering insight into deployment considerations, including a self-assessment framework for airports. This framework provides specific items to help airport managers plan for the incorporation of electric aircraft into their existing traffic operations and based aircraft fleet.

Overview of Historic Demand in Washington

The Washington aviation system is composed of 124 general aviation (GA) and 10 Primary commercial service airports. To provide the context for preparing and evaluating aviation demand forecasts for electric aircraft, it is important to have a general understanding of the projected growth of aviation without additional demand that may be catalyzed by the deployment of this new technology. This level of growth will serve as the baseline for the future demand analysis for electric aircraft. It is important to note that some of this demand may be met with electric aircraft as they replace conventionally fueled aircraft in the Washington fleet.

The 2017 WASP is the most recent state-specific forecast of aviation demand. Forecasts were developed for three components of aviation demand:[135]

- **Enplanements:** A passenger boarding a commercial service flight.
- **Operations:** A take-off or landing conducted by one of three types of aircraft.
    - Air carrier: Airport operations performed by aircraft with seating capacity of more than 60 seats or a maximum payload capacity of more than 18,000 pounds, carrying passengers or cargo for hire or compensation.
    - Air taxi /commuter operations: Airport operations performed by aircraft with seating capacity of 60 seats or less or a maximum payload capacity of 18,000 pounds or less, carrying passengers or cargo for hire or compensation on either a scheduled or charter basis (five or more round trip flights per week on at least one route according to published flight schedules), and/or carries passengers on an on-demand basis or limited scheduled basis.
    - Non-commercial (i.e., GA) aircraft operations: Airport operations performed by a civil aircraft, except air carriers or air taxis/commuters.
- **Based aircraft:** An operational and airworthy aircraft stored at an airport for most of the year.

These same indicators will be carried forward into this analysis. **Table 5.1.1** presents an overview of the statewide demand forecasts developed by the WASP (2014 baseline year). The WASP combined air carrier and air taxi/commuter operations; however, they are dealt with separately in the electric aircraft analysis below.

135 FAA Terminal Area Forecast (TAF) Glossary (2018). Available online at https://taf.faa.gov/Downloads/Glossaryfor2018TAF.pdf (accessed September 2020).

Table 5.1.1 WASP Forecast Summary

Forecast Element	2014	2019	2024	2034	Total Change, 2014 – 2034	Average Annual Growth Rate
Enplanements	21,266,635	25,507,926	29,662,115	38,975,299	83%	3.1%
Air Carrier and Air Taxi/ Commuter Aircraft Operations	594,438	670,398	738,004	879,595	48%	2.0%
Non-commercial Aircraft Operations	2,770,273	2,896,993	3,029,460	3,335,224	20%	0.9%
Based Aircraft	7,209	7,608	8,081	9,010	25%	1.1%

Source: 2017 WASP

Historic Commercial Service Activity

An analysis of historic trends in Washington conducted during the WASP found that:

- Enplanements at Washington's commercial service airports increased at an average annual growth rate greater than the U.S. and the FAA's Northwest Mountain Region between 2004 and 2014.
- Air carrier and air taxi/commuter operations decreased at a slower rate than the U.S. average between 2007 and 2014.

These trends indicated that demand for commercial aviation in Washington was returning more strongly during the post-Recession years in Washington state as compared to the U.S. As shown in **Table 5.1.1**, enplanement and air taxi/commuter operations are projected to increase by 83 and 48 percent (respectively) through 2034. These trends, however, do not necessarily indicate that all airports and markets witnessed equal upticks in activity levels during the study timeframe. Between 2007 and 2014, air carrier and air taxi/commuter operations decreased at a higher rate than the rate of decrease for enplanements during the same time period. This indicates higher aircraft load factors and increased seats per departure, meaning larger aircraft were being filled with more people than in previous years. This same trend continues today as airlines remain committed to "right-sizing" aircraft and focusing on markets with greatest demand—leaving small- and medium-sized communities across the U.S. with limited or no access to scheduled commercial service.

In 2014, commercial service activity was lost at Port Angeles/William R Fairchild International when Kenmore Air ceased providing scheduled flights between the airport and Boeing Field International. Grant County International/Moses Lake Airport lost scheduled commercial service in 2007. Airports located in small markets across the U.S. have lost service since early 2000 for a variety of reasons including airline consolidation, cost per enplanement passenger, volatile fuel costs, and cuts to federal aid to airlines serving these markets. Airlines have continued to tighten flight schedules to only operate the most profitable routes and increase aircraft load factors to maximize profits. A 2019 Government Accountability Office (GAO) Report on the Essential Air Service (EAS) Program also noted that airlines have cut service due to a lack of available aircraft between 19 and 50 seats.[136] Major airlines cited issues with excess capacity when operating an aircraft larger than 50 seats and insufficient capacity when operating aircraft with less than 15 seats.[137] Airports with serving communities with low population levels generated limited levels of aviation demand may also experience quality of service issues. In this case, a carrier reduces the frequency of flights to maintain profitability but in doing so no longer offers passengers convenient, reliable, and/or on-time service. Fewer people choose to use the service, thereby further reducing demand and exacerbating the issue. Recent changes to pilot certification regulations also make it difficult for regional airlines to hire and retain qualified pilots.

In these cases, affected communities lose connectivity and the economic benefits of air service. This includes the economic impacts of tourists and business travelers, as well as lost impacts associated with businesses that locate to another city or town with better access to scheduled commercial air service. Communities face diminished tax revenues, fewer jobs, and—in some cases—the perception that the area is not economically strong for investment. The anticipated advantages of electric aircraft address many of the issues that lead airlines to cut service to small communities. This includes the stable cost of electricity, commercial viability of regional passenger jets in the 19- to 50-seat range, and lower operating costs. Each of these factors could result in carriers providing higher levels of service more cost effectively, leading potentially to higher passenger demands. Higher demand can lead to more frequent flights and a higher overall quality of service, creating an upward spiral composed of demand, flight availability, and service levels. The deployment of electric aircraft by commercial operators offer hope to communities without convenient and reliable access to a hub airport where they can connect to marketplaces around the globe.

Conventional Indicators of Aviation Demand

Indicators of aviation activity including enplanements, operations, and based aircraft are affected by numerous trends both inherent to and separate from the aviation industry itself. Some of these trends affect forecasts of aviation activity regardless of aircraft fuel type. Socioeconomic factors such as population, the Washington Gross State Product

136 GAO-20-75-4 (December 2019). "Commercial Aviation: Effects of Changes to the Essential Air Service Program, and Stakeholders' Views on Benefits, Challenges, and Potential Reforms," p. 25. Available online at https://www.gao.gov/products/GAO-20-74 (accessed September 2020).

137 Ibid. p.26

(GSP), per capita income, and other external factors that affect aviation demands remain constant regardless of aircraft type (i.e., electric versus conventional fuel). How they affect demand may be different (in terms of extent, travel patterns, etc.), but the drivers themselves remain valid. Other demand factors, such as the cost of oil and its volatility which affects overall operating and airline ticket costs, are not applicable to electric aircraft. Some of the key factors used in identifying future aviation demands include the following:

- Population growth
- Employment
- Per capita income
- Distance to major airport
- Economic conditions (national and regional)
- Tourism opportunities at the destination

Other factors influence demand, but are more difficult to measure systematically:

- Alternative modes of transportation, including price, perceived comfort and status (e.g., car versus public bus), and travel time
- Uncertainty / risk (perceived and actual) associated with mode
- Reliability
- Type of airline service provided at the airport (regional/commuter versus major/national)

One of the foundational tasks for identifying future demand for electric aircraft in Washington is to consider how these "conventional" demand factors apply to electric aircraft. As discussed more fully in the "Beta Test Site Evaluation" component of the study, the first set of factors above are powerful indicators of aviation demand. The second set of factors are influential but vary significantly between regions and user groups while being difficult to quantify. This study assumes that the first set of factors apply equally to all aircraft (regardless of type). Electric aircraft are required to pass the same rigorous safety certification processes as their conventional counterparts and are assumed to offer the same level of reliability. These are the "constant" factors, affecting demand for air service equally regardless of aircraft type. There will likely be some variance in terms of how these factors affect demand (e.g., lower ticket costs mean people earning less income will have greater access to air service), but the factor itself is the same.

The remaining variables are alternative modes of transportation and type of service provided. A 2015 study conducted by the Federal Highway Administration (FHWA) showed that people travel by car 91 percent of the time for trips between 100 and 499 miles (see **Table 5.1.2**). This same range is anticipated to be most feasible for electric aircraft within the short- and mid-terms. As such, the greatest additional demand for air service associated with electric aircraft is anticipated to come from travelers who previously would have driven to their destinations but have shifted to aviation due to benefits including reduced travel time, greater comfort and perceived status, and additional productivity time during flight (i.e., working or engaging in a leisure activity).

Table 5.1.2 Airplane and Automobile Mode Share by Number of City Pairs by Distance

Distance (miles)	Aircraft	Automobile	Number of City Pairs
100 – 499	5%	91%	81,000
500 – 999	37%	61%	146,000
1,000 – 1,999	79%	20%	150,000
2,000 – 2,999	97%	2%	56,000
3,000+	97%	3%	7,000

Source: FHWA 2015

A 2019 Airport Cooperative Research Program (ACRP) report entitled, "Air Demand in a Dynamic Competitive Context with the Automobile" took a detailed look at travelers' choices between aircraft and automobile.[138] The study observes that concurrent evolutions in automobile and aircraft technologies will affect traveler behaviors associated with both modes. Accordingly, aircraft and automobile travel should be evaluated in terms of their relationship with one another. Emerging aviation technologies (e.g., electric aircraft) may make flying cheaper and offer the fastest way to move between two points. Advanced cars offer high levels of amenities within the vehicle, the ability to communicate with other vehicles on the road, and will likely become autonomous at some point in the future.[139] The report observes that these dynamics will fundamentally change travelers' mode choice, ultimately concluding that, "the traveler, while holding an underlying preference for air travel, weighs the cost of the trip against the perceived discomfort of, and distaste for, the automobile."[140]

The ACRP report went on to develop five overarching scenarios for the future of long-distance travel and, "specifically, the market contest between aviation and the automobile".[141] Presented in **Table 5.1.3**, these scenarios represent significantly different assumptions regarding the evolution of travel technologies and trends in the years ahead. Scenario 1 envisions a future in which demand for air travel decreases, while scenario 4 projects aggressive growth at hub airport. Neither of these scenarios seems

138 ACRP Research Report 204: "Air Demand in a Dynamic Competitive Context with the Automobile" (2019). Available online at https://doi.org/10.17226/25448 (accessed August 2020).

139 Ibid. p.1

140 Ibid. p.3

141 Ibid. p.9

likely in consideration of current and projected near- and mid-term electric aircraft technologies. Conversely, scenarios 2, 3, and 5 are highly relevant to electric aircraft and their anticipated role in the transportation network. These scenarios provide insight into how demand for aviation may change based on assumptions associated with traveler preference, cost, and level and quality of available air service.

Table 5.1.3 ACRP Report No. 204: Future Travel Scenarios

ACRP Scenario	Description
Scenario 1: Automobile dominates the future	If, somehow, automobile trips become less stressful and somewhat less costly; long, multiday trips become less onerous; and riders could stay connected on automobile trips (as with automated vehicles); then, air demand would decrease by about 16%.
Scenario 2: An optimistic scenario for smaller airports	If the number of flights to non-hub airports increased, the number of direct flights from smaller airports increased, stress at larger airports increased, tickets became cheaper, the stress of driving increased, the relative cost of driving increased, and future generations are somewhat less automobile-oriented, then air demand would increase by about 10%.
Scenario 3: Smaller airports benefit from new cheaper short-distance planes	This scenario is the same as Scenario 2, except only short-distance flights would have lower ticket prices; there would be more short-distance, direct flights; and there would be less stress at smaller airports. In this scenario, air demand would increase by about 14%.
Scenario 4: An aggressive scenario for hub airports	Hub airports lower their parking charges, decrease the amount of stress, and increase the frequency of direct flights. In this scenario, air demand would increase by 14%.
Scenario 5: Air dominates the future	Congestion on the highways means longer travel times for automobile trips. The price of gas goes up. As youth grow older, their concerns about long-distance highway trips remain and preference for private vehicle ownership goes down. The price of air trips goes down and flight frequencies increase. In this scenario, air demand would increase by about 16%.

Source: ACRP Report No. 204 2019

Because of their applicability to electric aircraft within the anticipated future timeframe, this Feasibility Study expounds on scenarios 2, 3, and 5 by translating how those scenarios could affect demand in terms of the three primary indicators of aviation activity (i.e., enplanements, operations, and based aircraft). Scenario 2, for example would not result in a 10 percent increase in all types of aviation activities. Instead, growth would primarily be witnessed in air taxi/commuter operations and enplanements, with enplanements increasing at a faster rate than operations. Air carrier enplanements and operations would follow existing demand patterns. It is assumed that any operations conducted by electric aircraft would replace those conducted by conventional aircraft (as aging aircraft are pulled from the fleet) and would not be associated with any additional demand. The following section presents the three e- aircraft feasibility scenarios, each of which is based on the scenarios developed by ACRP Report No. 204.

Scenario Forecasts

The Electric Aircraft Feasibility Study developed three potential scenarios for future aviation demands. Over time, travelers' comfort with and acceptance of electric aircraft will evolve as safety and reliability are proven. Aircraft ranges will increase as battery capacity improves, allowing passengers and pilots to fly longer distances in larger aircraft. UAM applications may enter the National Airspace System (NAS) to provide a new travel option to move into and within urban areas as well as over rural areas. As such, air travel demands are anticipated to grow at increasing rates over time. Each scenario is presented in terms of the short-, mid, and long-terms as shown in **Table 5.1.4**. Each indicator of aviation activity has a specific compound annual growth rate (CAGR) within each of these timeframes to reflect the evolution and adoption of electric aircraft through 2039.

Table 5.1.4 Electric Aircraft Scenario Timeframes

Term	Year(s)
Baseline	2019
Year 1	2020
Short-term: 2 - 5 years	2021 - 2024
Mid-term: 6 - 12 years	2025 - 2031
Long-term: 13 - 20 years	2032 - 2039

Source: WSDOT Aviation 2020, Kimley-Horn 2020

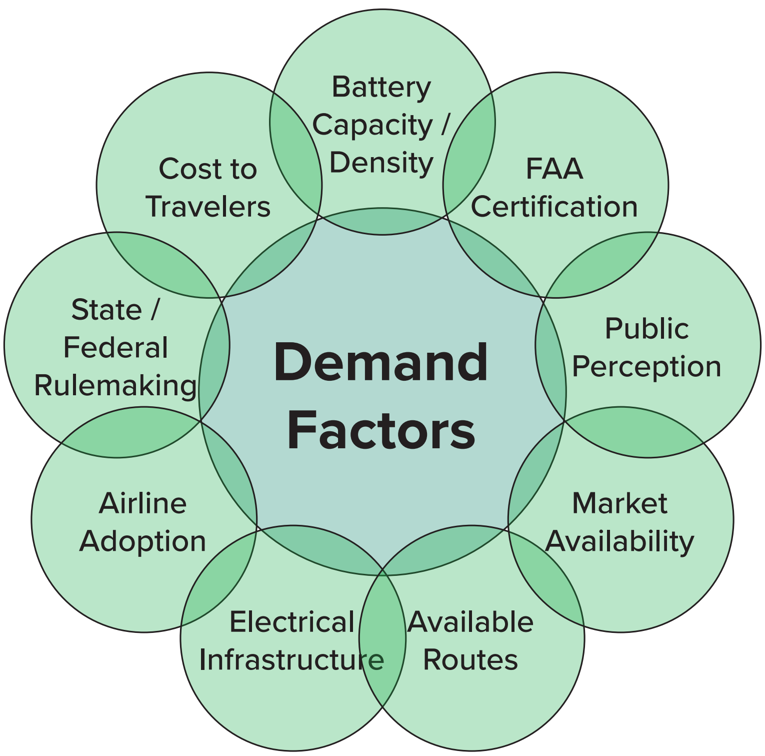
It is important to note that the three electric aircraft scenarios were developed in consideration of the current state of aviation technology at the time of this study. There is still great uncertainty about the future integration of electric aircraft into the NAS, as well as numerous hurdles that will need to be overcome prior to being fully embraced by the market. The International Civil Aviation Organization (IACO) maintains a list of electric and hybrid-electric aircraft on its webpage at https://www.icao.int/environmental-protection/Pages/electric-aircraft.aspx. Updated in July 2020, the table summarizes over 30 different technologies that have recently entered production or are currently under development. Electric and hybrid-electric technologies fall within four aircraft categories as follows: GA/recreational, business and regional, large commercial, and VTOL.[142] The GA/recreational group includes aircraft that are currently certified and in-production. Large commercial aircraft are anticipated to enter service after 2030 through 2050. Business and regional aircraft as well as VTOL projects are targeted for service entry generally between 2020 and 2026.[143] The IACO report demonstrates the fundamental difficulty in associating specific timeframes to forecast scenarios: Some new technologies continue to evolve while others are discontinued from further investigation. As such, it is important understand that the timeframes presented in this Feasibility Study are for illustrative purposes only and unlikely to align precisely with actual deployment and commercialization.

142 https://www.icao.int/environmental-protection/Pages/electric-aircraft.aspx

143 Note the IACO report does not provide target entry dates for all projects.

In addition to technological developments, many other factors will affect electric aircraft's integration into the NAS and overall air transportation marketplace. As highlighted in **Figure 5.1.1**, factors address local, state, and federal regulations; technological advancements; the adoption of electric aircraft by air carriers; infrastructure needs including electric utilities; and the flying public's acceptance of the new technology in terms of cost, perceived safety, and route availability. These factors will evolve in relation to one another, but also follow their own paths on often independent timeframes. As the diagram illustrates, demand associated with electric aircraft will substantially increase at the nexus of these factors. Also note that this "nexus" will be use-case dependent. For example, routes to support air cargo operations may be quite different than passenger service, and passenger perception does not apply to air cargo. The type of aircraft necessary to support pilot training and commercial passenger service are substantially different, as are the applicable federal regulations associated with each.

Figure 5.1.1 Key Electric Aircraft Market Integration Factors



Sources: Kimley-Horn 2020, WSDOT Aviation 2020

The aviation industry has also been dramatically affected by the COVID-19 pandemic that arose during the development of this study. Much of the media attention has focused on commercial passenger service, which has been most acutely affected by the virus.

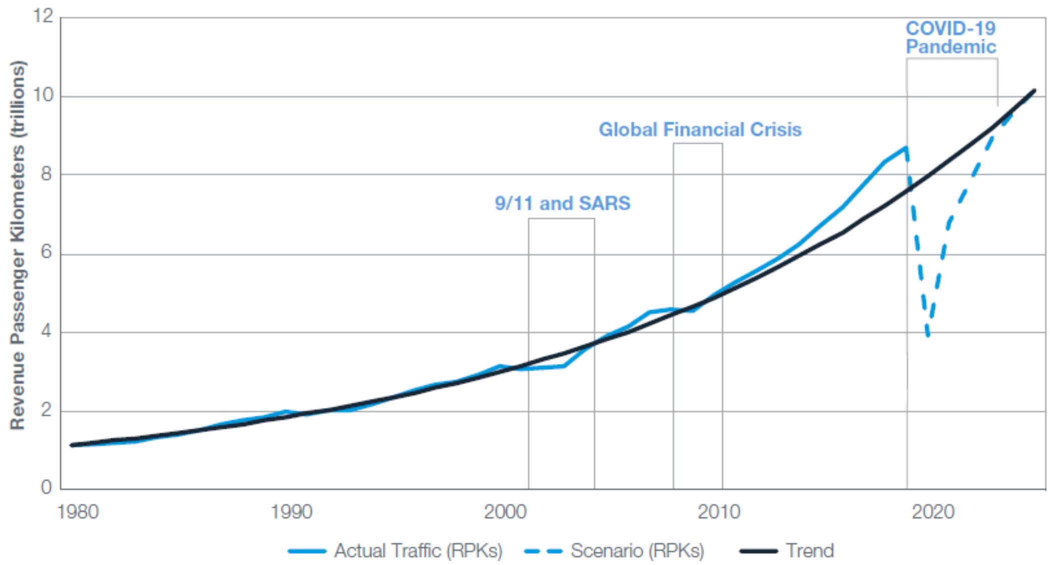
At the time of this writing in November 2020, domestic air travel is up from the lowest points when the virus struck, but the number of travelers is still down by approximately 70 percent below where it was this same time last year. Air cargo is similarly entering a recovery period. Travel consulting firm Accenture reported that global capacity declined 22 percent during the last two weeks of September 2020 compared to the same time last year, improving from a 26 percent decline during the previous month (4 percent growth).[144] GA activity has been affected more varyingly, with some airports reporting an uptick in operations as pilots have more time to fly, employers chose business/corporate aviation in lieu of scheduled commercial service, and fewer alternative recreational activities are available due COVID-related shutdowns. In fact, airports such as Chehalis-Centralia Airports (CLS) have reported record-setting fuel sales that are nearly double sales witnessed in previous years.

While challenges undoubtedly lie ahead, analysts generally expect a three- to five-year recovery period before air travel restores to pre-COVID levels. As the COVID-19 pandemic has severely impacted air travel and demand for passenger service, there are many unknowns regarding how the industry will recovery. However, with similar historical events causing disruptions to air travel, demand has returned at higher rates subsequent to each occurrence. The Boeing Commercial Market Outlook 2020-2039 observes that, "The fundamentals that have driven air travel the past five decades and doubled air traffic over the past 20 years remain intact. While aviation has seen periodic demand shocks since the beginning of the Jet Age, our industry has recovered from these downturns every time throughout its history."[145] This trend is illustrated in **Figure 5.1.2**, which shows the recovery of air travel following other major world events in the early decades of the 21st century.

144 https://www.accenture.com/us-en/insights/travel/coronavirus-air-cargo-capacity

145 Boeing (October 2020). Commercial Market Outlook 2020-2039. Available online at https://www.boeing.com/resources/boeingdotcom/market/assets/downloads/2020_CMO_PDF_Download.pdf (accessed October 2020).

Figure 5.1.2 Long-term Air Travel Growth Trends in Consideration of Major World Events



Sources: ICAO scheduled traffic through 1999 / 2000-2019E IATA stats / 2020F IATA December 2019 as presented by the Boeing Commercial Market Outlook 2020-2039

Demand is anticipated to return in a similar fashion post the pandemic. Hence, projected demands still appear reasonable over the long-term given the 20-year forecast horizon presented. Given the uncertainty associated with the many factors affecting the integration of electric aircraft into the marketplace coupled with the impacts of the COVID pandemic, actual implementation will most likely not follow the exact years presented in **Table 5.1.4**. Realistic and data-driven assumptions regarding the deployment of electric aircraft have been presented to the greatest extent feasible.

Electric Aircraft Scenario 1: Low Growth[146]

Scenario 1 offers an optimistic scenario for smaller airports, with most growth witnessed in air taxi and commuter operations and enplanements. This scenario assumes that commercial air carrier aircraft (60+ seats) have not reached commercial deployment; enplanements and operations will increase at the same rates as projected by the 2017 WASP for all commercial service airports except Sea-Tac. Sea-Tac growth rates are anticipated to follow those presented in the Sea-Tac Sustainable Airport Master Plan (SAMP) (May 2018), where noted. GA activity is anticipated to see moderate growth in the mid- and long-terms as lower cost of flying encourages new adopters. This scenario assumes that UAM have entered commercial markets, resulting in significant growth in air taxi/commuter activities. **Table 5.1.5** presents the projected CAGRs by term for each indicator of aviation activity, with specific assumptions provided below.

146 Electric aircraft scenario 1 is based on ACRP Report No. 204 scenario 2.

Table 5.1.5 Scenario 1 Forecast Overview

Aviation Activity Indicator		Short-term (2-5 years)	Mid-term (6-12 years)	Long-term (13-20 years)
Enplanements	Air carrier	3.10% (WASP) / 2.8% (Sea-Tac)		
	Air taxi/commuter	6.0%	8.0%	10.0%
Operations	Air carrier	2.00% (WASP) / 2.3% (SeaTac)		
	Air taxi/commuter	4.0%	6.0%	8.0%
	GA	0.07% (WASP)	2.0%	4.0
Based aircraft		1.1% (WASP)	2.2%	4.3%

Sources: WSDOT Aviation 2020, WASP 2017, SAMP 2018, Kimley-Horn 2020

Enplanements

- Air carrier enplanements are projected to grow at 3.1 percent CAGR for all commercial service airports (WASP) except Sea-Tac. Air carrier enplanements at Sea-Tac will increase at 2.8 percent CAGR (SAMP).
- Air taxi/commuter enplanements are projected to increase more rapidly over time to reach 10 percent CAGR in the long-term. This includes the implementation of UAM applications at airport and non-airport site (e.g., urban locations and other). This also reflects travelers becoming more accustomed to and comfortable with electric aircraft, improving technologies, and continuously decreasing costs over time.

Operations

- Air carrier operations are projected to increase 2.0 percent CAGR for all commercial service airports (WASP) except Sea-Tac. Air carrier operations are anticipated to align with forecast projects provided in the SAMP (2.3 percent CAGR).
- Air carrier/commuter operations are projected to increase at a slightly slower rate than enplanements since electric aircraft will increase in capacity over time (4.0 percent to 8.0 percent CAGR).
- GA operations remain at the current growth rate presented in WASP (0.7 percent CAGR) in the short-term. This is because the first electric aircraft to come to market are likely to replace existing aircraft, and no new demands will be created. Moderate growth is experienced in the mid- and long-term as lower cost of flying encourages new adopters (2.0 percent and 4.0 percent CAGR, respectively).

Based aircraft

- Based aircraft are anticipated to follow the same model as GA operations by following WASP projections in the short-term (1.1 percent CAGR), with higher rates of growth in mid- and long terms (2.2 percent and 4.3 percent CAGR, respectively). As electric aircraft are deployed for pilot training, pilots who were trained in electric aircraft as students will be more comfortable purchasing these aircraft once they are in the position to buy or rent aircraft for personal and businesses purposes.

Electric Aircraft Scenario 2: Moderate Growth[147]

Scenario 2 envisions a future in which small airports fully leverage the benefits of electric aircraft, including lower ticket prices and quality of service improvements. As air service improves, more travelers are enticed to fly to their destinations instead of drive, thereby further promoting flight frequency and reliability. Airlines add direct flights to a network of airports in small markets to enhance connectivity and the ability to arrive at one's ultimate destination more quickly. This scenario provides for more robust growth at Medium, Small, and Nonhub airports. Large aircraft (60+ seats) enter the market in a limited capacity in the long-term, although continue to primarily service smaller commercial service and large GA facilities. UAM have entered commercial markets, resulting in significant growth in air taxi/commuter activities, with increasing rates of growth over time (including air cargo operations). The GA market adopts electric aircraft more quickly over time. The lower operating expenses of electric aircraft entice more students to learn to fly, creating a new market of aircraft owners in the mid- and long-terms. **Table 5.1.6** presents the projected CAGRs by term for each indicator of aviation activity, with specific assumptions provided below.

Table 5.1.6 Scenario 2 Forecast Overview

Aviation Activity Indicator		Short-term (2-5 years)	Mid-term (6-12 years)	Long-term (13-20 years)
Enplanements	Air carrier	3.10% (WASP) / 2.8% (Sea-Tac)		4.0% / 3.1% (Sea-Tac)
	Air taxi/commuter	8.0%	10.0%	12.0%
Operations	Air carrier	2.00% (WASP) / 2.3% (SeaTac)		2.70% / 2.3% (SeaTac)
	Air taxi/commuter	6.0%	8.0%	10.0%
	GA	1.2%	3.2%	4.0%
Based aircraft		1.7%	3.5%	5.6%

Sources: WSDOT Aviation 2020, SAMP 2018, WASP 2017, Kimley-Horn 2020

Enplanements

- This scenario uses the same assumptions as above for air carrier enplanements for the short- and mid-terms.
- Large commercial aircraft (60+ seats) are projected to enter the market in a limited capacity in the long-term, with most growth witnessed at Medium, Small, and Nonhub airports (4.0 percent CAGR for all airports except Sea-Tac [3.1 percent CAGR]).
- Air taxi/commuter enplanements grow at an increasingly rapid pace as ticket prices fall and airlines add more frequent direct flights to a network of small airports (8.0 percent to 12.0 percent CAGR). Enplanements will grow more rapidly over time as UAM applications become more frequent.

147 Electric aircraft scenario 2 is based on ACRP Report No. 204 scenario 3.

Operations

- Air carrier operations increase at WASP projection rates (2.0 percent CAGR) in the near- and mid-terms, with some increase in operations in the long-term (2.7 percent CAGR). Growth for this activity indicator is less robust than air taxi/commuter operations because the system will start to transition to a point-to-point route system, making hub airports less critical.
- Similar to scenario 1, air carrier/commuter operations are projected to increase at a slightly slower rate than enplanements since electric aircraft will increase in capacity over time.
- GA operations are projected to increase at a slightly higher rate than WASP projections in the near-term (1.2 percent CAGR), with more significant growth in the mid- and long terms (3.2 percent and 4.0 percent CAGR, respectively) as new non-commercial users adopt the technology, use for pilot training expands, and UAM applications enter commercial deployment.

Based aircraft

- Based aircraft follow same model as GA operations described in Scenario 1, rising from 1.7 percent CAGR in the near-term to 5.6 percent CAGR by the end of the forecast period.

Electric Aircraft Scenario 3: High Growth[148]

This high-growth scenario envisions a future in which travelers embrace aviation as the preferred method of travel for short- and mid-range trips. Younger generations who grew up in the era of rideshare services exhibit less interest in private car ownership and are more open to early adoption of new technologies including UAM applications. This demographic is more likely to travel by electric aircraft to reach destinations within 500 miles, increasing demand and causing air service quality to improve system wide. Large commercial aircraft (+60 seats) enter the market by the end of the forecast horizon, with most air carrier activity occurring at Medium, Small, and Non hub airports due to the capacity and range of aircraft available within the forecast horizon. This scenario assumes that UAM have entered commercial markets, resulting in significant growth in air taxi/commuter activities (including for air cargo) and more rapidly rates of growth over time.

148 Electric aircraft scenario 3 is based on ACRP Report No. 204 scenario 5.

Table 5.1.7 Scenario 3 Forecast Overview

Aviation Activity Indicator		Short-term (2-5 years)	Mid-term (6-12 years)	Long-term (13-20 years)
Enplanements	Air carrier	3.10% (WASP) / 2.8% (Sea-Tac)		6.0% / 3.1% (Sea-Tac)
	Air taxi/commuter	10.0%	12.0%	16.0%
Operations	Air carrier	2.00% (WASP) / 2.3% (SeaTac)		2.5%
	Air taxi/commuter	8.0%	10.0%	12.0%
	GA	1.8%	4.2%	6.0
Based aircraft		2.2%	4.6%	6.2%

Sources: WSDOT Aviation 2020, WASP 2017, SAMP 2018, Kimley-Horn 2020

Enplanements

- This scenario offers the same assumptions Scenarios 1 and 2, with more robust growth in the long-term (6.0 percent CAGR; 3.1 percent CAGR [Sea-Tac only]).
- Air taxi/commuter enplanements increase rapidly, reaching 16 percent CAGR by the end of the forecast period.

Operations

- Air carrier operations follow WASP projections in the near- and mid-terms (2.0 percent CAGR; 2.3 percent CAGR for Sea-Tac), with large commercial aircraft (60+ seats) seeing increased demand by the end of the forecast period (2.5 percent CAGR).
- Air carrier/commuter operations are projected to increase at a slightly slower rate than enplanements because aircraft will increase in capacity over time (8.0 to 12.0 percent CAGR).
- GA operations follow the same trends as outlined in Scenarios 1 and 2 with more robust growth rates during all terms (1.8 to 6.0 percent CAGR).

Based Aircraft

- Based aircraft projects follow the same trends outlined in Scenarios 1 and 2 with more robust growth rates during all terms (2.2 to 6.2 percent CAGR).

Forecast Overviews

Table 5.1.8 summarizes the application of the growth rates defined for Scenarios 1 through 3 to actual activity data for each of the three indicators (baseline data sources noted in the paragraph below). The table shows the activity level for each forecast component during the baseline year (2019), the beginning of each term range (2021 [short-term], 2025 [mid-term], and 2032 [long-term]), and the end of the forecast horizon (2039). Total change and the average CAGR through the 20-year study timeframe are also presented. Scenario 1 provides the most conservative growth rates, Scenario 3 offers the most aggressive growth rates, with Scenario 2 falling in the middle. Each element of the forecast is presented separately after the table. This allows for a more detailed evaluation of specific forecast components within the three scenarios.

Baseline data were obtained from the FAA's Terminal Area Forecast (TAF) (accessed August 2020) for enplanements, operations, and based aircraft data for airports included in the National Plan of Integrated Airport Systems (NPIAS). Data from non-NPIAS airports were obtained from airport managers during the 2020 Washington AEIS or the FAA's 5010 Airport Master Record, in that order of preference. In all cases, data are assumed to offer the most current indicator of airport activity available at the statewide level.

Table 5.1.8 Electric Aircraft Forecast Summary by Scenario

Forecast Element	2019 (Baseline)	Near 2021*	Short-term 2025	Mid-term 2032	Long-term 2039	Total Change 2019 – 2039	Average CAGR
Scenario 1: Low Growth							
Air Carrier Enplanements	21,986,968	23,245,005	26,051,729	31,568,262	38,357,684	16,370,716	2.82%
Air Taxi/Commuter Enplanements	5,816,214	6,356,308	8,176,101	14,271,890	27,811,875	21,995,661	8.14%
Air Carrier Ops	538,627	560,388	606,581	696,771	800,371	261,744	2.00%
Air Taxi/Commuter Ops	195,879	207,788	247,758	379,565	650,508	454,629	6.19%
GA Ops	2,572,796	2,614,123	2,722,793	3,188,959	4,196,453	1,623,657	2.48%
Based Aircraft	6,816	6,967	7,358	8,744	11,741	4,925	2.76%
Scenario 2: Moderate Growth							
Air Carrier Enplanements	21,986,968	23,245,005	25,981,315	31,673,718	39,399,943	17,412,975	2.96%
Air Taxi/Commuter Enplanements	5,816,214	6,476,238	8,974,014	18,123,735	45,350,457	39,534,243	10.81%
Air Carrier Ops	538,627	560,388	606,581	701,553	845,383	306,756	2.28%
Air Taxi/Commuter Ops	195,879	211,784	272,418	475,522	926,658	730,779	8.08%
GA Ops	2,572,796	2,627,103	2,809,948	3,530,285	4,645,614	2,072,818	3.00%
Based Aircraft	6,816	7,008	7,630	9,904	14,503	7,687	3.85%
Scenario 3: High Growth							
Air Carrier Enplanements	21,986,968	23,308,055	26,051,729	31,718,221	39,901,221	17,914,253	3.02%
Air Taxi/Commuter Enplanements	5,816,214	6,596,168	9,833,040	22,514,066	63,629,697	57,813,483	12.71%
Air Carrier Ops	538,627	560,388	606,581	700,187	832,302	293,675	2.20%
Air Taxi/Commuter Ops	195,879	215,780	299,003	593,267	1,311,523	1,115,644	9.97%
GA Ops	2,572,796	2,642,678	2,905,062	3,945,273	5,971,518	3,398,722	4.30%
Based Aircraft	6,816	7,043	7,864	10,938	16,665	9,849	4.57%

Sources: FAA TAF (August 2020), FAA 5010 Master Record 2020, 2020 Washington AEIS, WASP 2017, SAMP 2018, WSDOT Aviation 2020, Kimley-Horn 2020

Note: This study applied WASP growth rates to all "year one" (2021) projections, as electric aircraft are assumed to generate no additional demands until after 2021.

Enplanements

Table 5.1.9 provides an overview of the three enplanement scenarios evaluated as part of the Washington Electric Aircraft Feasibility Study. Detailed results by year are presented in **Table 5.1.10**. As shown in **Figure 5.1.3**, air taxi/commuter enplanements overtake air carrier enplanements in the mid-term during all scenarios. This could have implications in terms of the types of airports that receive the most commercial passenger traffic while providing some congestion relief to commercial service and large GA airports currently experience capacity concerns.

Table 5.1.9 Scenario CAGRs by Forecast Year - Enplanements

		Scenario 1: Low		Scenario 2: Moderate		Scenario 3: High	
Term	Years	Air Carrier	Air Taxi & Commuter	Air Carrier	Air Taxi & Commuter	Air Carrier	Air Taxi & Commuter
Baseline	2019	-	-	-	-	-	-
Near	2020	3.10%	3.10%	3.10%	3.10%	3.10%	3.10%
Short	2021 – 2024	3.10%	6.00%	3.10%	8.00%	3.10%	10.00%
Mid	2025 – 2031	3.10%	8.00%	3.10%	10.00%	3.10%	12.00%
Long	2032 – 2039	3.10%	10.00%	3.10%	14.00%	6.00%	16.00%

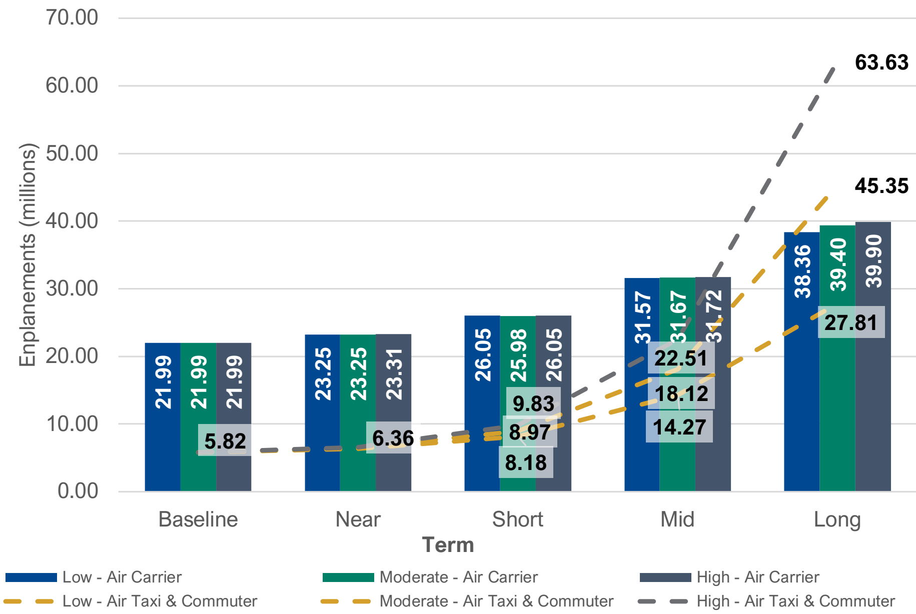
Sources: WASP 2017, Kimley-Horn 2020

Table 5.1.10 Scenario Forecasts - Air Carrier and Air Taxi/Commuter Enplanements by Year

Forecast Years	Air Carrier Enplanements						Air Taxi and Commuter Enplanements					
	Scenario 1: Low		Scenario 2: Moderate		Scenario 3: High		Scenario 1: Low		Scenario 2: Moderate		Scenario 3: High	
	CAGR	Number	CAGR	Number	CAGR	Number	CAGR	Number	CAGR	Number	CAGR	Number
2019-Baseline	**-**	**21,986,968**	**-**	**21,986,968**	**-**	**21,986,968**	**-**	**5,816,214**	**-**	**5,816,214**	**-**	**5,816,214**
2020	3.1%	22,607,231	3.1%	22,607,231	3.1%	22,668,564	3.1%	5,996,517	3.1%	5,996,517	3.1%	5,996,517
2021-Near	**3.1%**	**23,245,005**	**3.1%**	**23,245,005**	**3.1%**	**23,308,055**	**6.0%**	**6,356,308**	**8.0%**	**6,476,238**	**10.0%**	**6,596,168**
2022	3.1%	23,900,784	3.1%	23,900,784	3.1%	23,965,600	6.0%	6,737,686	8.0%	6,994,337	10.0%	7,255,785
2023	3.1%	24,575,078	3.1%	24,575,078	3.1%	24,641,708	6.0%	7,141,947	8.0%	7,553,884	10.0%	7,981,364
2024	3.1%	25,268,409	3.1%	25,268,409	3.1%	25,336,905	6.0%	7,570,464	8.0%	8,158,195	10.0%	8,779,500
2025-Short	**3.1%**	**26,051,729**	**3.1%**	**25,981,315**	**3.1%**	**26,051,729**	**8.0%**	**8,176,101**	**10.0%**	**8,974,014**	**12.0%**	**9,833,040**
2026	3.1%	26,714,350	3.1%	26,714,350	3.1%	26,714,350	8.0%	8,830,189	10.0%	9,871,416	12.0%	11,013,005
2027	3.1%	27,468,082	3.1%	27,468,082	3.1%	27,468,082	8.0%	9,536,604	10.0%	10,858,557	12.0%	12,334,565
2028	3.1%	28,243,097	3.1%	28,243,097	3.1%	28,243,097	8.0%	10,299,533	10.0%	11,944,413	12.0%	13,814,713
2029	3.1%	29,039,994	3.1%	29,039,994	3.1%	29,039,994	8.0%	11,123,495	10.0%	13,138,854	12.0%	15,472,479
2030	3.1%	29,859,394	3.1%	29,859,394	3.1%	29,859,394	8.0%	12,013,375	10.0%	14,452,740	12.0%	17,329,176
2031	3.1%	30,701,932	3.1%	30,701,932	3.1%	30,701,932	8.0%	12,974,445	10.0%	15,898,013	12.0%	19,408,677
2032-Mid	**3.1%**	**31,568,262**	**3.1%**	**31,673,718**	**6.0%**	**31,718,221**	**10.0%**	**14,271,890**	**14.0%**	**18,123,735**	**16.0%**	**22,514,066**
2033	3.1%	32,459,055	3.1%	32,676,431	6.0%	32,769,887	10.0%	15,699,079	14.0%	20,661,058	16.0%	26,116,316
2034	3.1%	33,375,005	3.1%	33,711,061	6.0%	33,858,258	10.0%	17,268,986	14.0%	23,553,606	16.0%	30,294,927
2035	3.1%	34,316,820	3.1%	34,778,630	6.0%	34,984,719	10.0%	18,995,885	14.0%	26,851,111	16.0%	35,142,115
2036	3.1%	35,285,234	3.1%	35,880,196	6.0%	36,150,712	10.0%	20,895,474	14.0%	30,610,267	16.0%	40,764,854
2037	3.1%	36,280,997	3.1%	37,016,847	6.0%	37,357,739	10.0%	22,985,021	14.0%	34,895,704	16.0%	47,287,230
2038	3.1%	37,304,882	3.1%	38,189,709	6.0%	38,607,364	10.0%	25,283,523	14.0%	39,781,103	16.0%	54,853,187
2039-Long	**3.1%**	**38,357,684**	**3.1%**	**39,399,943**	**6.0%**	**39,901,221**	**10.0%**	**27,811,875**	**14.0%**	**45,350,457**	**16.0%**	**63,629,697**
Average CAGR	-	2.82%	-	2.96%	-	3.02%	-	8.14%	-	10.81%	-	12.71%
Total Change	-	16,370,716	-	17,412,975	-	17,914,253	-	21,995,661	-	39,534,243	-	57,813,483
Percent Total Change	-	74.46%	-	79.20%	-	81.48%	-	378.18%	-	679.72%	-	994.01%

Sources: FAA TAF (August 2020), WASP 2017, SAMP 2018, Kimley-Horn 2020

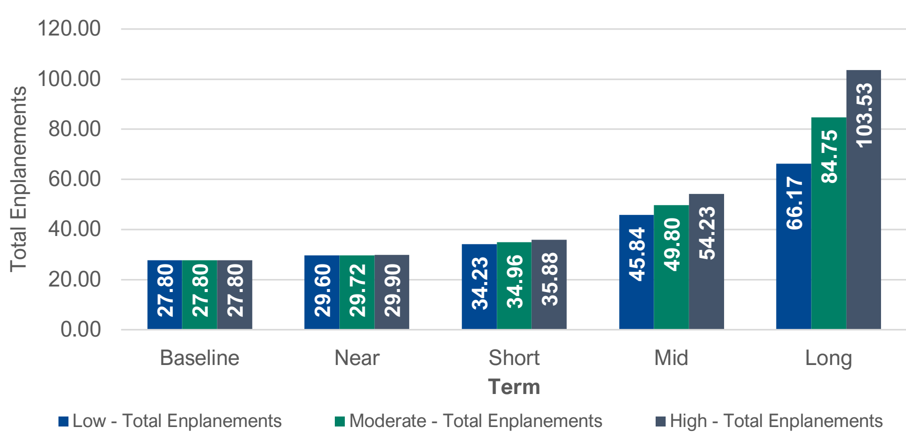
Figure 5.1.3 Scenario Forecasts - Air Carrier and Air Taxi/Commuter Enplanements



Sources: FAA TAF (August 2020), WASP 2017, SAMP 2018, Kimley-Horn 2020

Figure 5.1.4 provides total (air carrier and air taxi/commuter) enplanement forecast for each scenario. This shows that enplanements in Washington could increase from 27.8 million enplanements today to between 66.17 and 103.53 million through the forecast horizon.

Figure 5.1.4 Scenario Forecasts – Total Enplanements



Sources: FAA TAF (August 2020), WASP 2017, SAMP 2018, Kimley-Horn 2020

Operations

Table 5.1.11 provides an overview of the three operations by type scenarios evaluated as part of the Washington Electric Aircraft Feasibility Study. Detailed results for each type of aircraft operation by year are presented in **Table 5.1.12** (air carrier and air taxi/commuter) and **Table 5.1.13** (GA). **Figure 5.1.5** and **Figure 5.1.6** illustrate the scenario forecasts for air carrier and air taxi/commuter and GA operations, respectively. Similar to that observed above, the more robust growth rates anticipated in air taxi/commuter activities result in the number of these operations overtaking commercial service activity in the mid-term.

Table 5.1.11 Scenario CAGRs by Forecast Year – Operations

		Scenario 1: Low			Scenario 2: Moderate			Scenario 3: High		
Term	Years	AC	AT/C	GA	AC	AT/C	GA	AC	AT/C	GA
Baseline	2019	-	-	-	-	-	-	-	-	-
Near	2020	2.0%	2.0%	0.9%	2.0%	2.0%	0.9%	2.0%	2.0%	0.9%
Short	2021 – 2024	2.0%	4.0%	0.7%	2.0%	6.0%	1.2%	2.0%	8.0%	1.8%
Mid	2025 – 2031	2.0%	6.0%	2.0%	2.0%	8.0%	3.2%	2.0%	10.0%	4.2%
Long	2032 – 2039	2.0%	8.0%	4.0%	2.7%	10.0%	4.0%	2.5%	12.0%	6.1%

Sources: WASP 2017, Kimley-Horn 2020.

Acronyms: AC = air carrier; AT/C = air taxi/commuter; GA = general aviation.

Table 5.1.12 Scenario Forecasts - Air Carrier and Air Taxi/Commuter Operations by Year

	Air Carrier Operations						Air Taxi and Commuter Operations					
Forecast Years	Scenario 1: Low		Scenario 2: Moderate		Scenario 3: High		Scenario 1: Low		Scenario 2: Moderate		Scenario 3: High	
	CAGR	Number	CAGR	Number	CAGR	Number	CAGR	Number	CAGR	Number	CAGR	Number
2019-Baseline	**-**	**538,627**	**-**	**538,627**	**-**	**538,627**	**-**	**195,879**	**-**	**195,879**	**-**	**195,879**
2020	2.0%	549,400	2.0%	549,400	2.0%	549,400	2.0%	199,797	2.0%	199,797	2.0%	199,797
2021-Near	**2.0%**	**560,388**	**2.0%**	**560,388**	**2.0%**	**560,388**	**4.0%**	**207,788**	**6.0%**	**211,784**	**8.0%**	**215,780**
2022	2.0%	571,595	2.0%	571,595	2.0%	571,595	4.0%	216,100	6.0%	224,491	8.0%	233,043
2023	2.0%	583,027	2.0%	583,027	2.0%	583,027	4.0%	224,744	6.0%	237,961	8.0%	251,686
2024	2.0%	594,688	2.0%	594,688	2.0%	594,688	4.0%	233,734	6.0%	252,239	8.0%	271,821
2025-Short	**2.0%**	**606,581**	**2.0%**	**606,581**	**2.0%**	**606,581**	**6.0%**	**247,758**	**8.0%**	**272,418**	**10.0%**	**299,003**
2026	2.0%	618,713	2.0%	618,713	2.0%	618,713	6.0%	262,623	8.0%	294,211	10.0%	328,903
2027	2.0%	631,087	2.0%	631,087	2.0%	631,087	6.0%	278,381	8.0%	317,748	10.0%	361,794
2028	2.0%	643,709	2.0%	643,709	2.0%	643,709	6.0%	295,083	8.0%	343,168	10.0%	397,973
2029	2.0%	656,583	2.0%	656,583	2.0%	656,583	6.0%	312,788	8.0%	370,621	10.0%	437,771
2030	2.0%	669,715	2.0%	669,715	2.0%	669,715	6.0%	331,556	8.0%	400,271	10.0%	481,548
2031	2.0%	683,109	2.0%	683,109	2.0%	683,109	6.0%	351,449	8.0%	432,293	10.0%	529,702
2032-Mid	**2.0%**	**696,771**	**2.7%**	**701,553**	**2.5%**	**700,187**	**8.0%**	**379,565**	**10.0%**	**475,522**	**12.0%**	**593,267**
2033	2.0%	710,707	2.7%	720,495	2.5%	717,692	8.0%	409,930	10.0%	523,074	12.0%	664,459
2034	2.0%	724,921	2.7%	739,949	2.5%	735,634	8.0%	442,725	10.0%	575,381	12.0%	744,194
2035	2.0%	739,419	2.7%	759,927	2.5%	754,025	8.0%	478,143	10.0%	632,920	12.0%	833,497
2036	2.0%	754,208	2.7%	780,445	2.5%	772,875	8.0%	516,394	10.0%	696,212	12.0%	933,516
2037	2.0%	769,292	2.7%	801,517	2.5%	792,197	8.0%	557,706	10.0%	765,833	12.0%	1,045,538
2038	2.0%	784,678	2.7%	823,158	2.5%	812,002	8.0%	602,322	10.0%	842,416	12.0%	1,171,003
2039-Long	**2.0%**	**800,371**	**2.7%**	**845,383**	**2.5%**	**832,302**	**8.0%**	**650,508**	**10.0%**	**926,658**	**12.0%**	**1,311,523**
Average CAGR	-	2.00%	-	2.28%	-	2.20%		6.19%		8.08%		9.97%
Total Change	-	261,744	-	306,756	-	293,675		454,629		730,779		1,115,644
Percent Total Change	-	48.59%	-	56.95%	-	54.52%		232.10%		373.08%		569.56%

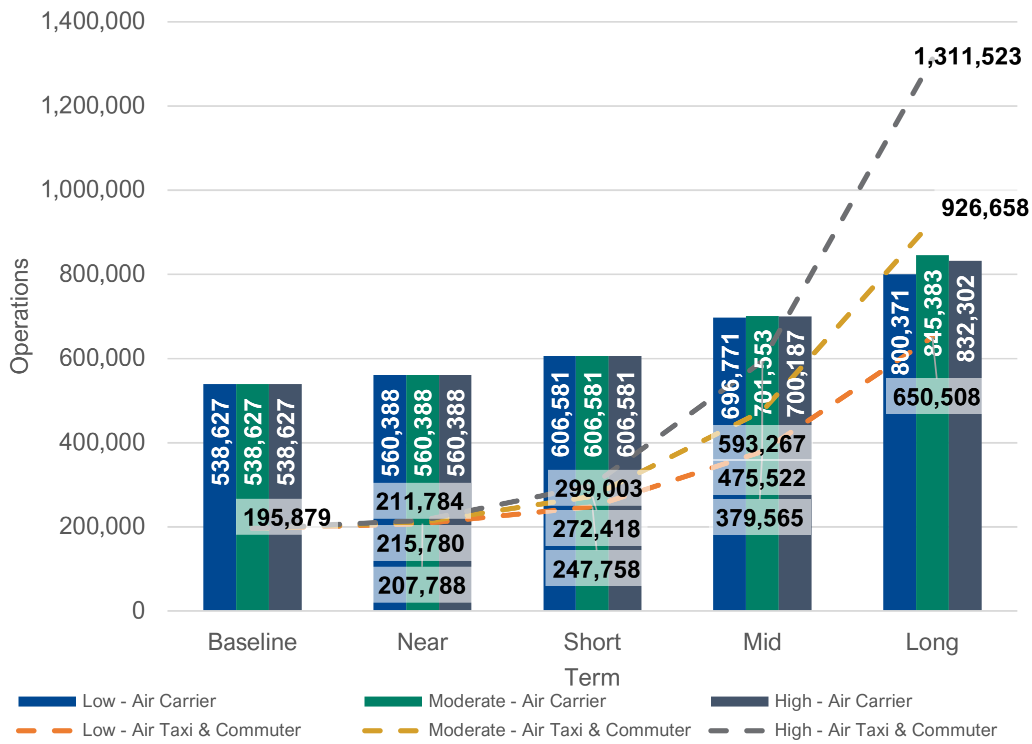
Sources: FAA TAF (August 2020), FAA 5010 Master Record 2020, 2020 Washington AEIS, WASP 2017, SAMP 2018, Kimley-Horn 2020

Table 5.1.13 Scenario Forecasts - GA Operations by Year

Forecast Years	GA Operations					
	Scenario 1: Low		Scenario 2: Moderate		Scenario 3: High	
	CAGR	Number	CAGR	Number	CAGR	Number
2019- Baseline	**-**	**2,572,796**	**-**	**2,572,796**	**-**	**2,572,796**
2020	0.9%	2,595,951	0.9%	2,595,951	0.9%	2,595,951
2021-Near	**0.7%**	**2,614,123**	**1.2%**	**2,627,103**	**1.8%**	**2,642,678**
2022	0.7%	2,632,422	1.2%	2,658,628	1.8%	2,690,246
2023	0.7%	2,650,849	1.2%	2,690,531	1.8%	2,738,671
2024	0.7%	2,669,405	1.2%	2,722,818	1.8%	2,787,967
2025-Short	**2.0%**	**2,722,793**	**3.2%**	**2,809,948**	**4.2%**	**2,905,062**
2026	2.0%	2,777,249	3.2%	2,899,866	4.2%	3,027,074
2027	2.0%	2,832,793	3.2%	2,992,662	4.2%	3,154,211
2028	2.0%	2,889,449	3.2%	3,088,427	4.2%	3,286,688
2029	2.0%	2,947,238	3.2%	3,187,257	4.2%	3,424,729
2030	2.0%	3,006,183	3.2%	3,289,249	4.2%	3,568,568
2031	2.0%	3,066,307	3.2%	3,394,505	4.2%	3,718,448
2032-Mid	**4.0%**	**3,188,959**	**4.0%**	**3,530,285**	**6.1%**	**3,945,273**
2033	4.0%	3,316,517	4.0%	3,671,497	6.1%	4,185,935
2034	4.0%	3,449,178	4.0%	3,818,356	6.1%	4,441,277
2035	4.0%	3,587,145	4.0%	3,971,091	6.1%	4,712,194
2036	4.0%	3,730,631	4.0%	4,129,934	6.1%	4,999,638
2037	4.0%	3,879,856	4.0%	4,295,132	6.1%	5,304,616
2038	4.0%	4,035,051	4.0%	4,466,937	6.1%	5,628,198
2039-Long	**4.0%**	**4,196,453**	**4.0%**	**4,645,614**	**6.1%**	**5,971,518**
Average CAGR	-	2.48%	-	3.00%	-	4.30%
Total Change	-	1,623,657	-	2,072,818	-	3,398,722
Percent Total Change	-	63.11%	-	80.57%	-	132.10%

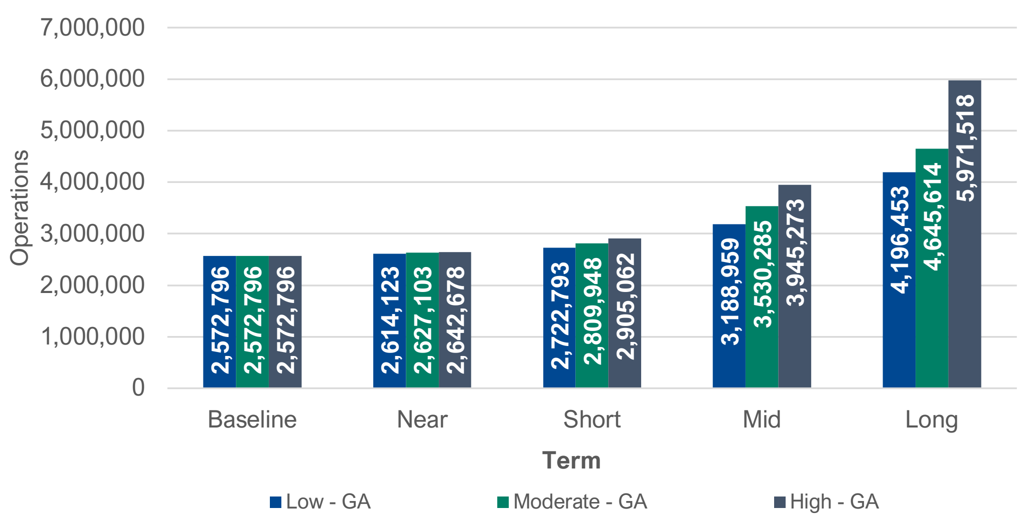
Sources: FAA TAF (August 2020), FAA 5010 Master Record 2020, 2020 Washington AEIS, WASP 2017, SAMP 2018, Kimley-Horn 2020

Figure 5.1.5 Scenario Forecasts – Air Carrier and Air Taxi/Commuter Operations



Sources: FAA TAF (August 2020), FAA 5010 Master Record 2020, SAMP 2018, Kimley-Horn 2020

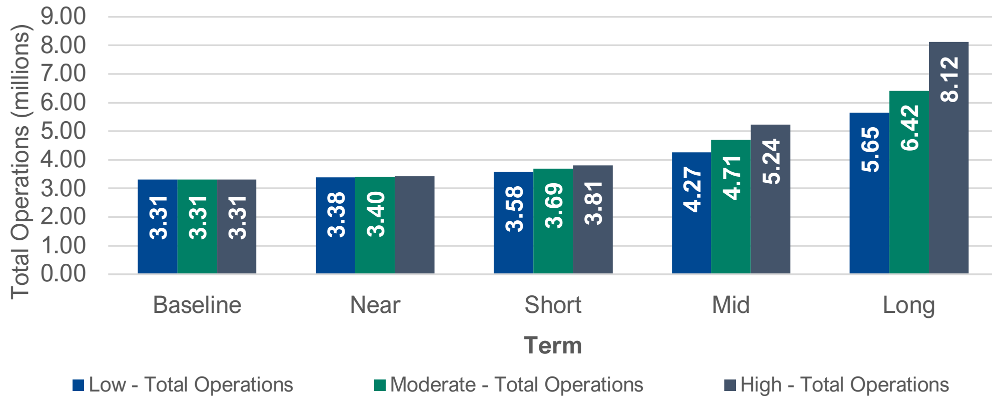
Figure 5.1.6 Scenario Forecasts – GA Operations



Sources: FAA TAF (August 2020), FAA 5010 Master Record 2020, 2020 Washington AEIS, WASP 2017, SAMP 2018, Kimley-Horn 2020

Figure 5.1.7 summarizes total operations projected with the deployment of electric aircraft between 2019 and 2039. This reveals that operations may increase from 3.31 million in 2019 to between 5.65 and 8.12 million by 2039. This represents between 2.3 and 4.8 million more operations in 2039 than experienced today.

Figure 5.1.7 Scenario Forecasts – Total Operations



Sources: FAA TAF (August 2020), FAA 5010 Master Record 2020, 2020 Washington AEIS, WASP 2017, SAMP 2018, Kimley-Horn 2020

Based Aircraft

Table 5.1.14 provides an overview of the three based aircraft scenarios evaluated as part of the Washington Electric Aircraft Feasibility Study. Detailed results by study year are presented in **Table 5.1.15**. Significant levels of growth illustrated in **Figure 5.1.8** during the mid- and long- terms may put additional pressure on airports in terms of meeting storage needs. Some areas of the state—notably the urban core centered on the Olympic Peninsula—already face severe hangar shortages. New aircraft added to the fleet may exacerbate this issue. Some electric aircraft are anticipated to be more expensive than their "conventional" peers (i.e., aircraft of similar size and sophistication), which will likely make many owners reluctant to store them on open ramp space. Airports selected as electric aircraft beta test sites and WSDOT should consider strategies to improve storage capacity. It may be possible to better distribute based aircraft across the aviation system by shifting demand to airports that have available capacity. Airports that have available space for development could consider constructing additional hangar storage, such as by taking advantage of WSDOT's Community Aviation Revitalization Board (CARB) Revolving Loan program.

Table 5.1.14 Scenario CAGRs by Forecast Year – Based Aircraft

Term	Years	Scenario 1: Low	Scenario 2: Moderate	Scenario 3: High
Baseline	2019	-	-	-
1	2020	2.0%	2.0%	2.0%
2 - 5	2021 – 2024	2.0%	2.0%	2.0%
6 - 12	2025 – 2031	2.0%	2.0%	2.0%
13 - 20	2032 – 2039	2.0%	2.7%	2.5%

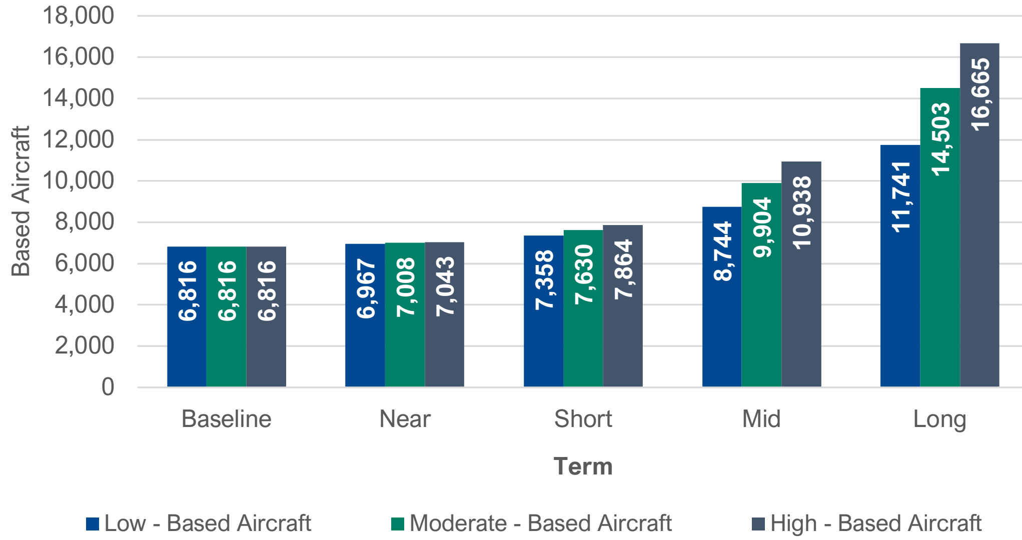
Sources: WASP 2020, Kimley-Horn 2020

Table 5.1.15 Scenario Forecasts – Based Aircraft by Year

Forecast Years	Scenario 1: Low		Scenario 2: Moderate		Scenario 3: High	
	CAGR	Number	CAGR	Number	CAGR	Number
2019- Baseline	**-**	**6,816**	**-**	**6,816**	**-**	**6,816**
2020	1.1%	6,891	1.1%	6,891	1.1%	6,891
2021-Near	**1.1%**	**6,967**	**1.7%**	**7,008**	**2.2%**	**7,043**
2022	1.1%	7,043	1.7%	7,127	2.2%	7,198
2023	1.1%	7,121	1.7%	7,248	2.2%	7,356
2024	1.1%	7,199	1.7%	7,372	2.2%	7,518
2025-Short	**2.2%**	**7,358**	**3.5%**	**7,630**	**4.6%**	**7,864**
2026	2.2%	7,519	3.5%	7,897	4.6%	8,225
2027	2.2%	7,685	3.5%	8,173	4.6%	8,604
2028	2.2%	7,854	3.5%	8,459	4.6%	8,999
2029	2.2%	8,027	3.5%	8,755	4.6%	9,413
2030	2.2%	8,203	3.5%	9,062	4.6%	9,846
2031	2.2%	8,384	3.5%	9,379	4.6%	10,299
2032-Mid	**4.3%**	**8,744**	**5.6%**	**9,904**	**6.2%**	**10,938**
2033	4.3%	9,120	5.6%	10,459	6.2%	11,616
2034	4.3%	9,512	5.6%	11,044	6.2%	12,336
2035	4.3%	9,922	5.6%	11,663	6.2%	13,101
2036	4.3%	10,348	5.6%	12,316	6.2%	13,913
2037	4.3%	10,793	5.6%	13,006	6.2%	14,776
2038	4.3%	11,257	5.6%	13,734	6.2%	15,692
2039-Long	**4.3%**	**11,741**	**5.6%**	**14,503**	**6.2%**	**16,665**
Average CAGR	-	2.76%	-	3.85%	-	4.57%
Total Change	-	4,925	-	7,687	-	9,849
Percent Total Change	-	72.26%	-	112.78%	-	144.50%

Sources: FAA TAF (August 2020), FAA 5010 Master Record 2020, 2020 Washington AEIS, Kimley-Horn 2020

Figure 5.1.8 Scenario Forecasts – Based Aircraft



Sources: FAA TAF (August 2020), FAA 5010 Master Record 2020, 2020 Washington AEIS, WASP 2020, SAMP 2018, Kimley-Horn 2020

Forecast Summary

The Washington Electric Aircraft Feasibility Study predicts a wide variety of potential futures for the implementation of electric aircraft in Washington. Should the key promises of this technology come to fruition—namely, the ability for travelers to reach their final destinations more cheaply, quickly, and with less hassle and fewer environmental impacts—the implications for the Washington aviation system and airports would likely be substantial. The scenarios evaluated show that total enplanements could grow from 27.8 million today to between 66.1 million (scenario 1) and 103.5 million (scenario 3) by 2039. Total operations could increase from 3.3 million to between 5.6 million (scenario 1) and 8.1 million (scenario 3) by 2039. With some airports in the state already facing capacity concerns, these additional demands could result in operational delays. By conducting this study, WSDOT Aviation has given itself and airports the opportunity to proactively prepare for these new demands. In the short-term, this study provides support for additional investment into the state aviation system to support the demand associated with electric aircraft deployment. Certain airside improvement projects can make operations more efficient, and landside improvements may be critical to support additional passenger activity. Hangar storage concerns may become critical should the state double its fleet over the next 20 years as projected in the study's scenarios. In the longer term, public policy may need to consider the implications of a transportation network dominated by air travel. In the Deployment section, this study turns from looking at demands at the statewide level to specific airport needs by providing a framework for airports to understand their level of preparedness in meeting the needs of electric aircraft.

Section 2: Deployment

The Electric Aircraft Demand Assessment presents a bold and visionary future for electric aircraft in Washington state. Should these ambitious projections become reality, WSDOT Aviation and airports will need to prepare for their arrival in terms of supporting electric aircraft, the pilots and passengers they carry, and ancillary effects such as changing travel patterns and on-airport revenue-earning strategies. This section offers guidance on beginning steps that airports can take to understand their current ability to support electric aircraft and strategies to enhance their preparedness for their arrival. Each airport and community have a unique set of needs; this section provides a broad framework for consideration as appropriate next steps are identified and implemented. This framework can also be used to help airports understand their potential role in the era of electric aircraft in terms of the five high-value use cases identified as part of this study:

- Regional commuter for five passengers or less
- Regional aircraft for up to 15 passengers
- Pilot training
- Personal business use
- Air cargo

The electric aircraft self-assessment framework is provided in **Table 5.2.1**. The framework provides a question pertaining to an airport's ability to support electric aircraft, an area for readers' responses, the relevancy of the question for further consideration, and specific action items and additional information to learn more. Note this framework assumes that the airport does not experience capacity concerns and is able to support additional activity without negatively effecting operational efficiency.

Table 5.2.1 Electric Aircraft Airport Self-assessment Framework

Questions for Consideration	Self-assessment	Relevancy	Action Items and Resources
Infrastructure and Pilot/Passenger Support			
Does my airport offer:			
At least a 3,000-foot long runway?	◻ Yes ◻ No	The Electric Aircraft Working Group (EAWG) Report (June 2019) states that e- aircraft will be able to operate from at least a 3,000-foot long runway due to their smaller size and electric propulsion systems. As such, this is the baseline criterion for supporting most fixed wing electric aircraft.	Airports that do not meet this metric can assess the feasibility of a runway extension. To receive state and/or federal funding (as applicable), the proposed extension must be depicted on the airport's approved Airport Layout Plan (ALP); be included in WSDOT Aviation's five-year Statewide Capital Improvement Program (SCIP) (for state funding only); and demonstrate there is an actual need for the project within the next five years. NPIAS airports must demonstrate that federal funding has been pursued before WSDOT Aviation will consider issuing a state grant for the project. For more information about WSDOT's Airport Aid Grant Program, visit *https://wsdot.wa.gov/aviation/Grants/default.htm*. NPIAS airports eligible for Airport Improvement Program (AIP) funds can visit *https://www.faa.gov/airports/aip/* for information about federal funding. Airports where a runway extension is not feasible may have the capacity to support aircraft with eVTOL capabilities.
Available hangar space?	◻ Yes ◻ No If yes, how many additional units are available? _____ If no, does the airport maintain a hangar wait list? ◻ Yes ◻ No	Available T- and/or conventional hangars (depending on type of aircraft based at the facility) is a critical factor in terms of where aircraft owners choose to base their aircraft. An electric aircraft will require a significant investment and owners will want to keep it out of the elements when not in use. Hangars may also be important for the installation of electric aircraft charging stations.	Airport sponsors interested in hangar development must first assess the feasibility of hangar development in terms of available land, zoning and land use regulations (as applicable); the airport master plan/ ALP; and community and existing tenant support. Hangars are not eligible for state funding through the Airport Aid Grant Program. Most Washington airports are eligible to apply for CARB revolving loan funds for hangars. These low-interest loans support revenue-producing capital projects at public-use GA airports. Visit *https://wsdot.wa.gov/aviation/funding/CARB-Loan* for more information about this program. The Aircraft Owners and Pilots Association (AOPA) has also published the "Aircraft Hangar Development Guide" to help GA airports navigate hangar development from planning through execution. The guide also includes additional references that provide more information about building hangars. The guide is available at *https://www.aopa.org/-/media/Files/AOPA/Home/Supporting-General-Aviation/Get-Involved/Airport-Support-Network/Airport-Support-Network-Aircraft-Hangar-Development-Guide/hangar-planning.pdf*.
Jet A or diesel fuel to support hybrid electric aircraft during the transition to full electric aircraft?	Yes No	While neither Jet A nor diesel fuel is required by all-electric aircraft, hybrid electric aircraft are anticipated to be first to market. This is especially likely for larger aircraft capable of carrying nine passengers or more. While the need for Jet A and diesel fuel may diminish in the long-term, it is an important consideration during the transition period.	Because Jet A and diesel fuel is a revenue-producing activity, this improvement is generally not eligible for state or federal funding. Airports interested in installing fuel can apply for a CARB loan or work with an existing or new fixed base operator (FBO) to provide. Many factors must be considered when initiating fuel service including storage, staffing, insurance, and environmental issues.

Questions for Consideration	Self-assessment	Relevancy	Action Items and Resources
Does the airport, community, or third party operating on my airport have interest in providing electric aircraft charging capabilities?	◻ Yes ◻ No ◻ Unknown	The “standard” energy draw of an electric aircraft is currently unknown and may change over time as battery technologies improve. It is recommended that airports start developing partnerships with local utility providers early to understand existing electrical capacity and current demands. This proactive planning approach may help identify and mitigate utility constraints so issues are not identified after electric aircraft fully arrive in the marketplace.	It is recommended that airports coordinate with electric aircraft manufacturers and the DOE to estimate the electric capacity required to support the type and frequency of electric aircraft operations anticipated to occur at the airport. Airports can then work through the Utility Coordination Process presented in the Selection of Beta Test Site section of this Electric Aircraft Feasibility Study to identify potential utility upgrades that may be associated with electric aircraft operations at the airport. Airport can also develop partnerships with energy service companies (ESCOs), FBOs, and other third-party companies to find innovative ways to fund electric aircraft charging stations, potential utility upgrades, or both. For example, a third-party company is offering light-duty charging stations to Large Hub airports with revenues being returned to the airport in exchange for carbon credits needed for the utility provider. The Washington State Department of Commerce maintains a website about the cost of electricity in the state. Airports can contact a member of the Office of Economic Development and Competitiveness team to learn more about electricity availability statewide at *http://choosewashingtonstate.com/why-washington/our-strengths/low-cost-energy/*.
Adequate multimodal options for pilots and passengers arriving at my airport, such as access to a courtesy or rental car, transportation network company (TNC), or transit option such as a light rail or public bus?	◻ Rental car ◻ Courtesy car ◻ TNC ◻ Public bus ◻ Commuter rail ◻ Heavy rail ◻ Bicycle ◻ Other: ___________	Pilots and passengers arriving on electric aircraft need a reliable way to leave airport property. While some pilots may visit an airport for only a short visit, travelers visiting a region for leisure or business must have access to ground transportation. Optimally, the airport would offer multiple options to meet the needs of most user groups (e.g., rental car and bus).	While the presence of on-airport rental car agencies is generally market-driven, airport managers/sponsors can work with local public transit providers to see if the airport can be added to an existing bus route. An inexpensive courtesy car can be purchased or even donated by a local airport user or advocate. Insurance can be costly. Some airports have found unique ways to pay this monthly cost, such as partnering with local businesses to add advertising signs to the car for a monthly fee. ACRP offers a number of reports on the integration of modal options at airports including Report No. 62, “Improving Public Transportation Access to Large Airports,” Report No. 83, “Strategies for Improving Public Transportation Access to Large Airports,” Report No. 4, “Ground Access to Major Airports by Public Transportation,” Report No. 18, “Integrating Aviation and Passenger Rail Planning,” and Legal Research Digest 35, “Legal Considerations in the Funding and Development of Intermodal Facilities at Airports”. These reports are available at the following website (searchable by title): *http://www.trb.org/Main/Blurbs.aspx*.

Questions for Consideration	Self-assessment	Relevancy	Action Items and Resources
Commercial Service Demands			
Does my airport support Part 135-certified carriers that provide on-demand, unscheduled charter-type air service? If no, was service provided by Part 135 operators in the past ?	◻ Yes ◻ No – Never ◻ No – Service was lost	The low cost of operating electric aircraft could catalyze a significant uptick in new demand for all types of passenger service. Airports that already support Part 135 carriers may be best positioned to incorporate electric aircraft into existing operations because they already have the facilities and services generally required to support some level of passenger traffic. However, airports that do not have any passenger service have the potential to fill a service gap in the system and should carefully consider the actions they could take to attract a Part 135 carrier utilizing electric aircraft to their market.	ACRP Report No. 18, "Passenger Air Service Development Techniques" provides clear and understandable guidance for airport managers and sponsors interested in retaining existing and/or attracting new commercial service in small communities. The report offers information on factors that can be used to assess if your community is a potential candidate for air service and air service development techniques. ACRP Report No. 18 is available at ***http://www.trb.org/Main/Blurbs/162396.aspx***. AC 150/5190-7, "Minimum Standards for Commercial Aeronautical Activities" offers sample questions for airport managers to consider when developing minimum standards for services or activities that are frequently offered at an airport. AC 150/5190-7 is available at ***https://www.faa.gov/documentLibrary/media/advisory_circular/150-5190-7/150_5190_7.pdf***.
What are the most feasible routes that my airport could offer? How are travelers currently reaching these destination(s) and what are the specific benefits air travel could provide?	Destination 1: _____________ Nautical miles (nm): __________ Destination 2: _____________ NM: ___________ Destination 3: _____________ NM: ___________	Airlines typically operate between markets that offer the greatest reliable demands. Currently, the Washington route model is primarily hub-and-spoke in which travelers are routed through large "hub" airports (including SeaTac and Salt Lake City International (SLC) airports). With the implementation of electric aircraft, some advocates envision a future point-to-point route system in which passengers travel directly between their place of origin and final destinations. In either model (i.e., hub and spoke or point-to-point), airport managers and sponsors should identify potential destinations within approximately 500 nm that may catalyze demand amongst business or leisure travelers.	The selection of airline routes is a complicated and data-driven process. ACRP Report No. 18, "Passenger Air Service Development Techniques" (noted above) provides insight into this process, which airport managers and sponsors should generally understand before taking any actions associated with air service development. Local and/or regional economic development organizations may be good partners to help identify specific communities within the 500 nm range that could have serve as key outbound destinations. The local chamber of commerce and/or visitors' bureau may be able to provide insight into where people are coming from when visiting the area. Note the 500 nm range is an optimal range for electric aircraft in the mid-term (five to 10 years). Ranges with power reserves will be less in the near-term. Airports that currently offer unscheduled commercial service could work with existing providers, including FBOs, to obtain information about their top markets and inquire if they are currently looking into electric aircraft opportunities.
Is scheduled commercial service provided by another airport within a 30-minute drivetime? Within a 60-minute drivetime?	◻ Yes – 60 min ◻ No	Many travelers are willing to drive upwards of 60 minutes, or more if greater service is provided, to access a commercial service airport. Statewide connectivity would be enhanced if scheduled commercial service could be provided to populations living and working beyond this drive-time threshold.	Drive-time analyses can be conducted using ArcGIS or other spatial mapping platform. If this work cannot be conducted in-house, a consulting partner can be engaged.

Questions for Consideration	Self-assessment	Relevancy	Action Items and Resources
How do most travelers in my community reach a hub airport for long-distance travel (such as SeaTac)?	◻ Drive ◻ Bus ◻ TNC ◻ Commuter rail ◻ Airport shuttle ◻ On-demand air service provided by FBO (such as charters) ◻ Other: ___________	If scheduled commercial service is not currently offered in your community, are travelers moving by automobile, rail, or bus to reach a hub airport? These travelers may provide a source of new demand for commercial service by electric aircraft. FBOs that are currently offered unscheduled charter service to hub airports may be a good candidate for electric aircraft deployment within the airports existing activities.	Airport managers and sponsors can ask the local chamber of commerce and economic and tourism development agencies about how travelers typically reach the community. Also consider contacting large businesses, facilities that cater to travelers (such as conference centers), and large hotels to obtain their input on the market's ability to support air service.
What are the key businesses/ industries in my region that could benefit from new or enhanced air service?	NA	Airports are enablers of regional economic activity by connecting businesses to marketplaces around the globe. Businesses rely on airports for the transport of perishable, high-value, and "just in time" goods; providing long-distance connectivity between staff and clients; and providing access to visitors for hospitality industries. Identifying businesses that could benefit from additional air service could enhance local support and provide market opportunities for electric aircraft.	ACRP offers a comprehensive online toolkit to help airports understand and increase their economic impact at *https://crp.trb.org/acrp0331/aviation-toolkit/#ert_pane1-2*. In particular, ACRP has developed a guide for airport managers to identify major industries in their regions that may be reliant on air transportation for the movement of goods or people. This guide is available at *https://crp.trb.org/wp-content/uploads/sites/7/2016/10/E2_Tool1-IdentifyingAirportReliantBusinesses.pdf*.
Are there specific attractions in my region that draw travelers from outside of Washington?	Yes No Unknown	Demand is often influenced by proximity to regional or natural attractions, as well as seasonal activities such as skiing and hunting. This can also offer airports an important source of demand that could be met by electric aircraft.	Local and regional tourism agencies may be great partners in identifying and connecting with regional attractions including natural areas, conference centers, or seasonal activities. The Washington Tourism Alliance (WTA) is a nonprofit tourism organization that fills this role in the state. This organization can be contacted at *http://watourismalliance.com/*
Does my airport have an existing terminal building that could be used to support scheduled air service passengers?	Yes No	Passengers traveling by scheduled air service require specific facilities within terminal buildings, including check-in and pre-boarding waiting areas; terminal concessionaires; and restrooms. Space must also be available for security screening requirements if warranted. Under Transportation Security Administration (TSA) security regulations, airports that provide scheduled service with aircraft with 61 or more seats are required to have a TSA-approved Airport Security Program (ASP).	Airports considering the implementation of scheduled commercial service are strongly recommended to develop or update their master plans to identify specific facility needs associated with this type of activity. ACRP Report No. 16, "Guidebook for Managing Small Airports" provides information regarding the decision to provide commercial service as well as an overview of the federal requirements, physical facilities, and administrative duties associated with accommodating air service. ACRP Report No.16 is available at *http://www.trb.org/Publications/Blurbs/162145.aspx*. GA airports that are not required to have an ASP but are interested in learning more about airport security can reference the TSA's "Security Guidelines for GA Airport Operators and Users," available at *https://www.tsa.gov/sites/default/files/2017_ga_security_guidelines.pdf*.

Questions for Consideration	Self-assessment	Relevancy	Action Items and Resources
Business Development			
Does my community or region offer a workforce that could support one or more of the high-value electric aircraft use cases?	◻ Yes ◻ No ◻ Unknown	A workforce is one of the key characteristics a business looks for when choosing where to locate. Businesses associated with the high-value electric aircraft use cases (i.e., regional commuter air service, pilot training, recreational flying, and air cargo) each require very different skillsets. Aligning the airport's intentions with the available workforce will help support and streamline electric aircraft implementation.	The Washington Workforce Training and Education Coordinating Board (Workforce Board) helps Washington's businesses find workers skilled in the areas required. The agency coordinates 16 programs administered by seven agencies. Additionally, Washington has 12 regional workforce areas, each of which has a four-year workforce plan. The Workforce Board can be contacted at *https://www.wtb.wa.gov/planning-programs/washington-workforce-system/*. The Washington State Department of Commerce has compiled a list of aerospace-specific workforce training and educational resources at *http://choosewashingtonstate.com/i-need-help-with/workforce-training/*. Additionally, this Feasibility Study conducted an analysis addressing electric aircraft education and workforce development. It provides information about the type of education and backgrounds appropriate to fill specific electric aircraft workforce needs.
Are there economic development organizations that could support efforts to support electric aircraft implementation?	◻ Yes ◻ No ◻ Unknown	Economic development organizations connect businesses, local government, and nonprofit organization to facilitate economic growth in specific communities and statewide. The implementation of electric aircraft will necessitate unique partnerships amongst stakeholders that may not have worked together previously. As such, engaging an economic development organization could help airports discover and leverage available resources and force new relationships supportive of their efforts.	The U.S. Economic Development Administration maintains a list of all statewide and regional economic development organizations in the U.S. The list is available at: *https://www.eda.gov/resources/economic-development-directory/states/wa.htm*. The Washington State Department of Commerce is responsible for economic development at the statewide level. The Department identifies Aerospace as one of the state's key sectors and maintains a dedicated team supporting the growth of this industry. Information about the agency's aerospace initiatives is available at *http://choosewashingtonstate.com/why-washington/our-key-sectors/aerospace/*.
Does my jurisdiction offer tax exemptions or other incentives to promote economic development?	◻ Yes ◻ No ◻ Unknown	Tax incentives can help new businesses get off the ground and can help defer the inherent risks of any new ventures.	The Washington State Department of Revenue maintains a list of state incentives available in the aerospace sector. These incentives include deferrals, reduced business & operating (B&O) rates, exemptions, and credits. Statewide tax incentive information is available at *https://dor.wa.gov/taxes-rates/tax-incentives/incentive-programs*. Airport managers and sponsors are also encouraged to check with local government agencies to see if any municipal or county-level incentives may be available.

Questions for Consideration	Self-assessment	Relevancy	Action Items and Resources
Does my airport offer a business-friendly environment for on-airport tenants?	Rate your airport's level of support for on-airport businesses: ◻ 1 – Great! ◻ 2 ◻ 3 – Neutral ◻ 5 ◻ 6 – Poor	An airport's potential to gain new on-airport tenants depends, in part, on its ability to support business needs and cultivate an environment of economic prosperity. This ability is influenced by the investment made in facilities and services at the airport, the formal policies that govern its management and organization, and the implementation of various strategies and initiatives that enhance an airport's attractiveness to potential businesses.	As one of the first steps towards enhancing the on-airport environment for businesses, airport managers can establish an open and ongoing dialogue with existing tenants to identify what is working well and pinpoint any areas where procedures, policies, or processes could be improved. ACRP Report No. 121, "Innovative Revenue Strategies for Airports—An Airport Guide," provides a range of ideas for enhancing on-airport revenue production, including several that pertain specifically to improving existing on-airport businesses.
How would my airport be impacted if revenue from fuel flowage fees were diminished or eliminated with the implementation of electric aircraft?	◻ 1 – Fuel not available ◻ 2 – None anticipated ◻ 3 – Limited ◻ 5 – Moderate ◻ 6 – Significant impacts to airport operations	Could my airport offset fuel flowage fee reductions with other revenue streams such as energy delivery fees, energy production, etc.?	Having a diversity of revenue streams is an important component of airport resiliency, as impacts to one revenue source (i.e., fuel) could be offset by increases to another. Airport managers may also need to implement alternative revenue-generating strategies. ACRP Report No. 16, "Guidebook for Managing Small Airports" identifies a relatively short list of income sources at most facilities, including commercial, hangar, and agricultural leases; commercial rent; terminal concessions rent; fuel flowage fees; and landing and ramp fees. In addition to those provided in Report No. 16, ACRP Synthesis 19, "Airport Revenue Diversification" offers more unique solutions for income generation. These are generally organized into three groups including (1) aviation services, such as ground handling, (2) non-aeronautical land development, including large-scale projects and stand-alone facilities; and (3) ancillary land uses, such as mineral extraction and renewable resources. ACRP Report No. 77, "Guidebook for Developing GA Airport Business Plan" provides tools and guidance to help airports develop and implement an airport business plan and enhance airport self-sufficiency. ACRP Report No.16 is available at *http://www.trb.org/Publications/Blurbs/162145.aspx*. ACRP Synthesis 19 is available at *http://www.trb.org/Publications/Blurbs/163650.aspx*. ACRP Report No. 77 is available at http://www.trb.org/Main/Blurbs/168114.aspx.
Can the airport/airport sponsor or the local community offer incentives, including in-kind assistance, to support the deployment of electric aircraft?	◻ Yes ◻ No ◻ Unknown	Airports can offer business tenants incentives for locating to their airports including cost or fee waivers (landing fees, lease fees/rent, charging station fees [as applicable]), staff training opportunities, and marketing assistance. Members of the local business community can provide support such as media coverage, lodging for non-local staff, and support from the economic development organization.	ACRP Report No. 47, "Guidebook for Developing and Leasing Airport Property" provides additional guidance on providing incentives and other assistance to on-airport tenants. The report is available at *http://www.trb.org/Publications/Blurbs/164688.aspx*.

Questions for Consideration	Self-assessment	Relevancy	Action Items and Resources
Partnerships			
Who are the local stakeholders/ decision makers who could help support this effort?	NA	As evidenced by the participants of the EAWG, the implementation of electric aircraft in Washington necessitates the involvement of a diverse stakeholder group composed of elected officials; federal, state, and local agencies/regulators; private manufacturers; various types of aviation users; and members of the public. Each of these groups can play a critical role in the integration of electric aircraft in Washington state.	Airport managers/sponsors should identify the key stakeholders that may play a role in the future of electric aircraft at the airport. This list could include: WSDOT Aviation and other modal managers Airport sponsor Airport board Existing on-airport tenants Major regional employers Metropolitan/regional planning organizations Local chamber of commerce/economic development agency or organization Airport pilot's group or other established user groups Local/regional colleges, universities, and other academic/research institutions
Are any existing on-airport tenants involved in an industry relevant to emerging aircraft technologies?	☐ Yes ☐ No ☐ Unknown	Airports across Washington are already home to literally hundreds of businesses involved in the aviation and aerospace industries. This sector tends to thrive in "clusters," which supports collaboration, innovation, and potentially shared supply chains.	Airports should consider their existing on-airport tenants to identify potential synergies with future electric aircraft implementation initiatives. The airport manager and tenant could work together to identify the type(s) of high-value use cases most appropriate for the airport environment and action steps that each could take to support the deployment of electric aircraft at the facility.
Opened Ended			
What specific assets and advantages does your airport and/ or community offer to make it a particularly appropriate location for the integration of electric aircraft?		Washington offers a robust system of 134 public-use airports, each of which is unique in terms of the facilities and services it offers, the type and frequency of activities it supports, and the community in which it is located. Airports should have a clear and well-defined value proposition about why their specific facility is well-suited to serve as an early adopter of this new technology. This can help gain support for electric aircraft amongst possible partners, community members, and elected officials as well as clarify next steps during the overall process.	Each of the questions in this matrix is designed to help airport managers/sponsors consider specific elements of their airport that may impact the future integration of electric aircraft. Each question should be carefully considered and responded to. That process will help illuminate a clear and concise message about the airport's potential future role in the integration of electric aircraft in Washington. The "Selection of Beta Test Sites" component of the Washington Electric Aircraft Feasibility Study provides additional information about specific high-value use cases associated with electric aircraft. The information presented may help clarify an airport's vision for itself in the marketplace.

Source: Kimley-Horn 2020

Section 3: Recommendations

The following section provides recommendations to support the development of and prepare for the implementation of electric aircraft. Separate recommendations are provided by airports and policymakers.

Airports

- Complete the airport self-assessment framework provided in **Table 5.2.1**. This tool provides a detailed source of information about the potential implications of electric aircraft at individual airports, as well as additional reference material to help airport managers/sponsors learn more. Airports that take the time to comprehensively consider each item's applicability to their own facility will be best positioned to take advantage of electric aircraft opportunities as they arise. The framework could also serve as the outline for a detailed airport-specific electric aircraft feasibility study.
- Consider if electric aircraft deployment should be incorporated into long-term planning efforts. Airport-specific forecasts of aviation activity are used to identify future infrastructure improvement needs. Airports should work with their planning team (internal and consultants) and the FAA to determine if electric aircraft should be included in the airport's future system requirements or forecasts of future demand.

Policymakers

- Consider the need for new zoning ordinances addressing UAM activities, which are likely be located off airport property and within urban cores.
- Permanently codify the CARB fund to provide airports with access to funds for hangar storage. Additional capacity is anticipated to become an acute need as electric aircraft gain market traction. Hangars are typically ineligible for state and federal grant funding, so providing an alternative means for airports to add storage capacity will be critical.
- Become involved in the long-term planning efforts of other transportation modes and communicate the potential future impacts of electric aircraft on the state's roadway network. Electric aircraft may reduce demands on highway networks, which could reduce capacity enhancement needs even if Washington's population continues to grow.
- Continue to support the development of a new commercial service airport through the Commercial Airport Siting Commission, which will likely become increasingly important as demand for air cargo and commercial passenger service increases over time.

Section 4: Summary

This component of the Washington Electric Aircraft Feasibility Study took a detailed look into the potential demands associated with electric aircraft at the statewide level—demonstrating that this technology may have a transformative effect not only on the way people and goods move through the air, but also on the entire multimodal transportation network in Washington state. This could provide congestion relief to roadway systems while causing additional constraints to certain airports that already experience operational delays based on existing aviation activity levels. While improving rapidly, electric aircraft technologies have not yet entered the market at a scale large enough to affect the system—giving airports and WSDOT Aviation ample time to prepare. The electric aircraft self-assessment framework helps airports identify the impacts of activity growth on their specific facilities, as well as resources to support their initiatives to address those impacts. Together, the demand and deployment analyses establish a solid foundation for planning at the system wide and airport-specific levels to ensure electric aircraft can be integrated into the NAS safely, efficiently, and provide the maximum benefit to all Washington residents and businesses.

Chapter 6:

Selection of Beta Test Site Airports

In previous tasks, the Washington State Department of Transportation (WSDOT) Aviation Division's Electric Aircraft Feasibility Study (or Feasibility Study) explored the state of the electric aircraft (electric aircraft) industry and evaluated potential implications of the technology's deployment from airport-specific and statewide perspectives. Designed to give a holistic and comprehensive overview of the many potential impacts of electric aircraft, these implications included economic, workforce development, airport infrastructure, and transportation network components. In this section, the findings of these previous tasks are brought together to provide actionable and data-driven guidance on the integration of electric aircraft into Washington's existing aircraft fleet and into the airport environment.

More specifically, this chapter identifies six priority airports for electric aircraft integration referred to as "beta test sites".[149] These beta test site airports may offer the greatest opportunities to maximize the benefits of electric aircraft for the following initial near-term high-value use cases:[150]

- Regional commuter for five passengers or less
- Regional aircraft for up to 15 passengers
- Pilot training
- Personal business use
- Air cargo

Using a multi-phase methodology developed in close coordination with WSDOT Aviation, this task identifies a specific airport with infrastructure and anticipated demand that most closely aligns with each use case. By deploying electric aircraft at these sites first, their implementation has the highest chance of success in terms of enhancing connectivity, supporting economic output, and leveraging the benefits offered by aircraft electrification. Identifying these sites now—prior to the widespread commercial deployment of electric aircraft—gives WSDOT Aviation and beta test site airports the opportunity to take actionable steps to turn the "vision" of electric aircraft into reality. Other airports interested in supporting electric aircraft can also use the findings and recommendations of this study to identify actions they may consider to support electric aircraft entry. WSDOT

149 While five use cases are identified by this Feasibility Study, WSDOT Aviation has requested the identification of six airports as beta test sites. Additionally, Seattle Tacoma International Airport (SeaTac) has already begun to prepare for the deployment of electric aircraft. The airport will not be selected as a beta test site during this process but is important in terms of the airport's role in the air transportation network as the other six airports are selected.

150 While larger electric aircraft are mentioned in other portions of this report, it is anticipated that the following will be the initial near-term high-value use cases.

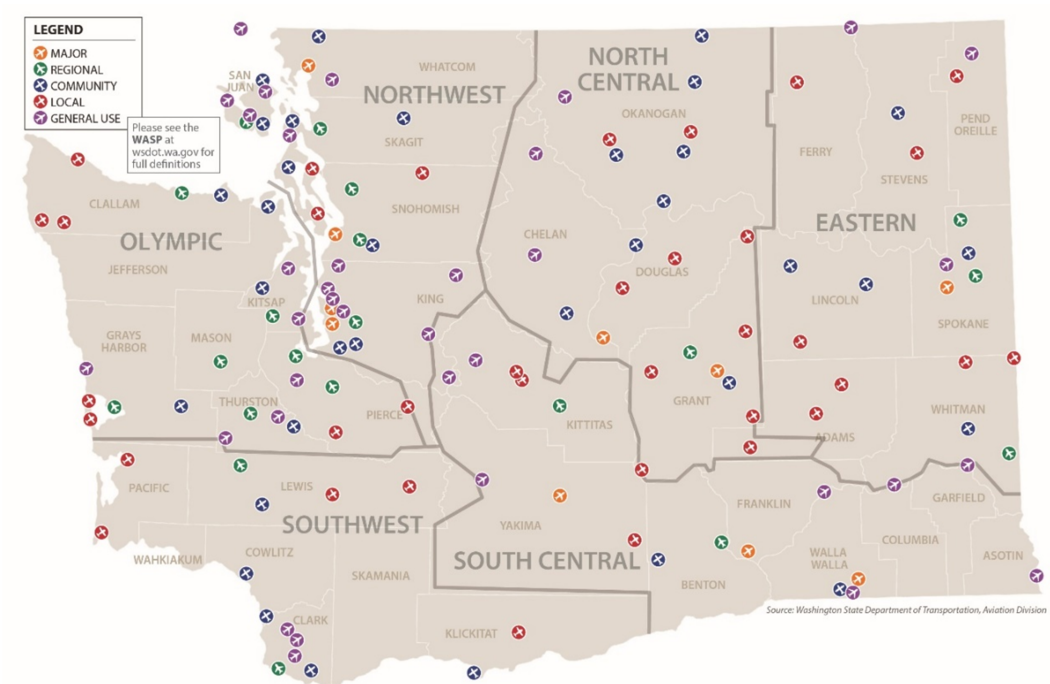
Aviation, beta test site airports, and potentially other interested airports should begin cultivating partnerships with industry and discussing the value and benefits of electric aircraft with local policymakers, aviation users, and the public. Airports may also need to consider infrastructure improvement needs to support aircraft operations, storage, and charging; additional pilots and passengers; and/or air cargo handling; as well as potential funding sources to address these needs. The potential implications of electric aircraft on existing revenue streams (i.e., fuel flowage fees, which often comprise a significant portion of on-airport revenue production) also need to be evaluated at the airport and statewide levels. These actionable next steps are discussed more fully in the "Recommendations for Electric Aircraft Advancement" component presented in subsequent chapters of this study.

This chapter first summarizes the methodology for beta test site identification, then looks more closely at each phase of the analysis. Airports identified as beta test sites for the deployment of electric aircraft are presented at the conclusion of this chapter.

Section 1: Methodology

As shown in **Figure 6.1.1**, the Washington state aviation system offers a robust and comprehensive network of 10 Primary commercial service and 124 general aviation (GA) public-use airports. Nearly all of Washington's counties hosts at least one airport, and all of WSDOT's six transportation regions is home to multiple facilities. Each airport supports a unique mix of aviation activities, users, and geographic regions and offers a set of facilities and services generally designed to support the type and frequency of activities that occur there. Commercial service airports typically offer at least a 5,000-foot-long runway, Jet A fuel, and conventional hangars to support jet activity; a terminal building for passengers; and (in many cases) air cargo handling facilities. Within the GA market, airport facilities and services vary widely. Some airports support mostly local users while others accommodate traffic from regional, domestic, and/or international origins. In this way, GA airports exist along a spectrum of sophistication, driven by the typical activities that occur there, the demands brought by surrounding communities, and other factors inherent to the airport itself and external considerations.

Figure 6.1.1 Washington System Airports by WSDOT Transportation Region



Source: WSDOT Aviation Economic Impact Study (AEIS) 2020

Like airports themselves, electric aircraft and each individual use case are optimally supported by a set of specific airport characteristics. At the broad scale, electric aircraft will generally require at least a 3,000-foot-long runway. Beta test site airports should also enhance transportation access and mobility across the state, be in a community with identifiable need for aviation services, and provide facilities to support additional pilots and/or passengers. On a more granular level, each use case will require an additional subset of airport characteristics. The regional commuter aircraft (up to 15 passengers) use case is anticipated to require a longer runway, terminal space for passengers, and conventional hangar space for aircraft storage. The pilot training and recreational use cases, however, are likely to require a shorter runway but should provide a building to conduct flight planning activities. The selection of beta test sites is designed to match the unique facilities, services, and other characteristics of individual airports with the specific needs of the high-value use cases presented at the beginning of this chapter.

Additionally, the following key considerations arose when developing the methodology to identify beta test site airports with WSDOT Aviation:

- **Data-driven approach with flexibility:** The foundation of the beta test site methodology should be objective, using clearly definable criteria. Concurrently, the methodology should have the flexibility to incorporate WSDOT Aviation's knowledge of the system and the unique needs, situations, and circumstances under which each airport operates.
- **Technological uncertainty:** At the time this methodology was developed (September 2020), the first electric aircraft were only beginning to come to market. One aircraft (Pipistrel's Alpha Electro) has an airworthiness certification from the Federal Aviation Administration (FAA), with several others in the final testing phases prior to entering commercial deployment. As such, the analyses presented here represent reasonable assumptions about the performance and operations of electric aircraft. However, a great deal of uncertainty remains, and requirements will likely change as the industry matures in the coming years.
- **Data availability:** The Washington Electric Aircraft Feasibility Study relies on existing data sources and previously published works including the 2017 Washington Aviation System Plan (WASP) (2015 study year) and 2020 Washington Aviation Economic Impact Study (AEIS) (2018 study year). As such, airport data may have changed, as airports regularly improve facilities. In all cases, the study team made every effort to obtain and apply up-to-date information to the greatest extent feasible within the scope of the study.
- **Understandable to multiple stakeholders:** Electric aircraft and their implications for the Washington aviation system and airports bring together a diverse array of stakeholders representing industry, policymakers, airport managers and sponsors, state and federal agency staff members, academic research institutions, and members of the public. As such, the methodology used to select beta test site airports is designed to be clear and intuitive to multiple audiences.

Because of the factors outlined above, a multiphase process was developed to select six beta test site airports in the state. As depicted in **Figure 6.1.2**, Phases I and II evaluate factors relevant to all electric aircraft, while Phases III and IV more closely evaluate the needs of the individual high-value use cases. A summary of the purpose and outcomes of each phase is as follows:

- **Phase I:** This phase identifies airports that have a least a 3,000-foot long runway. This serves as the baseline criterion for having the capacity to physically support most electric aircraft. Airports that meet this measure move forward in the selection process.
- **Phase II:** Airports are ranked using point values associated with various factors identified as generally supportive of all electric aircraft uses.
- **Phase III:** Based on the factors evaluated in Phase II, airports are ranked. Those with high scores are deemed the most eligible candidates as beta test site airports. High-ranking airports are evaluated for specific characteristics required to optimally support each high-value use case. Two to three airports per use case are selected to

move forward in the selection process, thus narrowing the field to no more than 18 facilities.

- **Final Selection:** The results of Phase II through IV are re-evaluated, and the final beta test site airports are selected by WSDOT Aviation.
- **Utility Coordination:** Local utility companies are identified. Beta test site airports will need to work with local providers to determine available electrical capacity to support electric aircraft. Power capacity may need to be added to support additional load depending on current capacity and existing demands. Third-party entities, including energy service companies (ESCOs) and renewable energy providers, may be able to offer airports alternative modes of project delivery and power generation to offset capital and infrastructure needs. FBOs could also conduct utility upgrades if they are going to be responsible for operating charging stations. In one example of an innovative delivery method at a Large Hub airport, a local utility provider is providing free light-duty charging stations with revenues returning to the airport in exchange for the carbon credits needed by the utility company.

This provides a systematic and data-driven approach to airport selection with an inherent flexibility to align use cases based on WSDOT Aviation's familiarity with the system and local needs and conditions. It is important to reiterate that much remains uncertain about the technical requirements of electric aircraft. Needs are highly generalized and based on the state of technology development at the time of this writing (November 2020). Phases are described in more detail in the sections that follow, including the relevancy of each factor and data sources used in the analysis.

Figure 6.1.2 Selection of Beta Test Site Methodology

Phase I: Baseline

Does the airport have at least a 3,000-foot runway?

If no, remove from analysis

Phase II: Points Analysis.

Rank airports based on these factors.

Conduct county-level demand analysis to identify potential need for aviation services

Airports receive a high/medium/low county-level score as follows:

- Population
- Population growth rate
- Annual per capita income
- Tourism-related economic impacts

Number of airports of supporting electric aircraft within 500 nautical miles (nm)

Existing on-airport aerospace manufacturing

Number of employees working in industries identified as “air reliant” within 10 miles of the airport

Presence of a fixed base operator (FBO) or pilot’s lounge

Previously supported scheduled commercial service

Availability of Jet A fuel*

Phase III: Assess Results

Rank and narrow potential airport list based on the scoring from Phase II. Reevaluate airports based on specific use cases.

Characteristics for consideration include:

- Geographic dispersion
- Airport interest

Final Selection Selection

Utility Coordination

Identify local utility providers that provide electricity to beta test site airports. Airports will need to work with local providers to determine available power capacity to support e-aircraft and implement power upgrades as warranted.

*Jet A or diesel fuel will be required by hybrid-electric aircraft. This aircraft will likely be the first to come to market and providing the facilities needed to support them is an important step in the transition to full-electric aircraft.

Source: Kimley-Horn

Section 2: Phase I: Baseline

The Electric Aircraft Feasibility Study was the key recommendation of the Electric Aircraft Working Group (EAWG) Report submitted to the Washington legislature in June 2019. The EAWG Report states that electric aircraft will be able to operate from at least a 3,000-foot long runway due to their smaller size and electric propulsion systems:

> *Electric aircraft propulsion lends itself well for STOL (Short Take-Off and Landing). Electric motors can be used to produce short bursts of large amounts of thrust to get the aircraft off the ground quicker. The motors can also be reversed on the landing touchdown to provide additional braking to slow the aircraft. Other electric aircraft designs that incorporate vertical take-off and landing technology such as a tilting wing and distribution of propulsion sources reduce the need for long runways even further.*

While runway minimums could decrease further as technology matures, this Feasibility Study assumes that a 3,000-foot long runway minimum is a reasonable assessment of the anticipated runway length requirements of most electric aircraft suitable for the high-value use cases in the near- and mid-terms. As such, this threshold has been set as the "baseline" requirement for a beta test site airport.

Based on data provided by the FAA's National Flight Data Center (NFDC, accessed August 2020), there are 81 airports in Washington potentially capable of supporting electric aircraft, including all commercial service and 72 GA airports.[151] These airports are listed in **Table 6.2.1** (based on airport classification first, then associated city) and illustrated in **Figure 6.2.1.** This represents 61 percent of all public-use airports in Washington. Airports are geographically dispersed across the state and represent a broad cross-section of airport types. This is demonstrated by the WASP classifications which are designed to indicate general levels of community demand, the primary aviation activities that occur at the airport, and critical aircraft.[152,153] These 82 airports will move forward into Phase II of the analysis.

151 This table does not include Sea-Tac. While the airport does meet the basic criteria of a 3,000-foot long runway, it will not be selected as a beta test site analysis for the purpose of this study and as such has been excluding from the evaluation process.

152 WSDOT Aviation (July 2017). "WASP". See Chapter 6: Classifications and Airport Metrics for more details about the WASP classification methodology.

153 Critical Aircraft is defined by the FAA as the most demanding type of aircraft to conduct at least 500 operations a year at an airport. Based on this aircraft's approach speed to the runway, tail height, and wingspan, an Airport Reference Code (ARC) is assigned and dictates the design standards for the airport. This aircraft is a good indicator of the types of activities that take place or are possible at an airport.

Table 6.2.1 Airports in Washington State Potentially Capable of Supporting Electric Aircraft

Associated City	FAA ID	Airport Name	Airport Classification	Longest RW (Feet)
Commercial Service				
Bellingham	BLI	Bellingham International	Major	6,700
Pasco	PSC	Tri-Cities	Major	7,711
Seattle	BFI	Boeing Field/King County International	Major	10,007
Seattle	SEA	Seattle-Tacoma International	Major	11,900
Spokane	GEG	Spokane International (Geiger Field)	Major	11,002
Walla Walla	ALW	Walla Walla Regional	Major	6,527
Wenatchee	EAT	Pangborn Memorial	Major	7,000
Yakima	YKM	Yakima Air Terminal (McAllister Field)	Major	7,604
Friday Harbor	FHR	Friday Harbor	Regional	3,402
Pullman/Moscow	PUW	Pullman/Moscow Regional	Regional	7,101
GA				
Everett*	PAE	Snohomish County (Paine Field)	Major	9,010
Moses Lake	MWH	Grant County International	Major	13,503
Arlington	AWO	Arlington Municipal	Regional	5,332
Bremerton	PWT	Bremerton National	Regional	6,000
Burlington/Mount Vernon	BVS	Skagit Regional	Regional	5,478
Chehalis	CLS	Chehalis-Centralia	Regional	5,000
Deer Park	DEW	Deer Park Municipal	Regional	6,100
Ellensburg	ELN	Bowers Field	Regional	5,590
Ephrata	EPH	Ephrata Municipal	Regional	5,500
Hoquiam	HQM	Bowerman Field	Regional	5,000
Olympia	OLM	Olympia Regional	Regional	5,500
Port Angeles	CLM	William R Fairchild International	Regional	6,347
Puyallup	PLU	Pierce County - Thun Field	Regional	3,651
Renton	RNT	Renton Municipal	Regional	5,382
Richland	RLD	Richland	Regional	4,009
Shelton	SHN	Sanderson Field	Regional	5,005
Spokane	SFF	Felts Field	Regional	6,000
Tacoma	TIW	Tacoma Narrows	Regional	5,002
Vancouver	VUO	Pearson Field	Regional	3,275
Anacortes	74S	Anacortes	Community	3,015
Auburn	S50	Auburn Municipal	Community	3,400
Brewster	S97	Anderson Field	Community	4,000
Chelan	S10	Lake Chelan	Community	3,506
Colfax	S94	Port of Whitman Business Air Center	Community	3,209
College Place	S95	Martin Field	Community	3,819
Kelso	KLS	Southwest Washington Regional	Community	4,391

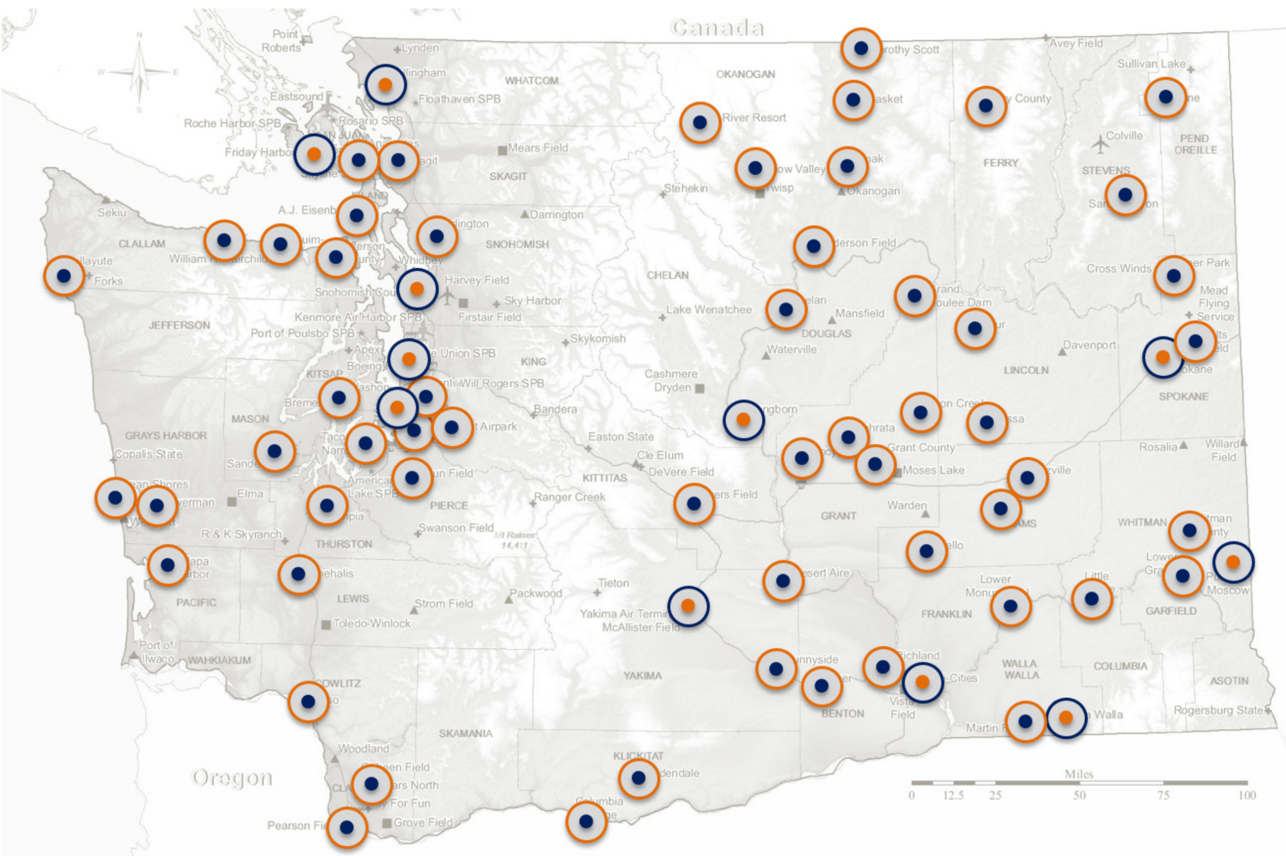
Associated City	FAA ID	Airport Name	Airport Classification	Longest RW (Feet)
Kent	S36	Norman Grier Field (Crest Airpark)	Community	3,288
Oak Harbor	OKH	AJ Eisenberg	Community	3,265
Oroville	0S7	Dorothy Scott	Community	4,017
Port Townsend	0S9	Jefferson County International	Community	3,000
Prosser	S40	Prosser	Community	3,452
Sequim	W28	Sequim Valley	Community	3,508
The Dalles	DLS	Columbia Gorge Regional / The Dalles Municipal	Community	5,097
Toledo	TDO	South Lewis County (Ed Carlson Memorial Field)	Community	4,479
Tonasket	W01	Tonasket Municipal	Community	3,053
Wilbur	2S8	Wilbur Municipal	Community	3,851
Chewelah	1S9	Sand Canyon	Local	3,446
Electric City	3W7	Grand Coulee Dam	Local	4,203
Goldendale	S20	Goldendale Municipal	Local	3,491
Ione	S23	Ione Municipal	Local	3,643
Lind	0S0	Lind Municipal	Local	3,197
Mattawa	M94	Desert Aire	Local	3,665
Ocean Shores	W04	Ocean Shores Municipal	Local	8,001
Odessa	43D	Odessa Municipal	Local	3,124
Omak	OMK	Omak Municipal	Local	4,667
Othello	S70	Othello Municipal	Local	4,000
Quillayute	UIL	Quillayute	Local	4,210
Quincy	80T	Quincy Municipal	Local	3,660
Republic	R49	Ferry County	Local	3,498
Ritzville	33S	Pru Field	Local	3,433
South Bend/Raymond	2S9	Willapa Harbor	Local	3,005
Sunnyside	1S5	Sunnyside Municipal	Local	3,423
Wilson Creek	5W1	Wilson Creek	Local	3,851
Winthrop	S52	Methow Valley State	Local	5,049
Anacortes	21H	Skyline SPB	General Use	5,000
Bellingham	0W7	Floathaven SPB	General Use	10,000
Clayton	C72	Cross Winds	General Use	3,800
Colfax	00W	Lower Granite State	General Use	3,400
Copalis	S16	Copalis State	General Use	3,560
Friday Harbor	W33	Friday Harbor SPB	General Use	10,000
Kahlotus	W09	Lower Monumental State	General Use	3,300
Kenmore	S60	Kenmore Air Harbor Inc	General Use	10,000
Mazama	W12	Lost River Resort	General Use	3,150
Poulsbo	83Q	Port of Poulsbo Marina SPB	General Use	12,000

Associated City	FAA ID	Airport Name	Airport Classification	Longest RW (Feet)
Renton	W36	Will Rogers Wiley Post Memorial SPB	General Use	5,000
Roche Harbor	W39	Roche Harbor SPB	General Use	5,000
Rosario	W49	Rosario SPB	General Use	10,000
Seattle	W55	Kenmore Air Harbor	General Use	5,000
Seattle	0W0	Seattle Seaplanes SPB	General Use	9,500
Starbuck	16W	Little Goose Lock and Dam State	General Use	3,400
Tacoma	W37	American Lake SPB	General Use	5,500
Vancouver	W56	Fly for Fun	General Use	3,275

Sources: FAA NFDC (accessed August 2020), WASP 2017

**Note: Paine Field (PAE) began scheduled commercial service in March 2019. However, the airport is classified as a GA facility by the FAA's current National Plan of Integrated Airport Systems (NPIAS) Report (2019-2023).*

Figure 6.2.1 Washington Airports Potentially Capable of Supporting Electric Aircraft



Source: WSDOT Aviation 2020

Section 3: Phase II: Points Analysis

Once the baseline analysis to determine all airports potentially capable of accommodating electric aircraft was established in Phase I, Phase II used a series of metrics determined to be most impactful in terms of maximizing the benefits associated with electric aircraft to score the 82 airports. Socioeconomic variables including population and per capita income offer one of the best indications of demand for air service. The level of connectivity offered by each airport is also an important consideration. Advocates of electric aircraft emphasize the technology's anticipated ability to fill gaps in the existing transportation network and enhance mobility and access across the state. This is particularly important for certain rural areas that are limited in terms of the ability to quickly, conveniently, and cheaply travel to the urban core. Existing on-airport activities conducive to electric aircraft provide an established base of aviation users and advocates. These activities also indicate an airport's economic vitality and contribution to its surrounding community—which also contributes to passenger demand. Existing facilities and services that support electric aircraft, pilots, and passengers will minimize additional investment needs, which is advantageous in terms of both time and funding. As such, the Electric Aircraft Feasibility Study identified the following factors to evaluate an airport's ability to successfully support electric aircraft, organized in terms of overarching thematic category:

- County-level demand analysis
    - Population
    - Annual per capita income
    - Percent population change (2010 – 2020)
    - Tourism-related economic impacts
- Connectivity
    - Airports within 500 nm potentially capable of supporting electric aircraft
    - Previously supported scheduled commercial service
- Economic vitality
    - Existing on-airport aerospace manufacturing
    - Number of employees working in industries identified as "air reliant" within 10 miles of the airport
- Infrastructure and services
    - Presence of an FBO or pilot's lounge
    - Availability of Jet A fuel[154]

154 While Jet A will not be required by full electric aircraft, it will be required by many hybrid-electric aircraft. This technology is anticipated to be commercially deploy prior fully electric, especially for regional commuter aircraft.

Each of these categories and factors is discussed in further detail in the sections that follow. Each subsection below contains more detailed information about data sources and points awarded to airports that meet each criterion. Total points awarded by airport are presented at the end of this section.

County-Level Demand Analysis

The ultimate success and profitability of electric aircraft will be driven by the industry's adoption of the technology and its ability to fill a need within the market—particularly if that entails shifting passengers away from existing travel patterns (e.g., car or rail), thereby creating new demands that previously did not exist. In a 2009 Airport Cooperative Research Program (ACRP) report entitled "Passenger Air Service Development Techniques," authors provided a simple answer to a question fundamental to the long-term market success of electric aircraft. Responding to the question, "How do air carriers decide which airports they will service?", authors wrote, "Airlines serve markets in which they can generate profits. In making those determinations, airlines consider many factors… Airlines are not motivated by altruistic concerns about local economic development".[155] The basic underpinning of those factors is passenger demand. The study notes, "There are fundamental and direct relationships between population, economic strength, the availability of competitive alternatives, and the amount of air service that carriers believe a community can support. All else being equal, communities with more population, employment, and income will demand more air service".[156]

Similarly, a Government Accountability Office (GAO) report, "Air Service Trends at Small Communities Since October 2000" quantified the impact of various economic factors on air service.[157] The report found that employment (or population), manufacturing earnings, minimum distance to a low cost carrier, and per capita income had a positive effect on the level of air service received by a small community.[158] Proximity or association with tourist destinations can also cause a significant uptick in demand.

As such, the Electric Aircraft Feasibility Study selected socioeconomic variables that indicate demand for aviation services to evaluate beta test site airports. The study used county-level data, as this information was readily available and is assumed to represent an airport's average catchment area. The study recognizes that this is a simplified airport market area. Airports and/or jurisdictions pursuing regional air service development must conduct a more detailed evaluation of existing and latent (i.e., unmet) demand within the surrounding market. **Table 6.3.1** summarizes the data sources used in the analysis.

155 Martin, Steve (2009). "ACRP Report No. 18: Air Service Development Techniques". Available online at https://www.nap.edu/download/14309 (accessed August 2020) p. 24

156 Ibid. p. 47

157 GAO-02-432. Commercial Aviation: Air Service Trends at Small Communities Since October 2000". Available online at https://www.gao.gov/assets/240/234156.pdf (accessed September 2020).

158 Ibid. p. 58

Table 6.3.1 County-level Demand Analysis Data Sources

Demand Factor	Data Source (year)*	Additional Notes
Population	U.S. Census Bureau [estimated] (2020)	None
Annual per capita income	U.S. Bureau of Economic Analysis (BEA) (2019)	None
Tourism-related economic impacts	Dean Runyan Associates. Washington State Travel Impacts & Visitor Volume, 2000-2017p. Prepared for the Washington Tourism Alliance. (2017)	Impacts presented in $Millions for employee earnings attributed to travel by out of state and international visitors.
Population growth	Washington Office of Financial Management, Forecasting and Research Division (2020)	Forecasts prepared in accordance with the Washington Growth Management Act and represents the period of April 1, 2010 to April 1, 2020.

Sources: Kimley-Horn 2020, U.S. Census Bureau 2020, U.S. BEA 2019, Dean Runyan Associates 2017, Washington Office of Financial Management 2020

**Note: Data is the most current available in all cases.*

To rank airports in terms of county-level demands, the Feasibility Study first developed the state average for each demand factor (e.g., average population for all counties in Washington with an airport). This was needed to translate different units (e.g., dollars, residents, percent change) to the same unit of measure so they could be evaluated consistently. For example, the study calculated that the average 2020 population of counties in Washington with an airport is 387,736. King County, Washington's most populous county, has 2,260,800 residents. Columbia County, the least populous county, has 4,185 residents. As such, King County is home to 583 percent of the state average, while Columbia County is home to 1.08 percent of the state average. This "percent of state average" methodology was applied to the four county-level demand indicators. Each percent total was summed, then counties were tiered (tier 1 through tier 4). A points value was then assigned to each tier, with 12 points assigned to tier 1 and four points assigned to Tier 4. **Table 6.3.2** provides the total numeric value for each demand indicator, percent of statewide total, and analysis outcomes in terms of percent total and tier ranking and points by county.

Table 6.3.2 County-level Demand Analysis by County

	Population		Per Capita Income		Tourism-related Economic Impacts		Population Change 2010-2020		Outcomes	
County	Number	Percent Average	Dollars ($)	Percent Average	Earnings ($Millions)	Percent Average	Percent Change (%)	Percent Average	Percent Average Totals	Tier (+Points)
Adams	20,450	5.27%	$42,800	82.29%	$8.30	1.53%	9.19%	85.02%	174.11%	Tier 3 (+6)
Asotin	22,640	5.84%	$47,104	90.57%	$11.20	2.06%	4.70%	43.48%	141.95%	Tier 4 (+3)
Benton	205,700	53.05%	$47,465	91.26%	$108.40	19.98%	17.42%	161.16%	325.45%	Tier 2 (+9)
Chelan	79,660	20.54%	$54,763	105.29%	$190.80	35.17%	9.95%	92.05%	253.06%	Tier 2 (+9)
Clallam	76,770	19.80%	$46,120	88.67%	$93.90	17.31%	7.51%	69.48%	195.26%	Tier 3 (+6)
Clark	499,200	128.75%	$53,423	102.72%	$137.40	25.33%	17.36%	160.60%	417.39%	Tier 1 (+12)
Columbia	4,185	1.08%	$50,073	96.28%	$2.30	0.42%	2.62%	24.24%	122.02%	Tier 4 (+3)
Cowlitz	110,500	28.50%	$44,990	86.50%	$51.50	9.49%	7.90%	73.08%	197.58%	Tier 3 (+6)
Douglas	43,750	11.28%	$41,508	79.81%	$13.90	2.56%	13.84%	128.04%	221.69%	Tier 2 (+9)
Ferry	7,910	2.04%	$36,071	69.35%	$4.00	0.74%	4.75%	43.94%	116.07%	Tier 4 (+3)
Franklin	96,760	24.96%	$37,390	71.89%	$68.20	12.57%	23.79%	220.09%	329.50%	Tier 2 (+9)
Grant	100,130	25.82%	$39,789	76.50%	$87.00	16.04%	12.35%	114.25%	232.62%	Tier 2 (+9)
Grays Harbor	74,720	19.27%	$40,429	77.73%	$117.40	21.64%	2.64%	24.42%	143.07%	Tier 4 (+3)
Island	85,530	22.06%	$55,724	107.14%	$70.60	13.01%	8.95%	82.80%	225.01%	Tier 2 (+9)
Jefferson	32,190	8.30%	$52,580	101.10%	$36.00	6.64%	7.76%	71.79%	187.82%	Tier 3 (+6)
King	2,260,800	583.08%	$90,438	173.88%	$4,598.10	847.62%	17.06%	157.83%	1762.41%	Tier 1 (+12)
Kitsap	272,200	70.20%	$56,244	108.14%	$100.70	18.56%	8.39%	77.62%	274.52%	Tier 2 (+9)
Kittitas	48,140	12.42%	$42,603	81.91%	$69.10	12.74%	17.66%	163.38%	270.44%	Tier 2 (+9)
Klickitat	22,770	5.87%	$48,654	93.55%	$12.20	2.25%	12.07%	111.66%	213.33%	Tier 2 (+9)
Lewis	80,250	20.70%	$43,453	83.55%	$64.20	11.83%	6.35%	58.75%	174.82%	Tier 3 (+6)
Lincoln	11,050	2.85%	$46,312	89.04%	$6.40	1.18%	4.54%	42.00%	135.07%	Tier 4 (+3)
Mason	65,650	16.93%	$42,767	82.23%	$37.20	6.86%	8.16%	75.49%	181.51%	Tier 3 (+6)
Okanogan	43,130	11.12%	$42,462	81.64%	$62.90	11.60%	4.89%	45.24%	149.60%	Tier 4 (+3)
Pacific	21,840	5.63%	$41,740	80.25%	$45.90	8.46%	4.40%	40.71%	135.05%	Tier 4 (+3)
Pend Oreille	13,850	3.57%	$41,664	80.11%	$7.50	1.38%	6.53%	60.41%	145.47%	Tier 4 (+3)
Pierce	900,700	232.30%	$52,114	100.20%	$338.00	62.31%	13.26%	122.67%	517.47%	Tier 1 (+12)
San Juan	17,340	4.47%	$76,749	147.57%	$72.80	13.42%	9.96%	92.14%	257.60%	Tier 2 (+9)
Skagit	130,450	33.64%	$53,060	102.02%	$106.60	19.65%	11.59%	107.22%	262.53%	Tier 2 (+9)
Snohomish	830,500	214.19%	$55,888	107.46%	$306.30	56.46%	16.42%	151.90%	530.02%	Tier 1 (+12)
Spokane	522,600	134.78%	$46,466	89.34%	$358.50	66.09%	10.90%	100.84%	391.05%	Tier 1 (+12)
Stevens	45,920	11.84%	$39,505	75.96%	$19.70	3.63%	5.49%	50.79%	142.22%	Tier 4 (+3)
Thurston	291,000	75.05%	$51,684	99.37%	$85.50	15.76%	15.36%	142.10%	332.28%	Tier 2 (+9)
Walla Walla	62,580	16.14%	$46,144	88.72%	$39.40	7.26%	6.46%	59.76%	171.89%	Tier 3 (+6)
Whatcom	228,000	58.80%	$48,792	93.81%	$159.80	29.46%	13.35%	123.50%	171.89%	Tier 3 (+6)
Whitman	50,480	13.02%	$40,935	78.71%	$31.20	5.75%	12.74%	117.86%	305.58%	Tier 2 (+9)
Yakima	258,200	66.59%	$43,379	83.40%	$112.50	20.74%	6.15%	56.89%	215.34%	Tier 2 (+9)
State Average	387,736	100.00%	$52,010	100.00%	$542.47	100.00%	10.81%	100.00%	400%	Tier 2 (+9)

Sources: U.S. Census Bureau 2012, U.S. BEA 2020, Dean Runyan Associates 2017, Washington Office of Financial Management 2020

Connectivity

The emergence of electric aircraft as a component of the U.S. fleet will be first driven by aligning the characteristics of specific aircraft with routes that provide the demand necessary to keep operations efficient and cost-effective. As such, it was important to evaluate potential destinations within range of the beta test site airports. An airport that provides ample demand and infrastructure but is beyond the range of electric aircraft in the near- and mid-terms would not be an ideal candidate for initial deployment. As such, this factor assessed the number of destination airports potentially capable of supporting electric aircraft within 500 nm of 10 airports geographically dispersed across Washington. This assessment applies the findings of an Airport Connectivity Assessment, which identified the number of destination airports potentially capable of supporting electric aircraft within six different radii between 50 and 1,000 nm. Two sample maps developed for Skagit Regional (BVS) are shown in **Figure 6.3.1** and **Figure 6.3.2**. The 500 nm radii applied in the selection of beta test site airports appears in **Figure 6.3.2**.

Figure 6.3.1 BVS, 50 – 200 NM

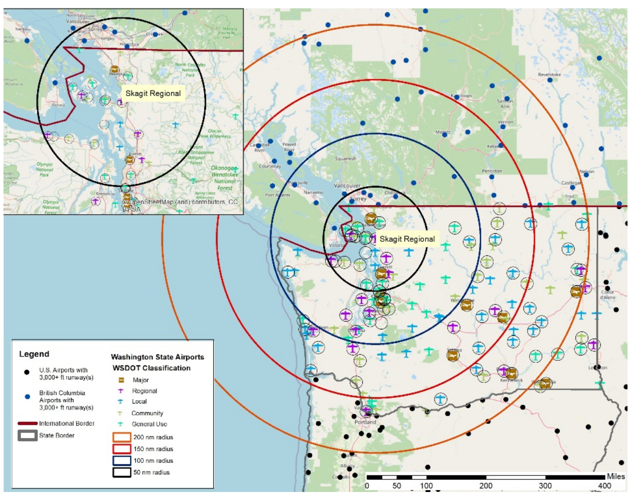
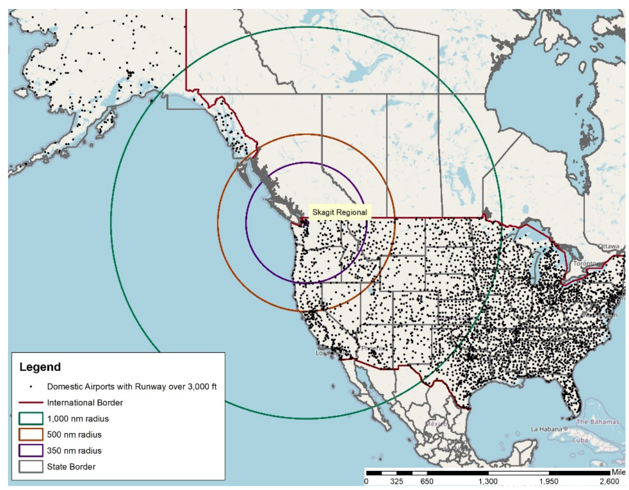


Figure 6.3.2 BVS, 350 – 1,000 NM



Sources: ArcGIS 2020, FAA NFDC 2020, WSP 2020

The 500 nm range is assumed to be a reasonable threshold for evaluation based on the current state of technology and generally aligns with the anticipated range of the most commercially viable mid-size passenger jets in the near- to mid-term (such as the Eviation Alice, which is currently the only aircraft under certification in the next five to 10 years that will meet that range). This assumption reflects ideal conditions and power reserves not included.

The 10 airports in the analysis were then associated with the remaining 72 airports in this phase by proximity (associated by county and then WSDOT Transportation Region, in that order of priority). Airports with a higher number of airports within range may be more attractive to potential air carriers and pilots and offer a greater level of travel flexibility and opportunity.

As shown in **Table 6.3.3**, there are between 363 and 558 airports potentially within 500 nm of Washington airports (based on the 10 geographically dispersed airports analyzed), with airports in the eastern portion of the state having access to more airports based on their geographic location. Destination airports are counted only once (i.e., a destination airport located 25 nm away from the study airport is only presented in the 50 nm results—not in 50 nm and 100 nm results, and so forth). In this way, results build upon one another for the cumulative total.

Table 6.3.3 Number of Airports Capable of Supporting Electric Aircraft by Range

			Number of Airports by Evaluation Radii (nm)							
Associated City	Airport	FAA ID	50	100	150	200	350	500	Cumulative 500 nm Total	Tier (+Points)
Burlington	Skagit Regional	BVS	19	17	21	31	117	158	363	Tier 4 (+4)
Hoquiam	Bowerman Field	HQM	9	27	28	26	111	196	397	Tier 3 (+6)
Moses Lake	Grant County International	MWH	12	28	42	53	164	174	473	Tier 2 (+8)
Omak	Omak Municipal	OMK	9	14	53	27	147	166	416	Tier 3 (+6)
Port Angeles	William R Fairchild International	CLM	16	23	10	33	105	181	368	Tier 4 (+4)
Seattle	Boeing Field/King County International	BFI	21	25	28	60	120	179	463	Tier 3 (+6)
Spokane	Spokane International (Geiger Field)	GEG	12	28	34	40	191	180	485	Tier 2 (+8)
Vancouver	Pearson Field	VUO	12	18	36	35	250	207	558	Tier 1 (+12)
Walla Walla	Walla Walla Regional	ALW	5	19	33	30	241	201	529	Tier 2 (+8)
Yakima	Yakima Air Terminal (McAllister Field)	YKM	6	16	44	35	227	201	529	Tier 2 (+8)

Sources: WSP 2020, ArcGIS 2020, FAA NFDC 2020

Pearson Field (VUO) north of Portland, OR, in Clark County offers access to the highest number of airports capable of supporting electric aircraft within 500 nm at 558 unique facilities. Skagit Regional (BVS) in Skagit County offers the least at 363, with the remaining airports providing access to an average of 450 facilities in Washington and across the western U.S. and Canada. Like the county-level demand analysis, each airport received a tier ranking from 1 to 4 based on the number of airports within 500 nm of its associated airport. Tier 1 airports, with 558 destinations potentially within range (airports in Clark County and potentially within the Southwest WSDOT Transportation Region), received 12 points. Tier 4 airports, with between 363 and 368 airports within 500 nm (airports

Skagit and Clallam counties and potentially within the Northwest WSDOT Transportation Region), received four points.

Additionally, this assessment identified airports that previously offered scheduled commercial service.[159] These airports already offer the baseline landside infrastructure to support commercial air passengers and are located in communities that relied on the mobility offered by commercial flight. In many cases, the loss of air service in small markets can have devastating effects on local economies. The availability of scheduled air service is often a key factor in where businesses choose to locate. If air service is lost, these businesses may choose to move elsewhere—resulting in lost jobs, wages, and economic output in multiple sectors. The effects of lost commercial service are discussed in more detail in the “Demand and Deployment” component of this Feasibility Study. In Washington state, Port Angeles/William R Fairchild International (CLM) and Moses Lake/ Grant County International (MWH) are both airports that have lost commercial service. Each of these airports received an additional six point in the analysis.

Economic Vitality

Washington state has long been recognized as a leader in the related industries of aviation and aeronautics. The state is home to some of the most cutting-edge industries in the field—many of which are working on electric aircraft research and development. The Washington State Department of Commerce reports that more than 1,400 aerospace-related companies are in the state.[160] Many of those companies are directly reliant on Washington’s airport system, either by being located on airport property or serving in the supply chain of those that are. Aerospace companies often cluster together—offering benefits in terms of partnerships, collaboration, and supply chain efficiencies. This trend is witnessed at the state level as well at individual airports.

Because of the benefits of co-location, the Washington Electric Aircraft Feasibility Study factored the presence of on-airport aerospace manufacturing into the beta test site airport evaluation. Additionally, the average aerospace employee earns $116,700 annually—over twice the average wage in Washington state.[161] The GAO study cited previously specifically found that “a community with $250,000 more in manufacturing earnings received 4.8 more jet departures per week than an otherwise similar community” (that

159 This analysis looks specifically at airports that supported air carriers with a Part 121 certificate from the FAA. A Part 121 carrier provided regularly scheduled commercial air service. Commuter and on-demand operators are certified under Federal Aviation Regulations (FAR) Part 135.

160 http://choosewashingtonstate.com/why-washington/our-key-sectors/aerospace/

161 Community Attributes, Inc. (March 2019). “Aerospace in Washington: Economic Impacts and Workforce Analysis”. Available online at https://aerospaceworksforwa.com/wp-content/uploads/2019/03/CAI.AWW-Econ-Impacts-and-Talent-Pipeline.Report.2019-0307.pdf (accessed August 2020).

is, after controlling for distance to a low cost carrier and per capita income).[162] The GAO study was referring to manufacturing more broadly; however, it is likely that aerospace manufacturing employees could have an even greater impact on demand due to their high wages and potential interest in the field. Data for this assessment were obtained from the Washington AEIS, which gathered on-airport employment details by industry type from all airports in the state aviation system.

As a second factor with the economic vitality category, the Washington Electric Aircraft Feasibility Study considered the number of "export industry" employees working within 10 miles of each airport. Export industries comprise the professional, technical, and scientific service and manufacturing business sectors. These industries have a particularly high propensity to use aviation services for business travel and air cargo, thereby serving as an appropriate and effective indicator of local economic activity. Data for this factor was also obtained from the Washington AEIS using ESRI's Community Analyst Business Summary reports. These reports provided the number of export industry employees within a 10-mile radius of each Airport Reference Point.

Table 6.3.4 summarizes the sources use to gather data for factors within the economic vitality assessment, as well as the number of points available for each factor.

Table 6.3.4 Economic Vitality Data Sources

Factor	Data Source (year)	Available Points
On-airport aerospace manufacturing	Washington AEIS (2018)	Yes = +6 / No = +0
Export industry employees	ESRI Community Analyst Reports (2018) as obtained by the Washington AEIS	Airports delineated into six tiers, with airports receiving between 0 – 12 points

Sources: Kimley-Horn 2020, Washington AEIS 2020, ESRI 2019

Infrastructure and Services

Airports that offer services for pilots and passengers generally receive more traffic. These locations provide a reason to touchdown—whether for fuel or simply a place to rest and plan one's next flight. Airports that are determined to be capable of supporting electric aircraft, especially those selected as beta test sites, will likely witness an uptick in operations as electric aircraft come online and are regularly flying in Washington. It will be important for airports wanting to attract electric aircraft activity to offer facilities for pilot and passenger comfort and reliable access to ground-based communications (use-case-specific infrastructure needs will be addressed in Phase IV). The beta test site airports may also require the installation of electric aircraft charging stations. While exact specifications are currently unknown, an existing structure (such as offered by an FBO or pilot's lounge)

162 GAO 02-243 (2002), p. 58

could make this process more seamless—particularly if the building already offers adequate utility connections (depending on ownership and other variables). Additionally, the airport may receive more ground-based travel as WSDOT staff, industry stakeholders, local policymakers, and interested member of the public travel to the airport to see electric aircraft in action. A pilot's lounge, FBO, or both would provide visitors with a place to regroup and stay out of the elements during inclement weather.

While Jet A fuel is not required by all-electric aircraft, hybrid electric aircraft are anticipated to be first to market. This is especially likely for larger aircraft capable of carrying nine passengers or more. While the need for Jet A fuel may diminish in the long-term, it is an important consideration during the transition period. Additionally, the availability of Jet A is an indicator of the type and frequency of aviation activity levels as well as the economic conditions of surrounding communities.

The data sources used to evaluate the two factors within the infrastructure and services category are provided in **Table 6.3.5**. In all cases, airports received six points for a response of "Yes" (indicating that the airport offers that facility or service) or zero points for a response of "No" (indicating the airport does not offer that facility or service).

Table 6.3.5 Infrastructure and Services Data Sources

Factor	Data Source (year)*	Available Points
Availability of Jet A fuel	FAA NFDC (2020)	Yes = +6 / No = +0
Pilot's lounge or FBO	WSDOT Airport Information System (AIS) (2016), Washington AEIS (2018), respectively	Yes = +6 / No = +0

**Note: The data is the most current available at the time of writing. Sources: Kimley-Horn 2020, Washington AEIS 2020, FAA NFDC 2020, WSDOT AIS 2016*

Section 4: Phase III: Assess Results

Based on the methodology and data outlined in the sections above, Washington's 81 airports capable of supporting electric aircraft were ranked to determine their ability to optimally leverage the benefits of electric aircraft to support the state's connectivity and economic vibrancy. The results of the analysis are shown in **Table 6.4.1**, with highest ranking airports illustrated in green moving down the spectrum of colors to red, which indicates airports that are not ideally suited as beta test site facilities. The majority of "green" airports fall within Washington's two highest airport classifications (Major and Regional), with only Southwest Washington Regional (Community) appearing as an outlier. Kenmore Air Harbor Inc. (S60) is classified as a General Use airport. However, the airport provides scheduled and unscheduled commercial service and is amongst the busiest airports in the state. It is only classified as a General Use airport because it is a seaplane base, which automatically classifies it as such. The next General Use airport in the ranking is Will Rogers Wiley Post Memorial SPB (W36), which is located adjacent to and shares facilities with Renton Municipal (RNT). RNT shares the top position with Boeing Field/King County International (BFI), Spokane International (Geiger Field) (GEG), Snohomish County (Paine Field) (PAE), and Felts Field (SFF), followed by Moses Lake/Grant County International (MWH).

Table 6.4.1 Selection of Beta Test Sites, Preliminary Results

Associated City	FAA ID	Airport	Washington Classification	Final Points Ranking
Seattle	BFI	Boeing Field/King County International	Major	48
Spokane	GEG	Spokane International (Geiger Field)	Major	48
Everett	PAE	Snohomish County (Paine Field)	Major	48
Renton	RNT	Renton Municipal	Regional	48
Seattle	SEA	Seattle-Tacoma International*	Major	48
Spokane	SFF	Felts Field	Regional	48
Moses Lake	MWH	Grant County International	Major	47
Arlington	AWO	Arlington Municipal	Regional	44
Kelso	KLS	Southwest Washington Regional	Community	44
Tacoma	TIW	Tacoma Narrows	Regional	44
Wenatchee	EAT	Pangborn Memorial	Major	43
Pullman/ Moscow	PUW	Pullman/Moscow Regional	Regional	43
Yakima	YKM	Yakima Air Terminal (McAllister Field)	Major	43
Chehalis	CLS	Chehalis-Centralia	Regional	42
Kenmore	S60	Kenmore Air Harbor Inc	General Use	42
Vancouver	VUO	Pearson Field	Regional	42

Associated City	FAA ID	Airport	Washington Classification	Final Points Ranking
Auburn	S50	Auburn Municipal	Community	40
Burlington/ Mount Vernon	BVS	Skagit Regional	Regional	39
Olympia	OLM	Olympia Regional	Regional	39
Pasco	PSC	Tri-Cities	Major	39
Richland	RLD	Richland	Regional	39
Anacortes	74S	Anacortes	Community	37
Renton	W36	Will Rogers Wiley Post Memorial SPB	General Use	36
Seattle	W55	Kenmore Air Harbor	General Use	36
Port Angeles	CLM	William R Fairchild International	Regional	36
Bellingham	0W7	Floathaven SPB	General Use	35
Bellingham	BLI	Bellingham International	Major	35
Chelan	S10	Lake Chelan	Community	35
Vancouver	W56	Fly for Fun	General Use	34
Ellensburg	ELN	Bowers Field	Regional	33
Walla Walla	ALW	Walla Walla Regional	Major	32
Deer Park	DEW	Deer Park Municipal	Regional	32
The Dalles	DLS	Columbia Gorge Regional / The Dalles Municipal	Community	31
Bremerton	PWT	Bremerton National	Regional	31
Seattle	0W0	Seattle Seaplanes SPB	General Use	30
Puyallup	PLU	Pierce County - Thun Field	Regional	30
Toledo	TDO	South Lewis County (Ed Carlson Memorial Field)	Community	30
Sunnyside	1S5	Sunnyside Municipal	Local	29
Quincy	80T	Quincy Municipal	Local	27
Prosser	S40	Prosser	Community	27
Port Townsend	0S9	Jefferson County International	Community	26
College Place	S95	Martin Field	Community	26
Shelton	SHN	Sanderson Field	Regional	26
Tacoma	W37	American Lake SPB	General Use	26
Poulsbo	83Q	Port of Poulsbo Marina SPB	General Use	25
Hoquiam	HQM	Bowerman Field	Regional	25
Oak Harbor	OKH	AJ Eisenberg	Community	25
Kent	S36	Norman Grier Field (Crest Airpark)	Community	24
Othello	S70	Othello Municipal	Local	24
Colfax	00W	Lower Granite State	General Use	23
Wilbur	2S8	Wilbur Municipal	Community	23
Electric City	3W7	Grand Coulee Dam	Local	23

Associated City	FAA ID	Airport	Washington Classification	Final Points Ranking
Wilson Creek	5W1	Wilson Creek	Local	23
Ephrata	EPH	Ephrata Municipal	Regional	23
Sequim	W28	Sequim Valley	Community	22
South Bend/ Raymond/	2S9	Willapa Harbor	Local	21
Friday Harbor	FHR	Friday Harbor	Regional	21
Omak	OMK	Omak Municipal	Local	21
Goldendale	S20	Goldendale Municipal	Local	21
Winthrop	S52	Methow Valley State	Local	21
Lind	0S0	Lind Municipal	Local	20
Ritzville	33S	Pru Field	Local	20
Clayton	C72	Cross Winds	General Use	20
Anacortes	21H	Skyline SPB	General Use	19
Starbuck	16W	Little Goose Lock And Dam State	General Use	17
Chewelah	1S9	Sand Canyon	Local	17
Odessa	43D	Odessa Municipal	Local	17
Mattawa	M94	Desert Aire	Local	17
Republic	R49	Ferry County	Local	17
Colfax	S94	Port of Whitman Business Air Center	Community	17
Oroville	0S7	Dorothy Scott	Community	15
Tonasket	W01	Tonasket Municipal	Community	15
Friday Harbor	W33	Friday Harbor SPB	General Use	15
Roche Harbor	W39	Roche Harbor SPB	General Use	15
Rosario	W49	Rosario SPB	General Use	15
Kahlotus	W09	Lower Monumental State	General Use	14
Ocean Shores	W04	Ocean Shores Municipal	Local	13
Quillayute	UIL	Quillayute	Local	12
Ione	S23	Ione Municipal	Local	11
Copalis	S16	Copalis State	General Use	9
Brewster	S97	Anderson Field	Community	9

**Note: As noted previously, Sea-Tac will not be selected as a beta test site airport. Sources: U.S. Census Bureau 2020, U.S. BEA 2020, Dean Runyan Associates 2017, Washington Office of Financial Management 2020, ArcGIS 2019, WSDOT AIS 2016, FAA NFDC 2020, Washington AEIS 2020, WSP 2020, Kimley-Horn 2020*

WSDOT Aviation determined that airports receiving a score of 36 points or higher should proceed to the next stage of the analysis. These 25 airports are depicted in **Figure 6.4.1**. Many of these high-ranking airports are located along the I-5 corridor, which runs from the Canadian border in WSDOT's Northwest Region, through the urban core of Seattle/ Tacoma, then south before continuing into Oregon near Portland. There are at least two airports in each WSDOT Transportation Region. This provides an opportunity to ensure geographic coverage to develop of a system or network of airports capable of supporting electric aircraft across Washington state.

Figure 6.4.1 Airports Receiving ≥36 Points During Phase II of the Beta Test Site Evaluation

Sources: U.S. Census Bureau 2020, U.S. BEA 2020, Dean Runyan Associates 2017, Washington Office of Financial Management 2020, ArcGIS 2019, WSDOT AIS 2016, FAA NFDC 2020, Washington AEIS 2020, WSP 2020, Kimley-Horn 2020

While the ultimate deployment of electric aircraft will be driven by market and industry readiness, airports selected as beta test sites are expected to start incorporating electric aircraft into their planning processes. Beta test sites will also play an active role in building a market for such operations. As such, sponsor willingness to support electric aircraft was a critical decision-making factor during the selection process. Airports selected as beta test sites will partner with WSDOT Aviation and other electric aircraft stakeholders to take actionable steps to turn the "vision" of electric aircraft into reality. Expectations of beta test site airports include (but are not limited to) the following:

- Pursuing airside and landside infrastructure and service improvements to support electric aircraft and key high-potential use cases such as pilot training, regional commercial air service, business/recreational flying, and/or air cargo (as required)
- Participating in the Electric Aircraft Working Group (EAWG)
- Actively advocating for and championing electric aircraft at local and statewide levels

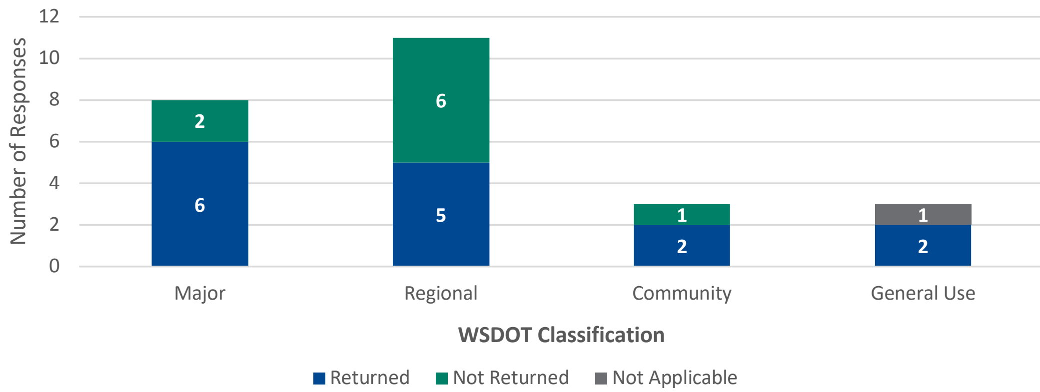
Funding is anticipated to come from a variety of sources including sponsor investment, public/private partnerships, and state grants and loans. Airports included in the NPIAS are also eligible to receive funding through the federal Airport Improvement Program (AIP), although the need must be justified by aviation activities anticipated within five years. Additional information about potential funding sources to support electric aircraft are provided in the “Environmental Impacts and Economic Benefits” section of this Feasibility Study.

To gauge sponsor willingness to serve as beta test sites, WSDOT Aviation distributed an “Electric Aircraft Interest Questionnaire”. The questionnaire asked for information regarding:

- Level of support for electric aircraft from the airport manager, decision-makers, and existing users
- Actionable steps that the airport has already taken to support electric aircraft
- Aviation activities currently occurring at the airport
- Interest in or ability to support the five electric aircraft high-value use cases

Airports were also able to provide supplemental information discussing their interest in becoming a beta test site, including specific details about how they believe electric aircraft could benefit their community and local businesses and enhance the air connectivity of Washington state. The number of responses received by WSDOT classification is depicted in **Figure 6.4.2**. Fifteen of the 25 questionnaires distributed were returned. Will Rogers Wiley Post Memorial SPB (W36) is recorded as Not Applicable. As noted previously, W36 is located within the property of Renton Municipal (RNT), and the two airports are managed by the same sponsor and share facilities. A survey was returned by RNT, and it is assumed that this survey covers both RNT and W36.

Figure 6.4.2 Number of Questionnaires Returned by WSDOT Classification



Source: Kimley-Horn 2020

All airports that returned a questionnaire expressed an enthusiastic interest in being selected as a beta test site, and many provide additional information about ongoing actions or plans to support electric aircraft in the future. Some concern was expressed regarding the local sponsor's ability to fund required infrastructure improvements. No airports that returned a survey stated that they would be unwilling to serve in this role.

Electric Aircraft Beta Test Sites

Based on the survey responses, additional supplemental documentation provided, and the need for geographic dispersion of airports across the state, the airports shown in **Table 6.4.2** were selected by WSDOT Aviation as the beta test sites for electric aircraft deployment.

Table 6.4.2 Electric Aircraft Beta Test Sites

Associated City	FAA ID	Airport	Service	WSDOT Region	WA Classification
Chehalis	CLS	Chehalis-Centralia	GA	Southwest	Regional
Moses Lake	MWH	Grant County International	GA	North Central	Major
Olympia	OLM	Olympia Regional	GA	Olympic	Regional
Seattle	BFI	Boeing Field/King County International	Commercial Service	Northwest	Major
Spokane	SFF	Felts Field	GA	Eastern	Regional
Yakima	YKM	Yakima Air Terminal (McAllister Field)	Commercial Service	South Central	Major

Source: WSDOT Aviation 2020

In addition to these airports, Sea-Tac, Pierce County-Thun Field (PLU), and Tacoma Narrows (TIW) are independently pursuing initiatives for the future deployment of electric aircraft. Details about each of the airports identified as beta test sites and the ongoing work of Sea-Tac, PLU, and TIW are provided below.

Chehalis | Chehalis-Centralia (CLS)

Strategically located along the I-5 corridor between Seattle, WA, and Portland, OR, Chehalis-Centralia Airport provides excellent connectivity for recreational activities, corporate/business activity, air cargo, and potential future passenger services provided by electric aircraft. The airport is a frequent stop for military and civilian training flights. This airport offers a 5,000-foot-long by 140-foot-wide concrete runway. A lounge is available for visiting pilots and passengers, and maintenance services are provided by Central Aircraft Repair. The airport offers Jet A fuel. CLS is in WSDOT's Southwest Region within Lewis County, and the airport is operated by the City of Chehalis.

Through lease agreements, fuel sales, and hangar rentals, the airport is self-sufficient. Adequate revenue is available to support payroll and operating expenses as well as provide matching funds for capital improvement projects. CLS currently hosts over 1,000 on-airport employees working for a combination of aeronautical and non-aeronautical-related businesses. Furthermore, CLS is an active member of its community by hosting community activities, U.S. Experimental Aircraft Associate (EAA) Young Eagles events, and STEM-based educational programs for local high schools. Airport staff are also actively developing a partnership with Centralia College for aeronautical-related higher education programs.An aviation expansion area (as depicted on Chehalis-Centralia's recent Airport Property Master Plan) preliminarily identifies an aviation expansion area that could be used for additional infrastructure required by future electric aircraft. This could include hangar storage or other facilities necessary for required utility infrastructure. An all-electric glider plan is currently based at CLS—one of only three LAK-17 MINI FES in the U.S (see **Figure 6.4.3**).

Figure 6.4.3 Electric Glider Plane Based at CLS

Source: Katie Hayes, www.chronline.com (accessed October 2020)

Moses Lake | Grant County International (MWH)

Operated by the Port of Moses Lake, MWH is approximately seven miles north of I-90, the central east-west corridor across Washington. The airport is within WSDOT's North Central Region. Grant County International Airport is a world-class heavy jet training and testing facility and is rapidly emerging as a center of innovation for electric aircraft. The 4,300-acre airport has five runways, the longest of which is 13,500-feet-long by 200-feet-wide. MWH also provides 240 acres of ramp space and one million square feet (SF) of adjacent industrial park. Million Air and Columbia Pacific provide FBO services including Jet A fueling, flight test support, and aircraft loading and unloading. U.S. Customs and Border Protection are available 24/7 to clear international flights arriving at Grant County International Airport.

With an annual average of 350 days of visual flight rule (VFR) weather, an onsite air traffic control tower, and open Class D airspace, MWH is uniquely suited as a testing center for military and commercial applications. The Moses Lake AeroTEC Flight Test Center is a cutting-edge testing center designed to support all phases of aerospace manufacturing, production, testing, and instrumentation. Facility amenities include a 65,000 SF wide-body hangar and 32,00-SF narrow-body hangar, a mobile telemetry trailer, flight simulator room, instrumentation lab, and other assets. Facilities at MWH have been used by the Boeing Company, Rolls-Royce, Mitsubishi, the U.S. military, and others to test the state-of-the-art aviation technologies. In May 2020, Grant County International Airport became host to the maiden voyage of a retrofitted Cessna 208B Grand Caravan—the world's largest all-electric aircraft flown to date. The aircraft is the collaborative endeavor of Washington-based magniX and AeroTEC.

In addition to its current role as a leader in aerospace innovation and flight testing, Grant County International Airport lost scheduled commercial service in 2007. Travelers generally drive approximately 180 miles to access Sea-Tac or 105 miles to Spokane International Airport to access a hub airport. Providing regional passenger service at this location would significantly enhance connectivity within central Washington.

Olympia | Olympia Regional (OLM)

Operated by the Port of Olympia, Olympia Regional Airport is located four nm south of the central business district of Olympia, WA. The airport is east of I-5 in Thurston County and within WSDOT's Olympic Region. The airport provides two runways, the longest of which is 5,500 feet long by 150 feet wide. The airport provides a passenger terminal, an air traffic control tower, and a full instrument landing system (ILS). OLM frequently support corporate/business aviation as well as flight instruction, wildland firefighting operations, and recreational activities. FBO services are provided by Safety in Motion Flight Center and the Glacier Jet Center, and the airport offers Jet A fuel.

Olympia Regional Airport has a diverse revenue stream comprised of airport land and hangar leases, fuel flowage fees, and landing fees. Over 180 employees work on airport property, including staff members of the Washington State Department of Enterprise Services/Real Estate Services, Washington State Patrol, Washington State Department of Natural Resources, and WSDOT Aviation Division. The Port of Olympia's Comprehensive Scheme of Harbor Improvements defines five specific airport land-use development areas including commercial air service, corporate aviation, GA, light industrial, and north airport commercial (aviation and non-aviation). Each of these development areas could potentially support future infrastructure needs associated with electric aircraft. Because the airport is in the state capital, OLM as a beta test site provides the opportunity to showcase the benefits of electric aircraft to state policymakers. The region would also greatly benefit from enhanced connectivity, due in part to travel associated with government business, including the movement of elected officials between the capital city and their local constituencies. OLM is also located within the South Puget Sound FTZ #216, which offers several advantages associated with reduced, deferred, or eliminated customs duties and federal excise taxes.

Seattle | Boeing Field/King County International (BFI)

Boeing Field/King County International is four miles south of downtown Seattle in the Duwamish corridor along I-5. The airport is within WSDOT's Northwest Region and is operated by King County. The 634-acre facility is the closest airport to downtown, providing superior access to the state's busiest urban core and aviation- and aerospace-related business situated throughout the Puget Sound region. The airport provides excellent intermodal connectivity for passengers and air cargo arriving at/departing from the airport, with access to a light rail, ridesharing options, rental cars, bus service, and an extensive highway/arterial network. The airport offers a 10,000-foot-long by 200-foot-wide primary runway (14R/32L), an ILS system, a 24/7 FAA-operated control tower, and Jet A fuel. U.S. Customs and Border Protection are available to process international flights.

BFI is home to a diverse tenant base supporting a wide range of aviation activities such as manufacturing, testing, air cargo, corporate aviation, recreational flying, and flight training. FBO services are provided by Kenmore Aero Services, Modern Aviation, and Signature Flight Support. Limited passenger service is provided by Kenmore Air and JSX.[163] Kenmore Air's operations may be particularly well-suited for electrification. The carrier provides connectivity to over 40 destinations in western Washington and British Columbia. With shorter take-off requirements, lower noise profiles, and zero emissions, electric aircraft could mitigate some of the company's current concerns—particularly associated with operations occurring within Seattle.

163 JSX has temporarily suspended service due to COVID-19 (October 2020).

BFI supports a wide variety of aircraft types, from the 777X being tested by the Boeing Company to small GA aircraft. The addition of an electric airplane test program fits the airport's role as a mixed-use facility capable of supporting all types of aviation activities and users. Aviation education plays a prominent role at King County International/Boeing Field. Raisbeck Aviation High School, South Seattle Community College, The Museum of Flight, and Opportunity Skyway all focus on programs to shape today's youth into tomorrow's aviation and aerospace workforce and leaders. Electric aircraft could be incorporated into the educational programs at these institutions including (but not limited to) aircraft maintenance, pilot, and other workforce needs.

In addition, King County is adopting a 2020 Strategic Climate Action Plan, with goals to reduce greenhouse gas emissions, increase sustainability, and prepare for climate change; testing of electric aircraft is aligned with these goals as a leading aviation technological advancement.

Boeing Field has a rich history in aeronautical innovation and excellence. Some key examples include Boeing's development of the 80A which changed air travel with its range and passenger amenities, to Aviation Partners' development of the blended aircraft winglet that has saved over 10 billion gallons of fuel to date. Electric airplane testing would continue this legacy at BFI.

Spokane | Felts Field (SFF)

Felts Field (SFF) is in eastern Washington along I-90, 5.5 miles northeast of downtown Spokane and approximately 13 miles west of the Idaho border. The Spokane City-County Airport Board owns and operates SFF, as well as the nearby Spokane International Airport/ Geiger Field (GEG). The airport is in WSDOT's Eastern Region within Spokane County. The region is well known for its agricultural production; healthcare/life sciences, trade, transportation, utilities, and government are also leading industries. The region boasts more than 120 manufacturers, suppliers, distributers, and organizations related to the aerospace industry.

The airfield encompasses 416 acres and offers two runways. The primary runway 4L/22R is 4,499 feet long by 150 feet wide; the secondary runway 4R/22L is 2,650 feet long by 74 feet wide. The airport is supported by a Category I ILS to support aircraft operations during poor weather conditions. The airport offers an air traffic control tower and a full-service FBO (Western Aviation) that provides avionics, aircraft maintenance, and line services including Jet A fuel. SFF frequently supports corporate/business, wildland firefighting, emergency medical service, and search and rescue operations. Four flight schools are located at the airport (three fixed-wing and one rotorcraft) and Spokane Community College's Aviation Maintenance Program utilizes the airfield. Further, SFF has taken an active role in engaging with its local community, such as hosting the popular "Felts Field Neighbor Day" which annually attracts 12,000 – 15,00 residents. Each of these activities demonstrates that SFF could be an ideal test best for pilot training activities using electric aircraft.

Additionally, Felts Field could play an important role in enhancing east/west connectivity within the state. Enhanced regional passenger service between the Spokane region and the Seattle/Tacoma urban core could increase business, workforce, and educational opportunities for residents of eastern Washington.

Yakima | Yakima Air Terminal (McAllister Field) (YKM)

The Yakima Air Terminal-McAllister Field (YKM) is strategically located in the center of Washington state along I-82, 30 miles south of I-90. The airport is in WSDOT's South Central Region within Yakima County. In addition to numerous agricultural activities, Yakima Valley is home to air-reliant industries such as aerospace manufacturing, logistics and distribution, healthcare, and food processing. The airport's location east of the Cascade Mountains provides over 200 days of sunshine per year. It has an arid climate and receives an average of nine inches of rainfall per year making it one of the driest places in Washington.

YKM's airfield encompasses approximately 865 acres, which supports one primary runway (9/27) and secondary runway (4/22), in which both have full-length parallel taxiway systems. Runway 9/27 is a precision instrument runway equipped with navigation equipment to facilitate aircraft operations during inclement weather. Additionally, YKM provides a wide range of aviation support services to include an air traffic control tower, a full-service FBO, aircraft maintenance providers, air cargo operations, medical evacuation services, aerial wildland fire support services, and aircraft manufacturing. The airport is fully staffed with airfield maintenance and operations personnel who perform airfield inspections, routine maintenance, and snow removal.

Yakima County hosts various business incentives to assist corporations as they launch their business in the Yakima Valley. These incentives include sales tax exemptions, business and occupational tax reductions, employee training grants and workforce development, site development assistance, industrial revenue bonds, small business assistance program, public infrastructure funding assistance, and export/foreign trade assistance. Each of these are tools available to bolster the emerging electric aircraft industry.

Seattle | Seattle-Tacoma International Airport (SEA)

Owned and operated by the Port of Seattle, Sea-Tac is the Pacific Northwest's busiest airport and ranks eighth in the nation for passenger activity and 21st for air cargo. The airport welcomed 51.8 million passengers in 2019, up from 49.8 million passenger the previous year, including 3.8 percent domestic growth and 5.5 percent international growth. The airport is served by 30 airlines, with Alaska, Delta, United, Southwest, and American Airlines responsible for approximately 90 percent of all passenger activity. These airlines connect to 91 non-stop domestic and 27 non-stop international destinations. Sea-Tac processed 454,000 metric tons of air cargo in 2019. The airport is approximately 14 miles south of downtown Seattle and covers 2,500 acres. The airport is accessible via State Route 99; I-5 and I-405 also converge near the facility. Intermodal connectivity is provided by multiple public bus options, a light rail system, rideshare and rental car providers, and several shuttle services. Sea-Tac is within WSDOT's Northwest Region and is located 14 miles south of downtown Seattle.

Sea-Tac is committed to sustainable airport operations and is proactively developing facilities and policies to support the integration of electric aircraft into its existing operations. The airport has already provided electric charging stations throughout the airport for ground support equipment (GSE) including baggage tugs, bag ramps, and pushback vehicles.[164] Through its Sustainable Airport Master Plan (SAMP) and subsequent planning efforts, Sea-Tac has preliminarily identified an area at the airport for the future installation of aircraft charging stations. Additionally, staff have identified specific routes with the greatest potential for near-term electric aircraft technologies within the 200 to 250 nm range. Potential destinations include Portland, OR; Vancouver and Victoria, British Columbia; and Wenatchee, WA. The airport has noted that air cargo routes operated by FedEx and other providers offer the highest potential for electric aircraft because specific flights are short (i.e., 30 minutes or less) and aircraft remain on the ramp for long periods before departing again. High-potential destinations for air cargo routes include the San Juan Islands, Port Angeles, Bellingham, and Olympia.

In parallel with its efforts to support electric aircraft, Sea-Tac is developing a plan to provide sustainable aviation fuel (SAF)—including a commitment to power every flight fueled at Sea-Tac with at least a 10 percent blend of SAF by 2028. SAF can be used to fuel hybrid-electric vehicles, thereby leveraging the benefits of both emerging technologies for greater greenhouse gas emission reductions and potential cost savings.

164 https://www.portseattle.org/news/sea-tac-airport-unveils-electrification-project-save-airlines-millions-fuel-and-dramatically

Pierce County | Pierce County-Thun Field (PLU) and Tacoma Narrows Airport (TIW)

Pierce County-Thun Field and Tacoma Narrows Airport are in Pierce County, 30 miles south of downtown Seattle in WSDOT's Olympic Transportation Region. Pierce County offers a diverse and vibrant economy, with healthcare companies being the region's largest private employers. Other top industries include aerospace; manufacturing and industrial; marine trade and logistics; and technology. The U.S. military is the largest public employer, centered at Joint Base Lewis-McChord. Pierce County is also home to two Amazon distribution centers, making it the largest distribution employer in the county.[165] All of these industries are often reliant on air transportation for the movement of goods and people, making both airports a sound choice for the deployment of electric aircraft. PLU and TIW are operated by Pierce County.

PLU is 240 acres and offers one runway (17/35) that is 3,651 feet long by 60 feet wide. The airport provides an important asset for search and rescue operations and emergency response activities due to its proximity to Mount Rainier. The Pierce County Sheriff's Department (Pierce County Air Unit) conducts all aviation-related law enforcement activities at Thun Field. Three busy flight schools operate on the field, and Clover Park Technical College offers comprehensive educational programs in aviation maintenance, pilot training, and avionics. Additionally, PLU support recreational flying, aerial/wildland firefighting, emergency medical evacuation, and other GA activities. Aviation support services include aircraft repair and maintenance, avionics sales and repair, and 24/7 self-service 100LL fuel.

TIW is 644 acres and offers one runway (17/35) that is 5,1002 feet long by 100 feet wide. The airport is primarily used by business jet travel and other GA activities. The airport provides an FAA contract tower as well as a variety of aviation- and non-aviation-related businesses including FBOs and companies that support scenic and commuter flights, aircraft maintenance and repair, and avionics repair. Several flight schools operate at TIW including Pavco Flight Center and ATP Flight School. TIW also offers U.S. Customs clearance for flight arriving from outside of the U.S., and Jet A is available.

Pierce County is currently exploring the feasibility of electric aircraft deployment at PLU and TIW. The County is planning to conduct its own study to assess specific opportunities, as well as identify infrastructure improvements that may be required to support electric aircraft. The diverse and active aviation training activities occurring on both airfields may offer opportunities for the integration of electric aircraft for pilot training, corporate aviation, air cargo, air taxi/commuter flights, and other aviation activities. Its proximity to the Washington State's central urban core and vibrant economic base may provide an excellent foundation for the integration of electric aircraft into the airports' existing fleets.

165 https://esd.wa.gov/labormarketinfo/county-profiles/pierce

Future Electric Aircraft Beta Test Sites

WSDOT Aviation recognizes that many airports across the state are well-poised to support electric aircraft in addition to the ones listed above. Many communities would benefit from new or additional air service, whether for regional passenger service, air cargo, or other aviation activity. Some of these airports are already actively working to support electric aircraft and have identified actionable next steps to advance their positions in the marketplace. WSDOT Aviation recognizes that the following airports offer great potential for electric aircraft and will strongly consider their future inclusion as beta test sites as feasible. It is important to reiterate that the initial beta test site airports are only a starting point in this process. As discussed in other sections of the Electric Aircraft Feasibility Study, this new technology could revolutionize the air transportation system—opening new opportunities for airports and communities that have historically been underserved in the marketplace. The airports identified for potential future consideration as beta test sites are presented in **Table 6.4.3**.

Table 6.4.3 Potential Future Electric Aircraft Beta Test Sites

Associated City	FAA ID	Airport	Service	WSDOT Region	WA Classification
Kenmore	S60	Kenmore Air Harbor Inc	GA	Northwest	General Use
Port Angeles	CLM	William R Fairchild International	GA	Olympic	Regional
Seattle	W55	Kenmore Air Harbor	GA	Northwest	General Use
Wenatchee	EAT	Pangborn Memorial	Commercial Service	North Central	Major

Source: WSDOT Aviation 2020

Figure 6.4.4 depicts the network of airports that comprise the proposed electric aircraft airport system in Washington state.

Figure 6.4.4 Proposed Electric Aircraft Airport System in Washington

Source: WSDOT Aviation 2020, Kimley-Horn 2020

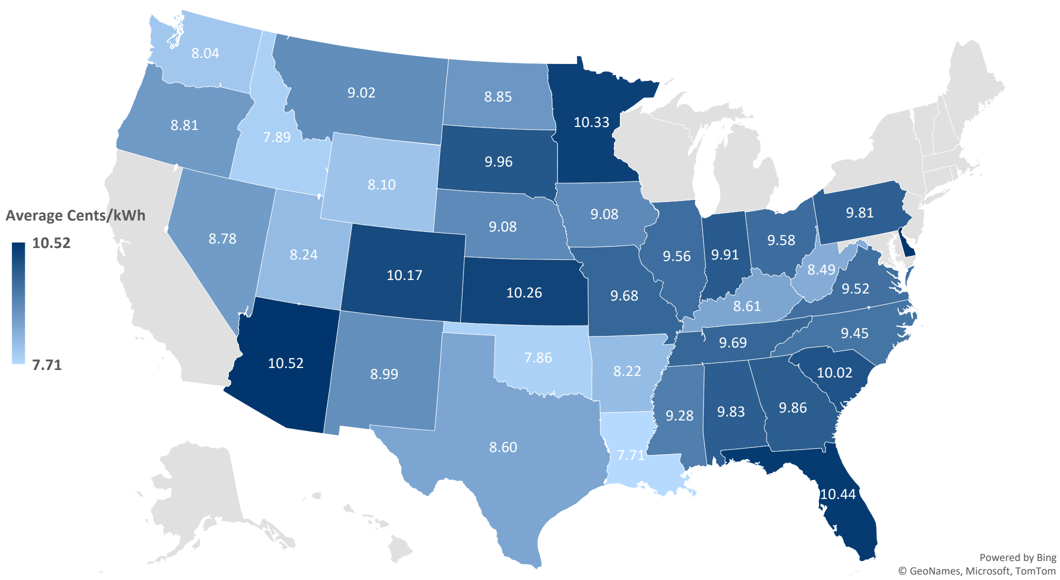
Section 5: Phase iv: Utility Coordination

Washington state enjoys some of the lowest electricity costs in the nation due to an abundance of clean hydropower. The U.S. Energy Information Administration reports that the state is the largest producer of hydroelectric power in the U.S., and hydroelectric power accounts for approximately two-thirds of the state's electricity generation (69 percent).[166] One asset, the Grand Coulee Dam, is the seventh-largest power plant in the world.[167] As indicated by the colors in **Figure 6.5.1**, the average cost of electricity in Washington is 8.04 cents per kilowatt hour (kWh), the fourth-lowest in the U.S. after Louisiana (7.71 cents/kWh), Oklahoma (7.86 cents/kWh), and Idaho (7.89 cents/kWh) (2019). Arizona and Delaware had the highest annual cost in 2019 at 10.52 cents/kWh. The average cost for all states was 9.24 cents/kWh in 2019.

166 https://www.eia.gov/state/analysis.php?sid=WA

167 Ibid.

Figure 6.5.1 Average Electricity Price by State, 2019 (Cents/kWh)



Notes: Data show the average cost for all end-user types. States depicted in grey are not included in the dataset. Source: U.S. EIA, Average Price by State by Provide (EIA-861), 2019

While electricity is abundant in the state, this does not mean that all airports have sufficient power to match the potential demand for electric aircraft. One of the most significant issues of integrating electric aircraft into the NAS is the ability to charge electric aircraft between flights. While the electric aircraft industry has identified various concepts for aircraft charging, these generally fall within two models: high-powered, rapid battery chargers or battery swapping.

In either case, greater power needs increase the potential need for upgrades to airport power infrastructure and the expansion of existing power supplies to ensure both adequate supply and resiliency. Some airports already have sufficient power supply to meet the new demands that are anticipated with electric aircraft. In this scenario, infrastructure modifications may only be associated with the installation of charging stations and associated transformers, switches, and cabling to connect with the power grid and manage high-voltage levels. For facilities without adequate existing electricity supplies, airports can work with their local distribution utility provider to upgrade the total capacity of connection to the main grid. Airports can also evaluate the feasibility of installing on-site power generation infrastructure, which may provide the opportunity for airports to operate independently of the main power grid. In all cases, airports must incorporate energy providers early in the planning process to understand their ability to provide power to electric aircraft charging, mitigate the risk of impacts to the grid, and enhance the resiliency of the system. Airports can work directly with their electricity providers, or partner with third-party companies such as ESCOs and renewable energy providers to identify innovative strategies to reduce or eliminate capital costs associated with electric aircraft charging stations and/or necessary utility upgrades.

There are eight electric utility providers, 24 public utility districts (PUDs),[168] and approximately 20 rural electric cooperatives represented by the Washington Rural Electric Cooperative Association[169] in the state. The eight utility providers are as follows:

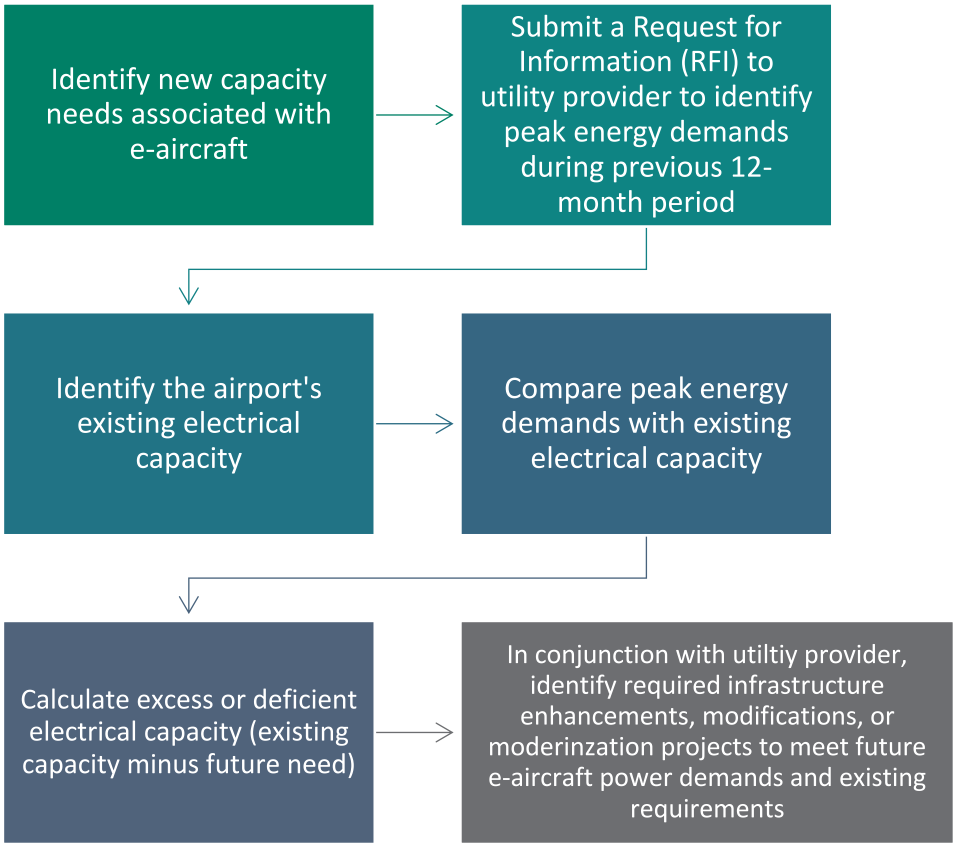
- Avista
- PacifiCorp
- Puget Sound Energy
- Bonneville Power Administration
- Seattle City Light
- Tacoma Power
- Snohomish PUD
- BC Hydro

WSDOT Aviation and beta test site airports must coordinate with their local utility and the Department of Energy (DOE) prior to the deployment of electric aircraft. At this time, the power requirements associated with electric aircraft are unknown. Further, specific airports' capacity needs associated with electric aircraft will be driven by various factors including the voltage requirements of specific technologies, the number of aircraft charging simultaneously, and the time it takes for the battery systems to charge. The process that airports can use to coordinate with their local utility companies to identify their abilities to support electric aircraft is depicted in **Figure 6.5.2**.

168 A PUD is a community-owned, locally regulated utility created by a vote of the people under RCW 54. This list of 24 excludes Snohomish PUD, which is listed separately below.

169 https://www.wreca.coop/about/

Figure 6.5.2 Utility Coordination Process



Source: Kimley-Horn 2020

If utility upgrades are not feasible, airports can use this same process to identify available power to support electric aircraft. In this case, the airport would calculate its available excess capacity (existing capacity minus current need), then calculate the number/type/duration of aircraft that could be charged within that threshold.

Power upgrades can require long lead times and may be costly depending on required infrastructure upgrades. Additionally, schedule and budget contingencies should be accounted for due to the potential for unforeseen issues to arise during design, review/permitting, and construction phases.

Section 6: Recommendations

The Electric aircraft Feasibility Study offers the following recommendations for airports and policymakers to facilitate the deployment of electric aircraft at beta test site airports.

Airports

- Identify space for future electric aircraft infrastructure development during the master planning process and depict this space on the Airport Layout Plan (ALP). This should also include future aircraft storage needs (i.e., T- and/or conventional hangars).
- Re-evaluate Transportation Security Administration (TSA) requirements as passenger service levels evolve. TSA regulations govern the security of airports with commercial service as provided by 49 Code of Federal Regulations (CFR) Part 1542. The TSA outlines three types of aviation programs for airports and operators:170
    - Twelve-Five Standard Security Program (TFSSP) provides requirements for FAA Part 135-certified carriers offering commercial air transport using aircraft with a maximum certificated takeoff weight between 12,500 pounds (5,670 kilograms [kg]) and 100,309.3 pounds (45,500 kg).
    - Private Charter Standard Security Program (PCSSP) is for operators with an FAA Part 121-, 125-, or 135-certificated carriers using aircraft with a maximum certificated take-off weight greater than 100,309.3 pounds (45,500 kg) or configured with 61 or more passenger seats. The PCSSP includes requirements to screen passengers and their accessible property.
    - Aircraft Operator Standard Security Program (AOSSP) is for operators with FAA Part 121 and 125 certificate holders and includes scheduled passenger service operations using aircraft with an FAA-certified seating capacity of 61 or more seats. This program applies to all scheduled passenger service operating into or out of a TSA-controlled sterile area.
- Re-evaluate TSA requirements associated with air cargo. TSA requires the screening of cargo transported on passenger aircraft at a level of security commensurate with the level of security of passenger checked baggage.171 This may necessitate the addition of air cargo handling facilities.
- Consider electrical infrastructure needs in terms of current power capabilities and density of expected demand during existing planning efforts to “future proof” against future utility constraints.
- Identify staff and personnel impacts that could result from the deployment of electric aircraft. In the near-term, this could include additional training regarding the safe operation of high-voltage aircraft charging systems, the identification of aircraft battery failures modes, and the potential effects of weather conditions on battery systems. Airports or airlines may need to hire additional staff trained to service and maintain aircraft charging equipment. Depending on the charging ownership model, this may be the responsibility of an FBO, contracted through a third-party provider, or provided by the airport directly.

170 https://www.tsa.gov/for-industry/aviation-programs

171 https://www.tsa.gov/for-industry/cargo-screening-program

- Ensure Aircraft Rescue and Firefighting (ARFF) personnel are trained and equipped to manage the specialized needs associated with electric propulsion. These may include handling emergencies such as battery or electrical fires, toxic gas emissions, or high voltage electrical arcing. Specific ARFF hazards might be comparable to those of the newer commercial aircraft (e.g., Boeing 787 and Airbus A350) equipped with batteries.
- Develop a team of electric aircraft advocates at the airport. This team could include local policymakers, aircraft manufactures/industry advocates, current and potential future airport users. This team should meet regularly, stay abreast of current development in the field, and identify actionable next steps to foster the deployment of electric aircraft.

Policymakers

- Advocate for the development of ASTM International standards for electric aircraft charging infrastructure for continuity between manufacturers.
- Work with each beta test site to understand specific needs in terms of infrastructure (e.g., hangar space and charging stations) and planning (e.g., updated master plan/ ALP to account for future electric aircraft needs). Identified needs should be quantified to calculate the total investment need required to develop a network of airports in Washington state capable of supporting electric aircraft.
- Develop innovative partnerships and programs to fund the installation of electric aircraft charging stations at beta test site airports. This program could be modeled on Washington state's Electric Vehicle Infrastructure Partnership Program (EVIPP). Through a competitive application process, the EVIPP awarded a total of $2.5 million for the installation of 15 new charging stations along I-5, I-90, and I-82/ US-395/I-182. The state legislature has provided $1 million per year for 10 years to continue this program in the Green Transportation Package, House Bill 2042. This initiative is funding through a $75 annual registration renewal fee for plug-in electric and hybrid vehicles. A similar fee could be applied to electric aircraft registration renewals to support public investment in airport charging stations.[172]
- Provide low-interest loans to airports to install electric aircraft charging stations through the Community Aviation Revitalization Board or another independent program specifically earmarked for electric aircraft infrastructure. This program could also be extended to private parties (e.g., FBOs). Note WSDOT Aviation would need to ensure such a program does not conflict with the Washington State Constitution, which prohibits the lending of state credit and the gift of public funds to private parties.
- Clearly tie electric aircraft to other state carbon emission/greenhouse gas reduction initiatives and goals. The Washington legislature has set a target to reduce emissions by at least 25 percent below 1990 levels by 2035, and the Department of Ecology has recommended a target of 40 percent below 1990 levels by that same year.[173] Additional funding to support airport infrastructure may become available if policymakers understand the role of electric aircraft in achieving these targets.

172 https://wsdot.wa.gov/business/innovative-partnerships/electric-vehicle-charging-infrastructure

173 https://www.governor.wa.gov/issues/issues/energy-environment

Conclusion

The long-term adoption of electric aircraft will rest heavily on the ability to reduce early barriers to entry and facilitate a network of airports with the necessary infrastructure to host these aircraft. As cars became electrified, many potential drivers were hesitant to purchase them because few charging stations were available. Because of coordinated partnerships between policymakers, vehicle manufacturers, utility providers, and others, a network of electric vehicle charging stations has been installed across most of the U.S. drivers know they can “charge up” well before reaching the range limits of their vehicles’ battery systems—ultimately leading to a significant uptick in demand for electric vehicles in recent years.

We are now in the early stages of that deployment process with electric aircraft. A network of airports capable of supporting electric aircraft needs to be developed so commercial and private aircraft owners and operators can safely and confidently fly between Washington communities. Beta test site airports, WSDOT Aviation, manufacturers, and policymakers all have a role to play in cultivating that network—from including electric aircraft infrastructure in local planning efforts, to making resources available to ensure those needs can be met. The beta test site selection process was designed to establish the foundation of that network, through which the benefits of electric aircraft can begin to be realized in Washington state.

Recommendations

The legislation for this report asked the study team to explore measurable goals for electric and hybrid-electric aircraft introduction into Washington State. After extensive research and stakeholder interviews with industry experts the following goals were set based on the level of uncertainty with respect to the timeline for viable commercial deployment.

	2030	2040	2050
Economic	• Fee structures in place to replace lost airport fuel-related revenue • Mechanisms in place to recharge eVTOL for urban and rural flights • Implement programs to share infrastructure costs with localities	• Electric aircraft infrastructure does not require subsidy	
Infrastructure	• Charging infrastructure available at all commercial airports for aircraft up to 10-15 passengers • Energy supply adequate to meet increased demand • Identify eVOTL platform sites	• Charging infrastructure available at all airports for general aviation • Infrastructure for aircraft up to 100 passengers at all commercial airports • Energy supply adequate to meet increased demand	• Infrastructure available for all aircraft at commercial airports
Social	• Implement public awareness campaign regarding electric aircraft safety		
Policy	• FAA certification of electric aircraft • Policies in place for the safety & security of eVTOL flight • Create workforce development programs at existing aviation schools • Consider infrastructure needs during airport planning process • Consider eVTOL platforms in state/local/regional planning	• FAA certification of electric aircraft	• FAA certification of electric aircraft

Environmental Impacts, Economic Benefits, and Incentives

The research on environmental and economic benefits of electric aircraft in Washington state identified several actions to facilitate adoption. The recommendations for policy makers and for airports are summarized below:

Policymakers	Airports
Build partnerships with stakeholders to advance electric aircraft integration within the state and consult with the Department of Energy for funding opportunities to support low-cost electric aviation engine technology	Develop electric aircraft infrastructure and evaluating alternate technologies to generate or isolate power such as coordinating with utility companies to install microgrids or self-contained power sources such as fuel cells
Coordinate among federal, state, and private funding agencies to help fund electric aircraft infrastructure and operations and provide competitive flying rates for a successful market entry for passenger service	Examine replacing airport fuel revenues by adjusting existing fees and/or creating new charges related to electric aircraft operations (battery recharges, landing fees, ramp parking, etc.)
Promote public acceptance by communicating the benefits of electric aircraft for economic growth and sustainability through emission reduction, noise mitigation, and economic impact benefits including direct and indirect job creation across sectors, labor income, and total business revenues.	Educate airport users, tenants, and community stakeholders regarding electric aircraft benefits and impacts
Develop incentives to support battery cluster and electrical engineering capabilities within Washington state	Continue developing partnerships with local universities to promote sustainable technologies such as WSU – Alaska Airlines woody biomass fuel partnership and seek collaboration with the U.S. Energy Service Company (ESCO) industry
Establish electric aircraft regional transportation routes along the state's congested corridors	Develop relationships with e-commerce providers (Amazon) and major manufacturers (Boeing) to establish electric aircraft air cargo activity through capital improvement projects

Policymakers	Airports
Promote the benefit of electric aircraft to all constituencies (e.g., faster, lower cost deliveries to rural areas, congestion relief in urban areas)	
Sponsor additional research that will help refine this analysis, focusing on infrastructure needs and funding requirements	
Develop policies and regulation regarding revenue generation and safety/security for urban UAS operations	

Transportation Network Assessment

The following provides recommendations associated with the integration of electric aircraft into Washington's existing multimodal transportation network. Recommendations are categorized in terms of applicability to airports and policymakers.

Airports

- Identify existing modal options in the vicinity of the airport and assess how the deployment of electric aircraft could affect or interact with those modes.
- Ensure the airport has adequate ground transportation options for arriving pilots and passengers. Public transit, light rail, courtesy cars, rental cars, and other ground transportation options offer visitors the ability to leave airport property and spend money in local communities. This increases the airport's economic impact, which can lead to additional support for the airport in terms of airport-compatible land use planning and zoning and local investment. Airports without a means to leave airport property may deter pilots from choosing that facility.
- Develop a partnership with local planners, as electric aircraft may need to be incorporated into local comprehensive and transportation strategic planning efforts. Planners should be educated about electric aircraft's potential roles within and impact on the broader transportation network.
- Identify high-potential electric aircraft routes for air cargo and passenger service, and calculate the cost associated with driving versus flying between specific destinations. This information is important during air service development efforts. Additional information about air service development is provided in the Airport Self-Assessment Framework in the Demand and Deployment section of this study. Additional information about calculating the cost of driving versus flying is provided in Economic and Environmental Benefits section.

Policymakers

- Coordinate with other modal managers during all regional and statewide long-term transportation planning efforts. Electric aircraft could shift demand away from existing modes, which would reduce associated capacity enhancement needs. By managing all modes of transportation as an interrelated system, state investment could be more effectively allocated within the state.
- Consider zoning ordinances and land use regulations that may be required by future UAS and UAM applications. It is anticipated that small packages will be delivered by unmanned aerial vehicles in the near-term. This activity will occur on off-airport property. As such, UAS and UAM platforms and/or vertiports will become a new type of land use that should be regulated to ensure the safety of people and property in nearby vicinities, as well as aircraft within the approach surfaces of nearby airports.
- Include electric aircraft in long-term statewide aviation planning efforts. The WASP was last published in 2017 using 2014 baseline data. Electric aircraft may shift demands within the state and open new opportunities for airports that currently do not support passenger service. This new technology may be appropriate to include when the WASP is next updated.

Workforce Development

Considering the structures of the regional aerospace industry and the relationships between firms, educational institutions, industry associations, and governmental agencies, a number of recommendations can be provided to enhance the workforce development programs to the benefit of the electric aircraft sector. The recommendations address actions to be taken by industry stakeholders to leverage existing capabilities and make novel investments with the goal of bringing the electric aircraft sector to technological maturity and facilitate commercial production. The actions involve identifying funding opportunities, developing job training programs, cultivating partnerships, expanding educational resources, and initiating policy changes.

The state of Washington has a robust aerospace workforce development infrastructure. Enhancing the various programs to include training to ensure skilled labor is available is essential to support the unique requirements of the electric aircraft industry. This may include the following actions:

Program Development

- Expand the capacity of apprenticeship programs and jobs skills training programs to narrow the gap between the demand for qualified labor by industry firms and the number of program graduates
- Expand course content on the tools and technologies related to the manufacture of electronics, semiconductors and electric power systems and the emergence of Industry 4.0 tools and technologies

- Develop a program of continuing education opportunities for new and journeyman staff in the aerospace industry to facilitate upskilling and continuous development as the industry continues to develop and incorporate new tools, processes and technologies into the workplace
- Identify the challenges of operating electric aircraft as a means of personal transportation and freight transportation to reduce the exposure of financial and market risk to operators and standardize operational regulations

Building Partnerships with Private Sector Entities

- Expand the institutional support for apprenticeship programs and increase the number of placements with small and medium-sized firms supporting the manufacture of components for electric aircraft
- Provide support for a position on the advisory board of the Center of Excellence representing the disciplines supporting the electric aircraft sector, including electric power systems, advanced electronics and advanced materials manufacturing
- Develop an incubator purposed to identify funding sources for research and business investment supporting the electric aircraft sector
- Develop an international marketing function between industry associations and economic development agencies to increase the market exposure of specialty producers in Washington state to the global aerospace market, especially Canada and Europe
- Develop a specialty discipline for electric aircraft within the General Aviation Manufacturers Association or similar industry association to facilitate research collaborations, business investments, governance, and economic development opportunities

Education and Research

- Define and standardize the technical terminology for the production and operation of electric aircraft
- Provide live demonstrations of the capabilities of electric aircraft to increase stakeholder education and engagement (e.g., Pipistrel Alpha trainer)
- Develop comparisons in vehicle performance and the procurement and operation costs between electric aircraft and their conventional equivalent
- Provide additional information on the sustainability of the disposal and reuse of electric vehicle batteries
- Investigate whether hydrogen fuel cells could be safely deployed as an alternative energy source
- Research the opportunities and limitations of developing and deploying hybrid fuel-electric power systems in aircraft

Policy Changes

- Research and develop policies enabling the deployment of electric aircraft at the local level as an urban mobility solution
- Determine the compatibility of the operation of electric aircraft with laws governing the conditions of land use
- Identify and integrate the infrastructure systems necessary to operate electric aircraft in the urban environment
- Investigate and identify the framework to govern the qualifications of crew operating electric aircraft
- Develop incentive programs targeted at industry firms to facilitate continuous learning related to electric aircraft systems for current employees
- Investigate the opportunities for electric aircraft to facilitate the movement of freight throughout the region and identify their strategic contribution to the regional freight transportation system

Funding Opportunities

- Leverage loan and grant funding programs administered by state government agencies providing public funds for business investments and infrastructure projects related to freight transportation, airport operations and electric vehicles
- Leverage federal grant programs administered by the Federal Aviation Administration and the U.S. Department of Transportation to fund regional infrastructure projects promoting economic vitality and freight transportation
- Identify private sector funding sources to establish an investment fund for infrastructure projects supporting the electric aircraft sector and the regional aerospace economy

Airport Recommendations

Airports can support workforce development for electric aircraft in several ways:

- Educate tenants, stakeholders, and the public about the opportunities electric aircraft will bring for increased aviation demand and new aviation-related jobs
- Encourage flight schools to integrate electric aircraft into their training and certification
- Support connections with local industries for apprenticeships
- Provide space and equipment for training
- Ensure facilities required for electric aircraft are available

Infrastructure and Battery Charging

There are three steps that need to be addressed first in order to advance the electric infrastructure front for e- aircraft:

- FAA/Regulatory involvement
- Standardization of charging technologies
- Early Department of Energy and utility engagement to help advance the technology

The FAA represents a critical path to both standardize and implement aircraft technologies. If the FAA considers technology a flight risk, such as a certain charger rate or battery swapping making an aircraft no longer air-worthy, this may narrow what solutions could be used. As far as safety is concerned, the FAA is already working with manufacturers to ensure the aircraft meet certification standards, so further regulatory oversight by WSDOT is not required at this time. The only additional regulatory needs may be incentive-based regulations to aid the electric aircraft industry and utilities that are looking to support its growth. Regulatory requirements may also be needed to address fuel tax parity with Jet A/AvGas and/or incentives to convert and recover revenues for the state. Additional legislation may be required to evaluate aeronautical/non-aeronautical uses to make charging infrastructure have a positive ROI for private vendors and potentially avoid state or Federal funding requirements.

The different charging methods are good for pilot cases and fleshing out the technologies, but eventually there needs to be scalable solutions for charging technologies that should focus around one or two standards.

Early utility engagement is very critical towards helping adoption of these projects with increased infrastructure needs. Utilities can help in many ways. First, if there is a large infrastructure upgrade required, the utility needs time and resources to help coordinate and build that infrastructure. This can take many years to orchestrate the planning, engineering, and construction required. Secondly, utilities can help with outreach and education. Many utilities, such as Avista[174] in Spokane WA, have helped sponsor “ride and drive” events to promote light duty electric vehicles and could do the same for new electric aircraft. Thirdly, utility rates and rate cases can be very critical to ensure that adoption of new technologies are still financially viable, and this takes time to get approved. Doing things like deferring demand charges, developing EV specific rate-cases, or “charge ready” infrastructure plans are all ways that early utility engagement can dramatically improve adoption of new technologies. Avista has even expressed interest in helping with pilot projects for some of these early engagement techniques. These activities usually need permission from the state regulator (Washington Utilities & Transportation Commission) to perform.

174 Information from interview with Avista conducted by WSP on May 22, 2020

Utilities cannot perform all of the tasks needed to modernize the grid and understand cutting edge new technologies. The US Department of Energy labs, especially PNNL and NREL, have been very involved with grid modernization initiatives.[175] In addition, the University of Washington hosts the "Clean Energy Testbeds", which helps accelerate the development, scale up, and adoption of new technologies.[176]

Demand and Deployment

The following section provides recommendations to support the development of and prepare for the implementation of electric aircraft. Separate recommendations are provided by airports and policymakers.

Airports

- Complete the airport self-assessment framework provided in **Table 5.2.1**. This tool provides a detailed source of information about the potential implications of electric aircraft at individual airports, as well as additional reference material to help airport managers/sponsors learn more. Airports that take the time to comprehensively consider each item's applicability to their own facility will be best positioned to take advantage of electric aircraft opportunities as they arise. The framework could also serve as the outline for a detailed airport-specific electric aircraft feasibility study.
- Consider if electric aircraft deployment should be incorporated into long-term planning efforts. Airport-specific forecasts of aviation activity are used to identify future infrastructure improvement needs. Airports should work with their planning team (internal and consultants) and the FAA to determine if electric aircraft should be included in the airport's future system requirements or forecasts of future demand.

Policymakers

- Consider the need for new zoning ordinances addressing UAM activities, which are likely be located off airport property and within urban cores.
- Permanently codify the CARB fund to provide airports with access to funds for hangar storage. Additional capacity is anticipated to become an acute need as electric aircraft gain market traction. Hangars are typically ineligible for state and federal grant funding, so providing an alternative means for airports to add storage capacity will be critical.
- Become involved in the long-term planning efforts of other transportation modes and communicate the potential future impacts of electric aircraft on the state's roadway network. Electric aircraft may reduce demands on highway networks, which could reduce capacity enhancement needs even if Washington's population continues to grow.
- Continue to support the development of a new commercial service airport through the Commercial Airport Siting Commission, which will likely become increasingly important as demand for air cargo and commercial passenger service increases over time.

175 https://www.energy.gov/grid-modernization-initiative

176 https://www.wcet.washington.edu/

Selection of Beta Test Site Airports

The Electric aircraft Feasibility Study offers the following recommendations for airports and policymakers to facilitate the deployment of electric aircraft at beta test site airports.

Airports

- Identify space for future electric aircraft infrastructure development during the master planning process and depict this space on the Airport Layout Plan (ALP). This should also include future aircraft storage needs (i.e., T- and/or conventional hangars).
- Re-evaluate Transportation Security Administration (TSA) requirements as passenger service levels evolve. TSA regulations govern the security of airports with commercial service as provided by 49 Code of Federal Regulations (CFR) Part 1542. The TSA outlines three types of aviation programs for airports and operators:[177]
  - Twelve-Five Standard Security Program (TFSSP) provides requirements for FAA Part 135-certified carriers offering commercial air transport using aircraft with a maximum certificated takeoff weight between 12,500 pounds (5,670 kilograms [kg]) and 100,309.3 pounds (45,500 kg).
  - Private Charter Standard Security Program (PCSSP) is for operators with an FAA Part 121-, 125-, or 135-certificated carriers using aircraft with a maximum certificated take-off weight greater than 100,309.3 pounds (45,500 kg) or configured with 61 or more passenger seats. The PCSSP includes requirements to screen passengers and their accessible property.
  - Aircraft Operator Standard Security Program (AOSSP) is for operators with FAA Part 121 and 125 certificate holders and includes scheduled passenger service operations using aircraft with an FAA-certified seating capacity of 61 or more seats. This program applies to all scheduled passenger service operating into or out of a TSA-controlled sterile area.
- Re-evaluate TSA requirements associated with air cargo. TSA requires the screening of cargo transported on passenger aircraft at a level of security commensurate with the level of security of passenger checked baggage.[178] This may necessitate the addition of air cargo handling facilities.
- Consider electrical infrastructure needs in terms of current power capabilities and density of expected demand during existing planning efforts to “future proof” against future utility constraints.
- Identify staff and personnel impacts that could result from the deployment of electric aircraft. In the near-term, this could include additional training regarding the safe operation of high-voltage aircraft charging systems, the identification of aircraft battery failures modes, and the potential effects of weather conditions on battery systems. Airports or airlines may need to hire additional staff trained to service and maintain aircraft charging equipment. Depending on the charging ownership model, this may be the responsibility of an FBO, contracted through a third-party provider, or provided by the airport directly.

177 https://www.tsa.gov/for-industry/aviation-programs

178 https://www.tsa.gov/for-industry/cargo-screening-program

- Ensure Aircraft Rescue and Firefighting (ARFF) personnel are trained and equipped to manage the specialized needs associated with electric propulsion. These may include handling emergencies such as battery or electrical fires, toxic gas emissions, or high voltage electrical arcing. Specific ARFF hazards might be comparable to those of the newer commercial aircraft (e.g., Boeing 787 and Airbus A350) equipped with batteries.
- Develop a team of electric aircraft advocates at the airport. This team could include local policymakers, aircraft manufactures/industry advocates, current and potential future airport users. This team should meet regularly, stay abreast of current development in the field, and identify actionable next steps to foster the deployment of electric aircraft.

Policymakers

- Advocate for the development of ASTM International standards for electric aircraft charging infrastructure for continuity between manufacturers.
- Work with each beta test site to understand specific needs in terms of infrastructure (e.g., hangar space and charging stations) and planning (e.g., updated master plan/ ALP to account for future electric aircraft needs). Identified needs should be quantified to calculate the total investment need required to develop a network of airports in Washington state capable of supporting electric aircraft.
- Develop innovative partnerships and programs to fund the installation of electric aircraft charging stations at beta test site airports. This program could be modeled on Washington state's Electric Vehicle Infrastructure Partnership Program (EVIPP). Through a competitive application process, the EVIPP awarded a total of $2.5 million for the installation of 15 new charging stations along I-5, I-90, and I-82/ US-395/I-182. The state legislature has provided $1 million per year for 10 years to continue this program in the Green Transportation Package, House Bill 2042. This initiative is funding through a $75 annual registration renewal fee for plug-in electric and hybrid vehicles. A similar fee could be applied to electric aircraft registration renewals to support public investment in airport charging stations.[179]
- Provide low-interest loans to airports to install electric aircraft charging stations through the Community Aviation Revitalization Board or another independent program specifically earmarked for electric aircraft infrastructure. This program could also be extended to private parties (e.g., FBOs). Note WSDOT Aviation would need to ensure such a program does not conflict with the Washington State Constitution, which prohibits the lending of state credit and the gift of public funds to private parties.
- Clearly tie electric aircraft to other state carbon emission/greenhouse gas reduction initiatives and goals. The Washington legislature has set a target to reduce emissions by at least 25 percent below 1990 levels by 2035, and the Department of Ecology has recommended a target of 40 percent below 1990 levels by that same year.[180] Additional funding to support airport infrastructure may become available if policymakers understand the role of electric aircraft in achieving these targets.

179 https://wsdot.wa.gov/business/innovative-partnerships/electric-vehicle-charging-infrastructure

180 https://www.governor.wa.gov/issues/issues/energy-environment

ADA Statement

This material can be made available in an alternate format by emailing the Office of Equal Opportunity at ***wsdotada@wsdot.wa.gov***, or by calling toll free 855-362-4ADA (4232). Persons who are deaf or hard of hearing may make a request by calling the Washington State Relay at 711.

It is the Washington State Department of Transportation's (WSDOT) policy to assure that no person shall, on the basis of disability, be excluded from participation in, be denied the benefits of, or otherwise discriminated against under any of its programs, services, or activities. Any person who believes their Americans with Disabilities protection has been violated may file a complaint with WSDOT's Office of Equal Opportunity (OEO). For additional information regarding ADA complaint procedures and/or information regarding our non-discrimination obligations, please contact Larry Watkinson, WSDOT ADA Compliance Manager, at ***wsdotada@wsdot.wa.gov*** or by calling toll free 855-362-4ADA (4232).

Request for Reasonable Modification

WSDOT will modify its policies, practices, and procedures to ensure individuals with disabilities have an equal opportunity to participate in its programs, services, or activities unless the modification fundamentally alters the program, service, or activity, creates a safety issue, or is not otherwise required by the ADA. Requests for modification can be made to any WSDOT employee or at ***wsdotada@wsdot.wa.gov*** or by calling toll free 855-362-4ADA (4232).

Title VI Notice to the Public

It is WSDOT's policy to assure that no person shall, on the grounds of race, color, national origin, or sex, as provided by Title VI of the Civil Rights Act of 1964, be excluded from participation in, be denied the benefits of, or be otherwise discriminated against under any of its federally-funded programs and activities. Any person who believes his /her Title VI protection has been violated, may file a complaint with WSDOT's Office of Equal Opportunity (OEO). For additional information regarding Title VI complaint procedures and/or information regarding our non-discrimination obligations, please contact OEO's Title VI Coordinator at 360-705-7090.

FOR MORE INFORMATION

David Fleckenstein
Director, Aviation Division
360-709-8020
fleckda@wsdot.wa.gov

T.S. “Max” Platts
Planner, Aviation Division
360-709-8028
plattst@wsdot.wa.gov