

FLYING GREEN: THE LOW-CARBON AIRPORT OF TOMORROW

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Executive Summary

As an Energy Policy and Climate (EPC) master's candidate, and legislative assistant on Capitol Hill, I will use my combined policy research and analysis skills to conduct a policy gap analysis on federal aviation environment policy. Then use my legislative background to write a new policy based on the outlined and documented research in my capstone report.

The purpose of this capstone report is twofold. The first is to perform a policy gap analysis on the current state of existing federal aviation greenhouse gas (GHG) emission environmental policy to identify where there might be policy deficiency that can be addressed through new targeted policies. The second goal is to develop new policy framework that will help reduce GHG emissions in the commercial aviation sector.

The International Council on Clean Transportation (ICCT) estimates that 918 million metric tons of CO₂ is generated from global aviation operations, including commercial, belly freight and dedicated freight.¹ Of that total, 81%, or 747 MMT, come from commercial aviation. Of that 747 MMT total, the United States emissions account for 182 million metric tons (MMT), 24%, of CO₂ out of the global total of 747 MMT, and 126 MMT, 17%, of that total comes solely from U.S. domestic flights.² Additionally, passenger air travel is producing the fastest rate of individual emissions growth of any economic sector in the country.³ Because of this growth, the emissions from the U.S. commercial aviation sector outpace current policy mechanisms designed to combat climate change and reduce emissions.

¹ ICCT. 2018. CO₂ Emissions from Commercial Aviation, 2018.

https://theicct.org/sites/default/files/publications/ICCT_CO2-commercl-aviation-2018_20190918.pdf

² Ibid.

³ Gossling, Stephan, Paul Upham. 2009. Introduction: *Aviation and Climate Change in Context* in *Climate Change and Aviation. Issues, Challenges and Solutions*. Earthscan. London, UK.

Current science underscores the need to achieve net zero carbon emissions by 2050. Achieving net zero emissions would require massive and immediate decarbonization of the economy, including a price on carbon. A price on carbon would accelerate existing programs that are noted within the report. However, the political reality is that these policies will not pass in the current divided congress, with republicans blocking serious climate change proposals. The policy approach in this report could be accomplished in the current political climate and in the near term.

The following report targets the opportunity to address scope 3 ground operations emissions in the commercial aviation sector. The report also recommends the creation of two new policy mechanisms. The first is a grant program to assist airports and airlines in inventorying their GHG emissions from ground operations. The second is the creation of an investment tax credit scheme to incentivize deployment of Zero Carbon Ground Operations (ZCGO) flight operations ground support equipment (GSE). The resulting policy proposal will form the basis for legislation to support achievement of ZCGO.

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Introduction

Statement of Purpose – The purpose of this capstone project is to complete a comprehensive gap analysis on aviation sector GHG environment policy in the United States, then identify new opportunities for legislation and federal law to reduce such emissions. I will research the methods used by the aviation industry to conduct emissions inventories for the aviation sector, and more specifically airport ground operations, in the United States. Then, after cataloguing these emission sources, I will assess what opportunities might exist to reduce emissions for each emissions source. If there is significant opportunity to develop new policy recommendations for zero emissions mitigation, specifically in airport operations, I will identify those opportunities. Then, I will write policy recommendations supporting an industry transition to a low carbon future. The resulting analysis and policy recommendations is intended to become the framework for legislation to address the challenge of GHG emissions reduction in the commercial aviation sector.

Background – The EPA estimates that aircraft contribute 12 percent of U.S. transportation emissions, which accounts for approximately 3% of total greenhouse gas emissions in the United States, and passenger air travel is producing the fastest rate of individual emissions growth of any economic sector in the country. Emissions from the aviation industry come from a number of different sources, including the aircraft themselves, facilities operations, ground operations, and ground transportation operations. Approximately 70% of aircraft emissions is CO₂, with the remaining 30% comprising a mix of nitrous gases, water vapor, sulfates and other particulate

matter.⁴ Approximately 90% of these emissions take place at an elevation above 3,000 feet. The remaining 10% take place through taxiing, landing and take-off (LTO).⁵

According to the IPCC 1.5°C special report, we only have 11 years to reduce carbon emissions by 45%, and only 31 years before we must reach net zero emissions, if we are to keep global average temperature rise to only 1.5°C.⁶ Indications are emerging that we may slip past 1.5°C in this time period. It is anticipated that next IPCC report will be available in 2022.

Additionally, ICAO reports that airplane CO₂ emissions reached 900 million metric tons (MMT) in 2018 (2.4% of global CO₂ emissions), and would then triple to 2.7 billion metric tons by 2050.⁷ According to Airport Council International (ACI), twelve of the world's fastest growing airports are in emerging economies like India and China⁸, which underscores the international nature of this complex problem. However, according to a recent study by the International Council on Clean Transportation, the United States accounts for about one-quarter, 182 MMT, (24%) of global passenger transport-related CO₂. Of that 24%, 126 MMT (17% of global total) of emissions come from domestic U.S. passenger operations. This sizable percentage of global emissions from U.S. domestic aviation points to the need to rapidly reduce these emissions. In doing so, the United States can become a global leader and example for emerging economies in how they can create policies to support aviation emissions reductions.

⁴ FAA Office of Environment and Energy. 2015. Aviation Emissions, Impacts & Mitigation A Primer www.faa.gov/regulations_policies/policy_guidance/envir_policy/media/primer_jan2015.pdf

⁵ Ibid.

⁶ Intergovernmental Panel on Climate Change. 2018. Special Report: Global Warming of 1.5 °C. www.ipcc.ch/sr15/.

⁷ Assembly, 40th Session - International Civil Aviation Organization. 2019. ICAO Global Environmental Trends Present and Future Aircraft Noise and Emissions. https://www.icao.int/Meetings/A40/Documents/WP/wp_054_en.pdf

⁸ Airports Council International. 2019. World's top five fastest growing airports for passengers and cargo revealed. <https://aci.aero/news/2019/09/17/worlds-top-five-fastest-growing-airports-for-passengers-and-cargo-revealed/>

Reducing our emissions by such a substantial amount will require carbon mitigation policies in every economic sector, including transportation and specifically in aviation. In fact, the EPA has ruled that CO₂ from aviation causes pollution and in 2016 created a legal requirement that the EPA establish a CO₂ emissions standard for aircraft.⁹ The continued progress on this proposed standard is unclear at this time due to current administration priorities. To date this standard has not been finalized by EPA.

In addition to inflight operations, there are emissions from ground operations that also factor into the aviation sector's emissions inventory profile. These emissions are difficult to inventory due to the complex nature of ownership of aviation assets by airlines, ground operation contractors, and the airport itself, and a complex regulatory framework with domestic and international components. Ground operations comprise two different subsets of activities that factor into the emissions inventory. The first is apron and tarmac ground operations which include aircraft activity with the engine on during LTO, ground support equipment that powers on-board aircraft operations at the gate, and equipment that services the aircraft including baggage handling, food service, fueling, etc. The second is airport passenger operations which include systems that move passengers around, and to and from, the airport, shuttle busses to rental car locations, metro areas, hotels, and onsite and offsite parking lots. Ground operations generate the same emissions pollutants as aviation operations, and further contribute to the commercial aviation sector's impact on our climate and air quality.

⁹ Environmental Protection Agency. 2016. Final Rule for Finding That Greenhouse Gas Emissions from Aircraft Cause or Contribute to Air Pollution That May Reasonably Be Anticipated to Endanger Public Health and Welfare <https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-finding-greenhouse-gas-emissions-aircraft>

Anticipated Findings – Over the course of researching this report, I have found that there is a sizeable amount of information and published research on aviation emissions within the United States Government (USG). The Department of Transportation (DOT), Environmental Protection Agency (EPA), Federal Aviation Administration (FAA), and National Aeronautics and Space Administration (NASA) have all conducted research focused on aviation emissions.

There are also initiatives led by industry associations, the Airport Council International (ACI and ACI-NA), and international governmental organizations like the International Civil Aviation Organization (ICAO), a United Nations Specialized Agency with representatives from member States that establishes international “Standards and Recommended Practices” for global aviation.¹⁰ Aviation is unique in that domestic policy can be heavily influenced by these international and non-governmental organizations. The international nature of the commercial aviation sector requires that nations work under a unified set of standards and protocols to avoid potentially conflicting regulatory regimes in separate countries. The ICAO was conceived in 1944, in Chicago, Illinois, by 52 signatory states and is sometimes referred to as the Chicago Convention. ICAO is a United Nations Specialized Agency and as of March 2019, 193 states are now signatories to the Chicago Convention.¹¹ ICAO has since been the leading international government organization in setting aviation industry standards for the past 75 years.¹² These ICAO Standards and Recommended Practices (SARPs) cover several different areas including safety, security, efficiency, economic sustainability and environmental responsibility.

Furthermore, there is also a complex network of ownership of aviation assets, making it difficult to establish congruent policy that is applicable to all stakeholders. Sifting through these

¹⁰ ICAO. 2019. About ICAO. <https://www.icao.int/about-icao/Pages/default.aspx>

¹¹ Ibid.

¹² Ibid.

various policies in my research has informed my thinking of where exactly new opportunity for federal policy might be most effective.

When starting my research, I had anticipated there would be some existing void in commercial aviation environmental policy that could be entirely or partially filled by new federal policy. In examining how this complex web of domestic and international policies fit together I believe that I have found an opportunity for new policy initiatives. Identifying where these new opportunities exist is a key outcome of conducting a policy gap analysis that allows policy makers to invest their time in initiatives that will break new ground. Policy makers in the U.S. Congress have demanding roles, and the key to enacting new legislation is to present lawmakers with a problem that must be solved. Reducing aviation emission is certainly a problem worth addressing. Identifying what is already being done, and determining where one can supplement the existing body of work is also critically important in finding a path forward for that change.

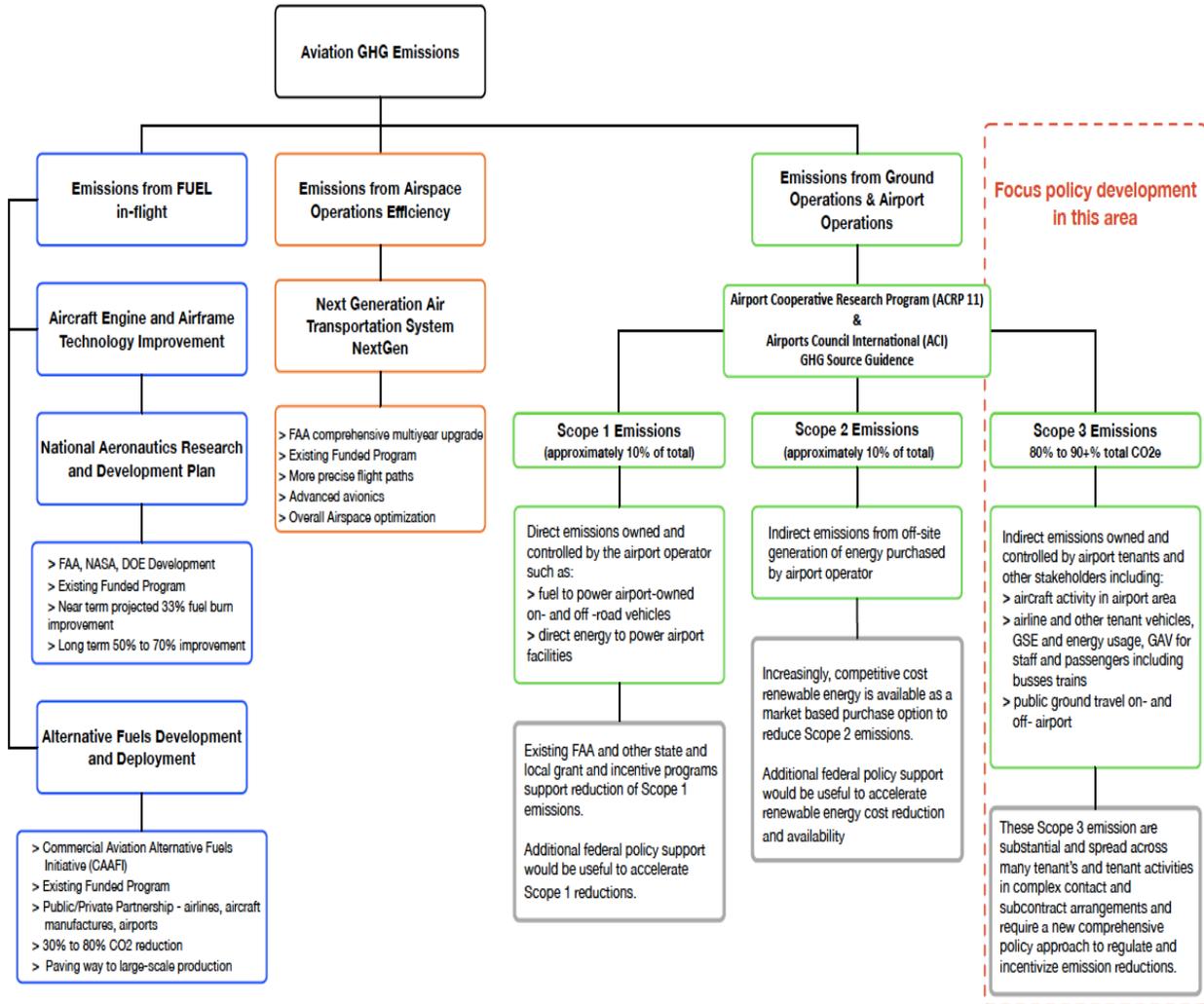
Methods

Policy Gap Analysis Overview - A policy gap analysis is an important analytical tool that can help identify suboptimal or missing strategies, structures, capabilities, processes, practices, technologies or skills, and then recommends steps that will help an organization meet its goals.¹³ A gap analysis examines the current state of affairs in any industry, policy sector, business or any other area to identify what is, in order to find out what can be. There are two types of gap analysis – concrete and conceptual. For the purpose of researching and writing this capstone report, I will be using a concrete gap analysis which focuses on the use of existing emissions data

¹³ Smartsheet. 2019. The Complete Guide to Gap Analysis. <https://www.smartsheet.com/gap-analysis-method-examples>

sets, existing domestic and international policy, and existing technologies. A gap analysis compares performance to potential. In the context of reducing emission from the aviation sector, I ask several questions in an effort to identify potential. What policies currently exist? What research currently exists? What are stakeholder groups doing to identify these issues on their own? The diagram on the next page helps explain where there is potential and opportunity to write new federal policy to reduce aviation sector emissions.

An enlarged version of this roadmap can be found in Appendix A.



Policy Gap Analysis Roadmap - The graphic on page 10 is a road map of how I will be analyzing emissions from the aviation sector. To analyze the broader emissions portfolio of the industry it is important to breakdown the largest emissions sources into several categories. The graphic above shows three large buckets.

1. Fuel Emissions from In-flight Operations – The first bucket I have identified is fuel emissions from in-flight operations, which are the largest identifiable bucket of emissions from the industry. These emissions are the result of burning fuel to run the engines on the aircraft. There are several ongoing international and domestic policies that are driving the industry to reduce emissions from in-flight operations.
2. Emissions from Inefficiencies in Operations – the second bucket is the emissions that are generated as a result of the inefficiencies in operations in the United States air traffic control system. These operational inefficiencies can be the result of a number of different factors, including weather, outdated technology, traffic volume, popular travel times, and existing inefficiencies in business as usual operations that cause ripple effects in the air traffic control system. These disturbances to the system result in longer flight times and delays where aircraft sit on the tarmac for up to 3 hours at a time waiting to take off. The resulting emissions contribute the overall GHG portfolio of the industry.
3. Emissions from Ground Operations and Airport Operations – The third bucket of emissions are those generated as a result of operating airport facilities. Airports and airlines utilize large fleets of ground service vehicles that consume a large amount of energy servicing aircraft and moving passengers throughout the airport complex.

Analysis

Emissions Reductions for In-flight Operations - There are a number of international and domestic policies that are incentivizing the decarbonization of the aviation sector. The industry recognizes that the development of more sustainable aviation fuel is an important goal of reducing greenhouse gas emissions industry wide.

According to the International Air Transportation Association (IATA), 4.3 billion passengers flew in 2018, up from 3.1 billion passengers in 2013, which is an increase of approximately 38% in five years.¹⁴ As a result of this significant increase in air traffic, fuel consumption has increased accordingly. Furthermore, IATA estimates that fuel consumption increased from 74 billion gallons of kerosene in 2013 to 94 billion gallons in 2018, reflecting a growth of 27%.¹⁵ As a result of this increase in fuel consumption driven by passenger demand, greenhouse gas emissions increased from 710 million metric tons (MMT) in 2013, to 895 MMT by 2018.¹⁶ The unprecedented passenger growth in demand for air travel is outpacing current emissions reductions policies. Reducing the aviation sector's growing GHG profile will be key to meeting the emissions reduction targets outlined in the IPCC special report.

Rapid development of sustainable aviation fuel (SAF) is of critical importance if we are to meet our emissions reduction targets domestically and internationally. Since airplanes generate emissions during flight at various altitudes, in various climates, and at various different locations, the global aviation community has agreed that international regulations and policy are the most appropriate mechanism to facilitate SAF development and deployment. To facilitate

¹⁴ IATA. 2019. Industry Statistics Fact Sheet.
https://www.iata.org/pressroom/facts_figures/fact_sheets/Documents/fact-sheet-industry-facts.pdf

¹⁵ Ibid.

¹⁶ Ibid.

SAF development, ICAO has created the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). CORSIA is an emissions reduction scheme based on a single unified market for the aviation industry, whose standards for implementation were adopted in January 2019.¹⁷ CORSIA incentivizes airlines to use alternative fuels that displace emissions by allowing an airline to purchase emissions unit equivalents to offset requirements.¹⁸ CORSIA is scheduled to begin in 2021. ICAO forecasts that CORSIA will mitigate around 2.5 billion metric tons of CO₂ between 2021 and 2035.¹⁹ While CORSIA is an international aviation program, it is important to note that its incentives impact domestic policy and industry actions because of the nature of the airline industry.

In the United States, several federal government agencies have been conducting research and development of SAF for deployment in the global and domestic aviation industries for over a decade. As a response to the global demand for SAF, first caused by volatility in petroleum prices, the Commercial Aviation Alternative Fuels Initiative (CAAFI) was formed in 2006 by FAA and industry. CAAFI is a public-private partnership with stakeholders from across the industry, including airlines, engine manufacturers, plane manufacturers, biofuels producers, the EPA, FAA Office of Environment and Energy Research and Development, U.S. Department of Agriculture, Rocky Mountain Institute, ACI-NA, and Airlines for America (A4A).²⁰ All of these stakeholders have come together to focus on the development of SAF options that offer equivalent safety and costs compared to petroleum based jet fuels. The most important characteristic for the SAF is that it can be “dropped in” or is functionally equivalent to fuel used

¹⁷ IATA. 2019. Fact sheet: CORSIA. https://www.iata.org/pressroom/facts_figures/fact_sheets/Documents/corsia-fact-sheet.pdf

¹⁸ Ibid.

¹⁹ Ibid.

²⁰ CAAFI. 2019. Members. <http://caafi.org/about/members.html>

in existing engine technologies and planes. To date, CAAFI has made substantial progress in achieving its goal of promoting drop in SAF to the domestic and international aviation industry partners. As aviation activity increases both domestically and worldwide, SAF is a necessary component to reducing emissions at home and abroad. Some of the key CAAFI accomplishments in the development and deployment of SAF fuels are as follows:²¹

1. CAAFI has collaborated with the FAA, ASTM International (one of the world's biggest global standard setting entities), and aircraft manufacturers to validate and establish drop-in SAF standards.
2. CAAFI has formed a strategic partnership with A4A and the Defense Logistics Agency (Department of Defense) to create a single market for SAF.
3. CAAFI has facilitated the "Farm to Fly 2.0" agreement between USDA, DOE, & CAAFI sponsors to "accelerate feedstock development, execute feasibility studies, & foster regional development activities."
4. CAAFI has partnered with ICAO to establish a best practice evaluation framework for SAF. This evaluation framework has been endorsed by ICAO.
5. CAAFI has issued national guidance for SAF producers on how to sell SAF to airlines with A4A.

These critical milestones have demonstrated significant progress between U.S. federal agencies, industry, and fuel producers.

After conducting this initial assessment of existing policy, it is also important to forecast whether operating under the existing scenarios will result in desirable outcomes, and in our case,

²¹ CAAFI. 2019. Fueling solutions for secure and sustainable aviation. http://caafi.org/about/pdf/CAAFI_Brochure.pdf

significant emissions reductions. The John A. Volpe National Transportation Systems Center (Volpe Center) is a government run transportation policy think tank based at the Massachusetts Institute of Technology and operated by DOT. In 2012, the Volpe Center issued a final report titled *Alternative Aviation Fuel Scenario Analysis Report* which presents a detailed analysis and “bottom up projection of the potential production of alternative jet fuels in North America.”²² This report has identified several deployment pathways based on current SAF production and also estimates SAF production based on more optimistic and aggressive scenarios. The FAA’s target emissions goal is to achieve carbon neutral growth of U.S. aviation at 2005 emissions levels, starting in 2020.²³ Additionally, in order to achieve carbon neutral growth at the FAA target level, 20-40% of projected 2020 fuel demand would need to be fulfilled using zero-carbon alternative fuels.²⁴ The fuel production pathways examined in the preliminary Volpe “bottoms up” projection had an estimated average 1/3 reduction in life cycle CO₂ emissions, for a pool of alternative fuels, and a best case scenario of 11% total emissions reductions.²⁵ An 11% total reduction coupled with other market based solutions will help the industry reduce its emissions.

There are also several government programs that focus on the improvement of airframes and engines, further reducing the emissions from inflight operations. The Continuous Lower Energy, Emissions and Noise (CLEEN) Program is the FAA's principal environmental effort to accelerate the development of new aircraft and engine technologies.²⁶ The CLEEN program is a cost sharing partnership program with industry that invests in developing technologies that will

²² John A. Volpe National Transportation Systems Center. 2012. *Alternative Aviation Fuel Scenario Analysis Report*. <https://rosap.ntl.bts.gov/view/dot/9705>

²³ Ibid.

²⁴ Ibid.

²⁵ Ibid.

²⁶ FAA. 2019. The Continuous Lower Energy, Emissions and Noise (CLEEN) Program. https://www.faa.gov/about/office_org/headquarters_offices/apl/research/aircraft_technology/cleen/.

reduce noise, emissions, and fuel burn. The original list of companies included Boeing, General Electric Aviation, Honeywell Aerospace, Pratt & Whitney, and Rolls Royce. It is through the CLEEN partnership that these private companies pursued research and development of new engine and airframe technologies to increase fuel economy of the aircraft that they manufacture. The success of the CLEEN program has led to the expanded CLEEN II to additional companies to develop technologies that will be flight ready by 2026. The CLEEN II program goal is to reduce aircraft fuel burn by 40% from 2010 levels. Researchers at the Partnership for Air Transportation Noise and Emissions Reduction (PARTNER) Center of Excellence at Georgia Tech University conducted an assessment of CLEEN program technologies and estimated that full deployment could reduce U.S. fleet-wide fuel burn by 2 percent from 2025 through 2050, representing a cumulative savings of 22 billion gallons of jet fuel.²⁷ This 2% reduction is representative of the tailpipe emissions reductions from the 40% reductions in fuel burn. This estimate also factors in the substantial increase in passenger volume in the next several decades, which will offset some of the gains realized from the new CLEEN and CLEEN II technologies. This estimate would comparatively equate to the removal of 1.7 million cars from our roads over the same 25-year period.²⁸ CLEEN and CLEEN II funds are also used in the development of SAF.

In addition to the PARTNER lab at Georgia Tech University, the FAA also established the Aviation Sustainability Center (ASCENT), continuing the tradition of university research and focusing solely on SAF and environment issues.²⁹ ASCENT's first project for the FAA is

²⁷ FAA. 2019. Fact Sheet – Continuous Lower Energy, Emissions, and Noise (CLEEN) Program. https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=22534

²⁸ Ibid.

²⁹ United States Government. 2015. U.S. Aviation Green House Gas Emissions Reduction Plan. https://www.icao.int/environmental-protection/Lists/ActionPlan/Attachments/30/UnitedStates_Action_Plan-2015.pdf

examining potential regional supply chains within the United States that can meet U.S. goals for SAF production and deployment.³⁰

As part of my gap analysis, identifying the current state of aviation policy for in-flight operations is part of establishing a policy baseline. Based on my research of existing policy in the aviation sector that has to deal with in-flight operations emissions, I believe that there is sufficient existing policy to address the source of inflight operations emissions. However, additional policy, like a price on carbon, is needed to further accelerate emissions reductions. The combination of existing international and domestic policy initiatives has created a policy matrix that is sufficiently driving the deployment of SAF in the global and U.S. market place. The public-private partnerships with significant government input and funding will also continue to drive emissions reductions from in-flight operations.

Emissions Reductions from Efficiencies Improvements in Operations - The second bucket of emissions from in-flight aviation operations is caused by the inefficiencies in our current United States National Airspace System (NAS). The NAS is administered by the FAA and is commonly known as our air traffic control (ATC) system. The NAS has evolved over time from its humble beginnings almost a century ago. In 1926, Congress charged the Secretary of Commerce with “setting air traffic rules, certifying pilots and aircraft, establishing airways and operating aids to navigation.”³¹ In 1938, Congress established the Civil Aeronautics Authority and in 1958 Congress created the Federal Aviation Agency which we now know as the modern FAA.³²

³⁰ Ibid.

³¹ National Air Traffic Controllers Association. 2013. A History of Air Traffic Control. https://www.natca.org/images/NATCA_PDFs/Publications/ATCHistory.pdf

³² Ibid.

By the mid 1990s, outdated technology plagued the NAS and ATC infrastructure. ATC centers and towers around the country experienced power outages, computer failures that lead to major disruptions, compromising passenger safety. The Air Transportation Association estimated that these delays cost upwards of \$3.5 billion in wasted fuel, passenger time, and underutilized air craft.³³ These delays continued into the early 2000s and recognizing the need for change, President George W. Bush and Congress established the Commission on the Future of the United States Aerospace Industry (CFUSAI).³⁴ The Final Report that was submitted to Congress in 2002. It is interesting to note, that the over 300-page report does not differentiate between noise pollution and emissions, and CO2 is only mentioned twice in the entire document. Congress responded to the final report by enacting the Vision 100 – Century of Aviation Reauthorization Act, which established the multi-agency Joint Planning and Development Office (JPDO).³⁵ The JPDO was tasked with creating an integrated plan for a Next Generation Air Transportation System to modernize the NAS, which would form the basis for NextGen.

NextGen or the Next Generation Air Transportation System is conceptual policy framework developed by the FAA to modernize America’s air transportation system.³⁶ For the purposes of this capstone report the NAS is synonymous with the air transportation system. The modernization of the NAS is one of the most ambitious infrastructure improvement projects in U.S. history. The ongoing modernization of the NAS has several different components that make up its implementation plan.³⁷ These four areas are:

³³ Ibid.

³⁴ NASA. 2002. Final Report: Commission on the Future of the United States Aerospace Industry. <https://history.nasa.gov/AeroCommissionFinalReport.pdf>

³⁵ Vision 100 – Century of Aviation Reauthorization Act – P.L. 108-176. 2003. United States Congress. <https://www.congress.gov/bill/108th-congress/house-bill/2115>

³⁶ FAA. 2019. What is NextGen. https://www.faa.gov/nextgen/what_is_nextgen/

³⁷ FAA. 2017. NextGen Priorities: Joint Implementation Plan Update Including Northeast Corridor. <https://www.faa.gov/nextgen/media/NGPriorities-2017.pdf>

1. Multiple Runway Operations (MRO) – Multiple Runway Operations improve operation efficiency by closely spacing parallel runways, reducing flight delays. MRO allows for simultaneous approaches, increasing the number of aircraft that can land in a given time frame. This improvement increases capacity during peak times and reduces traffic flow restrictions. Traffic restrictions often lead to increased fuel burn while aircraft wait their turn to land.
2. Performance Based Navigation (PBN) – PBN is an advanced satellite ATC system that creates state of the art, precise 3-D flight paths.³⁸ The new 3-D flight paths offer greatly increased operational benefits including safety, efficiency, reduced cost, and importantly, reduced carbon emissions. PBN is a drastic improvement over the old system of NAVAIDs (navigational aids) which forced pilots to zig-zag between ground-based systems. PBN allows for straight-line, point to point routes. The new PBN routes reduce fuel consumption of aircraft and emissions by shortening flight distance.³⁹
3. Surface Operations and Data Sharing – According to FAA, some of the greatest efficiencies can be gained while aircraft are still on the ground and at the gate. An important aspect of implementing NextGen is to facilitate greater data sharing between stakeholders.⁴⁰ Increasing the amount of shared data increases predictability which leads to efficiency improvements. To facilitate the new data sharing strategy, FAA is developing and implementing the Terminal Flight Data Manager (TFDM). The TFDM is the surface management solution for NextGen and managing aircraft on the ground,

³⁸ FAA. 2018. Performance Based Navigation: In the Operation.

https://www.faa.gov/nextgen/how_nextgen_works/new_technology/pbn/in_depth/

³⁹ Ibid.

⁴⁰ FAA. 2019. NextGen Priorities – Surface Operations and Data Sharing.

<https://www.faa.gov/nextgen/snapshots/priorities/?area=sops>

much like PBN is the solution for aircraft in flight. TFDM is critical to modernizing airport surface management as passenger volume and air traffic increase nationwide. TDFM is critical to streamlining the flow of departures from airports, minimizing wait times on the tarmac which saves fuel and reduces emissions.⁴¹

4. Data Communications (Data Comm) – The Data Comm program is a NextGen initiative to improve data communications services between pilots and air traffic controllers⁴². The program aims to improve digital information links between ground infrastructure and flight deck avionics systems. This improved digital information link will improve information flow, increasing efficiency in ATC clearances, instructions, traffic flow management (LTO and approach), flight crew requests and report communications.⁴³ By improving communications infrastructure, Data Comm will allow for critical NextGen operational improvements that will: reduce delays and increase route efficiency, enhance safety, reduce the impact of ground delays, and will reduce environmental impacts caused by reductions in fuel burn leading to lower emissions.⁴⁴

These four focus areas form the basis for the NextGen efficiency improvements. It is through these improvements that NextGen program aims to reduce its emissions footprint to mitigate the environmental impacts and emissions from aviation operations. These operational improvements are part of the NextGen environment and energy strategy, that addresses these issues through the lens of how they impact the ability of the NAS to function. Two of the major climate goals for the NextGen program are:⁴⁵

⁴¹ FAA. 2018. Terminal Flight Data Manager (TFDM). https://www.faa.gov/air_traffic/technology/tfdm/

⁴² FAA. 2017. Data Communications (Data Comm). <https://www.faa.gov/nextgen/programs/datacomm/>

⁴³ Ibid.

⁴⁴ Ibid.

⁴⁵ FAA. 2018. Environment and Energy: In the Operation. https://www.faa.gov/nextgen/how_nextgen_works/eande_safety/eande/in_depth/

1. Air Quality: FAA NextGen pursues the goal of significantly reducing air quality impacts attributable to aviation.
2. Energy: FAA NextGen seeks to achieve net fuel burn reduction by 2020 relative to a 2005 baseline, and the rapid deployment of SAF.

NextGen is working extensively on the FAA office of Environment and Energy on a five-pillar approach to meet the FAA NextGen environment goals. The five pillars are:⁴⁶

1. Accelerating the maturation of new aircraft technologies.
2. Advancing sustainable alternative aviation fuels.
3. Advancing air traffic management modernization and operational improvements.
4. Developing policies, environmental standards, and market-based measures.
5. Improving scientific knowledge and enhancing environmental modeling capability.

It is through a combination of in-flight emissions reductions initiatives, including the development of SAF through CAAFI and new technologies through ASCENT and CLEEN, that FAA and other federal government agencies seek to drastically reduce the emissions from in-flight operations. Between 2010 and 2015, FAA estimates that NextGen improvements have saved 59 million gallons of fuel and reduced fuel CO₂ emissions by 565 thousand tons.⁴⁷

With full implementation of the NextGen program, USG estimates that the emissions reductions from NextGen will support the overall aspirational goal of carbon neutral growth by 2020. The figure on the next page shows a life cycle analysis of CO₂ emissions impacts, as a percent of the 2005 level with an aggressive mitigation system improvement scenario.⁴⁸ This figure shows how

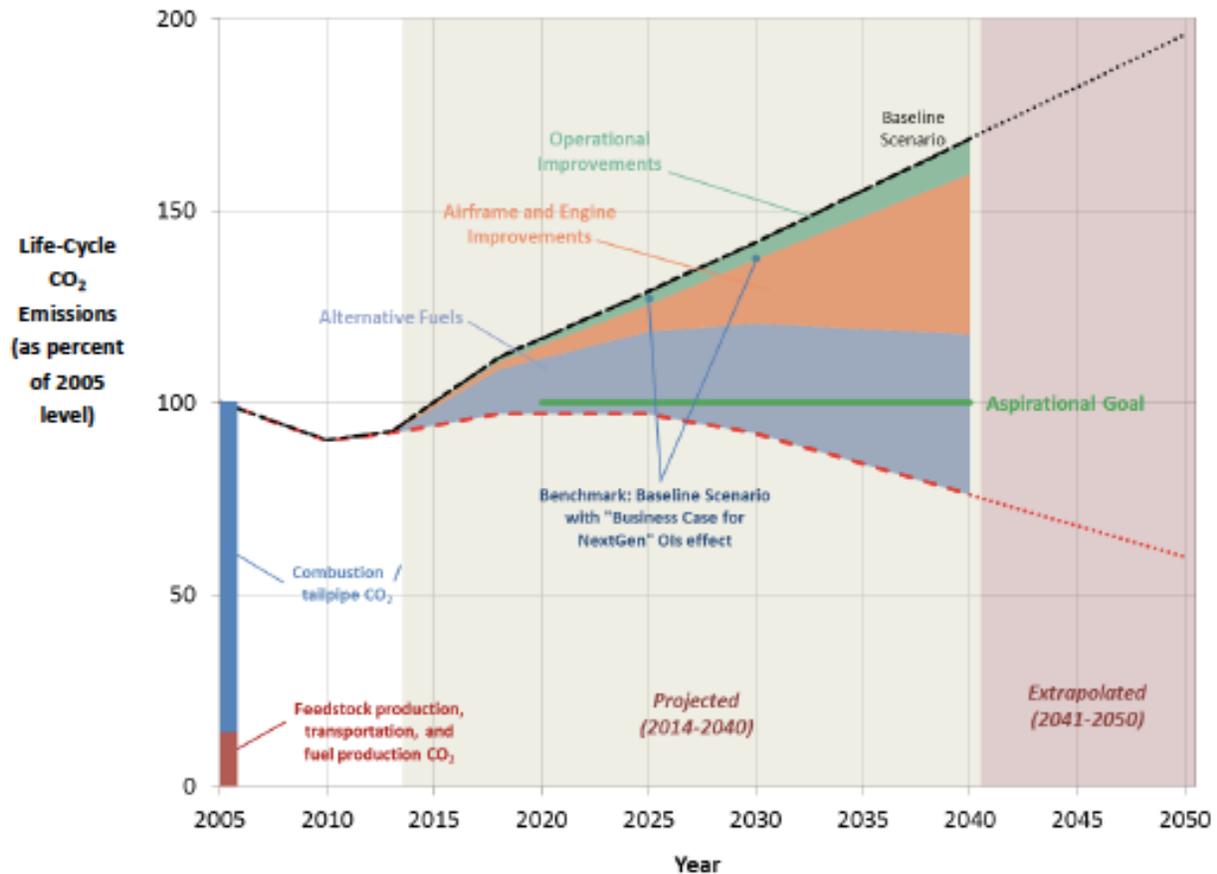
⁴⁶ Ibid.

⁴⁷ United States Government. 2015. U.S. Aviation Green House Gas Emissions Reduction Plan. https://www.icao.int/environmental-protection/Lists/ActionPlan/Attachments/30/UnitedStates_Action_Plan-2015.pdf

⁴⁸ Ibid.

NextGen and SAF development and deployment will help the aviation sector achieve these emissions reduction targets set by FAA and USG.

Figure ES-2 Projected life-cycle CO₂ emissions impacts – aggressive system improvement scenario



After conducting a policy analysis of the FAA NextGen program, it is clear that the United States is pursuing an ambitious emission reduction policy. Implementation of this policy will require a tremendous amount of effort and resources. As noted above, the NextGen project is one of the largest infrastructure projects in American history, demonstrating the scope of the project and the commitment by the USG to significant reductions from the aviation sector. As part of the policy gap analysis, the objectives outlined by FAA and other USG departments and agencies show that there are sufficient existing policy mechanisms to facilitate emissions reductions. As was the case with emissions reduction policy for in-flight operations, I believe

there is similar policy commitment to emissions reductions in the NAS through NextGen efficiency improvements that will help substantially reduce overall aviation sector emissions.

Emissions Reductions from Ground Operations - The final large source of emissions from the aviation sector originates from ground operations. Ground operations emissions can come from a number of sources, including onsite emissions from facilities, emissions from ground support equipment (GSE), emissions generated by power producers offsite that is used to power airport facilities, and emissions from auxiliary vehicles such as vans or shuttle busses that connect passengers to parking facilities, rental car operations, and other transportation hubs. Categorizing emissions from ground operations is a more nuanced task than simply taking an inventory of tailpipe emissions from aircraft. There are several different inventory reporting standards and approaches that airports can use to try to analyze the environmental impacts that result from ground operations on a day to day basis. This section will detail how existing methods are used to inventory ground operation emissions and as is the case with previous sections, the report will examine the efficacy of new policies that can help the aviation industry move toward ZCGO.

Reducing airport emissions can help airports lower energy consumption and operating costs, and achieve positive environmental outcomes. Airports are also subject to different federal, state, and local government laws and regulations, making it a prudent course of action for airport operating authorities to explore ground operations emissions reduction policies. The ground operation emissions can be categorized into three separate categories:⁴⁹

⁴⁹ FAA. 2019. Airport Carbon Emissions Reductions.
https://www.faa.gov/airports/environmental/air_quality/carbon_emissions_reduction/

- Scope 1: Scope 1 emissions are emissions from airport-owned or airport-controlled sources. Examples include onsite power plants that burn fossil fuels to power airport infrastructure, conventional gasoline vehicles and GSE that use gasoline or diesel fuel.
- Scope 2: Scope 2 emissions are indirect emissions that come from the purchase of offsite electricity or heat from the grid.
- Scope 3: Scope 3 emissions are emissions from third party sources that the airport does not control. Examples include tenant emissions, including airline GSE and auxiliary vehicle fleets, on airport aircraft emissions, emissions from passenger vehicles arriving or departing the airport, and emissions from waste disposal and processing.

For the purposes of this capstone report it is important to note, for my analysis, scope 1 GSE and auxiliary vehicles owned and operated by the airport will be included in scope 3. There are currently policies that exist or that are being proposed to address scope 1 and scope 2 emissions through existing FAA, state, and local programs. An example of how state and local programs combine to address scope 1 and scope 2 emissions would be the efforts by Dallas-Fort Worth (DFW) to achieve carbon neutral accreditation through the Airport Carbon Accreditation Program. Texas has a very strong renewable portfolio standard (RPS) which has incentivized the rapid deployment of solar and wind renewable energy generation.⁵⁰ Because of this rapid deployment to meet RPS goals, coupled with a highly competitive, deregulated energy market in Texas, DFW purchases 100% of its electricity from cost competitive renewable energy

⁵⁰ NC Clean Energy Technology Center - DSIRE. 2018. Texas Renewable Generation Requirement. <https://programs.dsireusa.org/system/program/detail/182>

generation, more specifically Texas wind farms.^{51,52} DFW has also installed onsite solar and geothermal technologies to diversify its energy sources.⁵³ By purchasing 100% of its electricity from renewable sources and developing its own onsite renewable generation, DFW was able to reduce its non-vehicle scope 1 and scope 2 emissions and was able to lower its per passenger carbon emissions by 5.4%.

The first step airports can take in reducing their GHG emissions is to estimate or inventory their emissions. It is important to understand where emissions come from to develop policy to reduce those emissions. There are several different GHG emissions inventory tools that are available to airports that come from both the federal government and industry.

The first set of tools that an airport can use to inventory its emissions are several federal models. To create a complete inventory of the emissions sources from an airport, it is likely that several different models will need to be used to draw a complete understanding of the GHG emissions inventory scope.

The first model which was developed by the FAA is the Aviation Environmental Design Tool (AEDT). AEDT is a software system developed by the FAA Office of Environment and Energy. AEDT dynamically models aircraft performance and can be used to compute emissions from fuel burn.⁵⁴ AEDT can measure everything from single flight gate to gate emissions to complex analyses of entire metroplexes with multiple airports. The latest version of the AEDT

⁵¹ Mia Taylor. Travel Pulse. 2019. DFW Becomes Largest Airport in the World to Achieve Carbon Neutral Status. <https://www.travelpulse.com/news/airlines/dfw-becomes-largest-airport-in-the-world-to-achieve-carbon-neutral-status.html>

⁵² Dallas-Fort Worth International Airport. 2019. Sustainability/Environmental. <https://www.dfwairport.com/sustainability/>

⁵³ Ibid.

⁵⁴ FAA. 2015. Aviation Emissions and Air Quality Handbook. https://www.faa.gov/regulations_policies/policy_guidance/envir_policy/airquality_handbook/media/Air_Quality_Handbook_Appendices.pdf

software can compute emissions for CO₂, which is an improvement over prior models that only included EPA criteria pollutants (CO, Pb, NO₂, O₃, PM₁₀, PM_{2.5}, and SO₂).⁵⁵ The new ability to model CO₂ allows the AEDT model to quantify GHG emissions from all sources including aircraft, APUs (Auxiliary Power Units), GSE (Ground Support Equipment), and an array of stationary sources.⁵⁶

Another model being used to assess air quality impacts of airport development projects is the Emissions and Dispersion Modeling System (EDMS). The EDMS was developed by the FAA in the mid-1980s and is designed to assess the air quality impacts of airport emission sources which consist of aircraft, APUs, GSE, ground access vehicles, and stationary sources.⁵⁷ The EDMS was one of the first and only air quality assessment tools specifically engineered for the aviation community. EDMS specifically incorporates GSE emission factors from the EPA's NONROAD model for non-road vehicle emissions.⁵⁸ Additionally, the FAA mandated in 1998 that EDMS be the required model to perform air quality analysis for aviation emissions.⁵⁹

Overtime, the two models improved and FAA added functionality, giving these models the capability to quantify CO₂ emissions. In 2015, FAA released AEDT2b which replaced several models including EDMS.⁶⁰ The new AEDT2b model has the capability to model all airport emissions sources under scope 1 and scope 3 including emissions from APUs, GSE, on-airport motor vehicle fleets, boilers, and generators. This new inventory capability gives the

⁵⁵ Ibid.

⁵⁶ Ibid.

⁵⁷ Ibid.

⁵⁸ Ibid.

⁵⁹ FAA. 1998. Emissions and Dispersion Modeling System Policy for Airport Air Quality Analysis; Interim Guidance to FAA Orders 1050.1D and 5050.4A. 18068 Federal Register/Vol. 63, No. 70/Monday, April 13, 1998

⁶⁰ FAA. 2018. Air and Noise Models: 2018 Southwest Region Airports Conference.

https://www.faa.gov/airports/southwest/airports_news_events/2018_conference/media/session-d-air-and-noise-models.pdf

federal government agencies and stakeholders a thorough understanding of ground operations emissions sources.

Another inventory mechanism that airports can use comes from the private sector. Airport Council International has developed its own emissions reporting tool aptly named the Airport Carbon and Emissions Reporting Tool (ACERT). ACERT can be used to generate comprehensive airport emissions inventory reports that are consistent with ACI's Airport Greenhouse Gas Emissions Management Guidance Manual.⁶¹ The ACI guidance manual is an important private sector document that outlines the criteria for the Airport Carbon Accreditation (ACA) program, which is the only global airport-specific carbon management standard.⁶² The methodology for ACERT also delineates Scope 1, Scope 2, and Scope 3 emissions in the same way that the federal inventory models do, which is an important feature and lends credibility to the industry GHG reporting tool because it uses government methodologies. One distinction between the two modeling tools is that the ACERT tool can be used by any airport in the United States and is also distributed internationally. Another distinction is that the ACI ACERT tool is provided to the ACI member airports at no cost, while airports must purchase an AEDT license from the government.

It is important to note, that for the purposes of writing this capstone report, that I was not able to acquire access to either reporting tool due to the cost and barriers to access. It is also important to note that while inventory tools are readily available and that airports can theoretically use them to inventory their emissions, comprehensive attempts to do this have not been undertaken due to the sizable costs associated with completing a full inventory.

⁶¹ ACI. 2019. Airport Carbon and Emissions Reporting Tool (ACERT) v5.1. <https://aci.aero/About-ACI/Priorities/Environment/ACERT/>

⁶² Ibid.

In addition to reporting models that have been developed by the government and private industry, there are also federal programs that research and develop practical solutions to problems faced by airport operators. One such federal research program is the Airport Cooperative Research Program (ACRP) which is run by the Transportation Research Board at the National Academies.⁶³ ACRP was authorized as part of the Vision 100 – Century of Aviation Reauthorization Act. As recently as 2015, the ACRP conducted research into inventorying GSE emissions. The landmark report, *ACRP Report 149: Improving Ground Support Equipment Operational Data for Airport Emissions Modeling*, is comprehensive guidance document that details GSE fleet and activity data for use with the EDMS and AEDT.⁶⁴ Report 149 identifies that “although airport GSE can provide significant contributions to an airports overall emissions, little guidance is available to help airports accurately capture actual GSE activity at their facilities in a manner suitable for the FAA’s approved emissions models.”⁶⁵ Report 149 also identifies that this can lead to inaccurate inventory predictions of air quality impacts because airport staff are using inconsistent data collection methods. This has led airports to choose not to collect specific GSE activity data due to resources constraints and instead using default values in the EDMS and AEDT databases. Taking an inventory of GSE fleets can require a substantial amount of data depending on the approach that an airport wishes to take in doing so. Information required to conduct an inventory of GSE emissions of a single vehicle includes: GSE type (baggage tug, boarding stairs, belt loaders), GSE count, fuel type (gasoline or diesel), horsepower, and age. The amount of data an operator must attain becomes a question of cost vs.

⁶³ ACRP. 2019. Airport Cooperative Research Program. <https://www.faa.gov/airports/acrp/>

⁶⁴ ACRP. 2015. ACRP Report 149: Improving Ground Support Equipment Operational Data for Airport Emissions Modeling.

⁶⁵ Ibid.

benefit in that manpower and cost can limit the amount and the quality of the data obtained. The graphic below (Figure 7) from Report 149 details a decision tree that an airport operator, government agency, or stakeholder can use to evaluate how advanced the approach should be to collecting the data for the GSE emissions inventory.⁶⁶

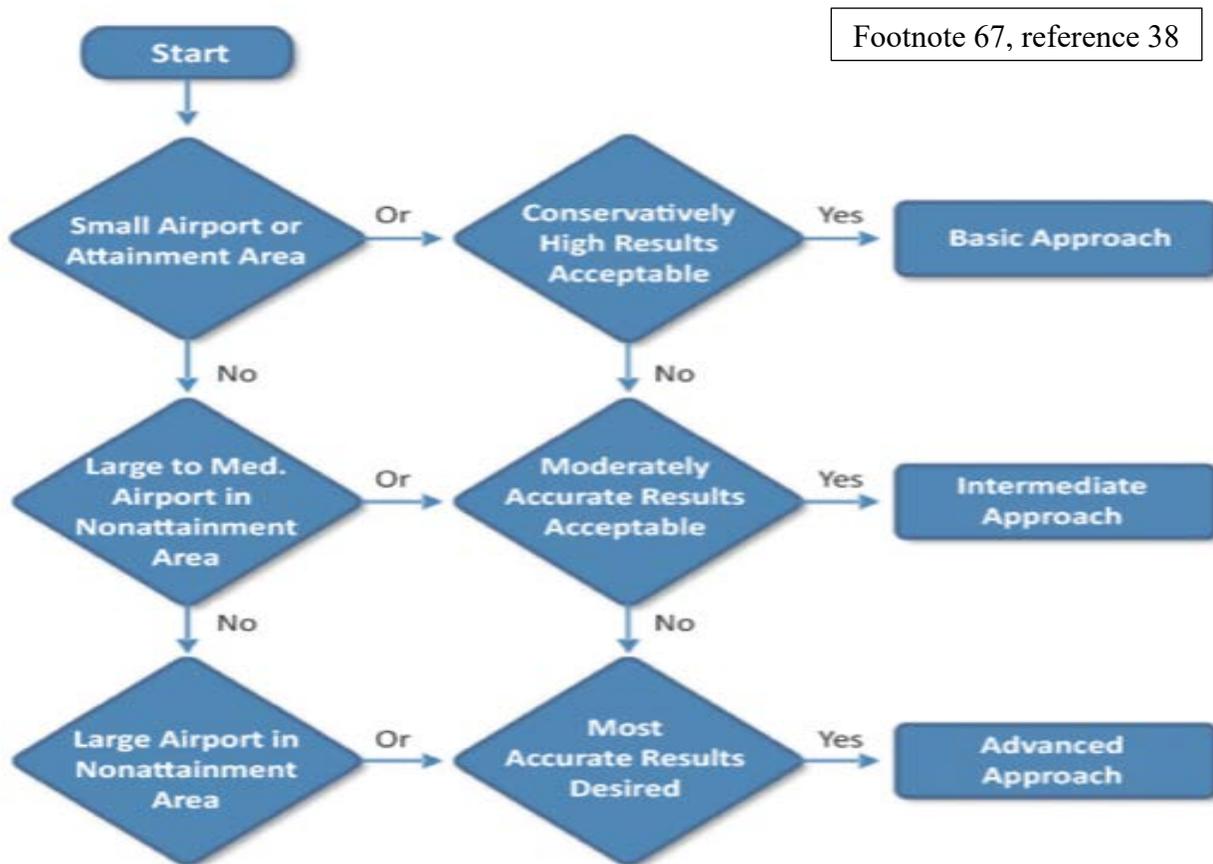


Figure 7. Airport GSE emissions inventory approach selection decision-tree diagram.

Ideally, federal databases should exist to catalog GSE population data so accurate emissions inventories could be readily developed and adjusted as vehicles are added and removed from service. Unfortunately, as outlined in a 1999 EPA report titled *Technical Support for Development of Airport Ground Support Equipment Emission Reductions*, no such database

⁶⁶ Ibid.

exists and no standard GSE tracking procedures exist across airports.⁶⁷ There are several methodologies that can be used to estimate GSE population, the EPA approach summarized in detail in Appendix B. However, these methodologies are not 100% accurate as they require conducting regression analysis on sample populations that must then be extrapolated into predictive national GSE population totals. In the 1998 report, it was estimated that with a bottom up regression, there is a national GSE population of 45,000 units.⁶⁸ This estimate is also contrasted with a top down approach from the 1991 Nonroad Engine and Vehicle Emission Study Report, which estimates a national GSE population of 85,000 units.⁶⁹ These drastically different population estimates make it difficult to then estimate a national GSE emissions inventory because it is not known how many GSE vehicles are currently in operation across the country. Furthermore, the emissions reduction calculations in the 1998 report for EV GSE are baselined to electricity being generated by coal fired power plants in the worst-case scenario, and natural gas power plants in the best-case scenario. Since these estimates are now outdated by two decades it is reasonable to assume that the emissions reduction estimate calculations cannot be relied upon. Furthermore, according to California Air Resources Board (CARB) analysis, the useful life survival curve for GSE is 16 years⁷⁰, meaning that after 21 years since the initial EPA GSE population estimate, a significant portion of GSE nationwide fleet estimate have been retired. Throughout my research it has also become clear that a second effort to fully estimate the

⁶⁷ EPA. 1998. Technical Support for Development of Airport Ground Support Equipment Emission Reductions. <https://nepis.epa.gov/Exe/ZyPDF.cgi/P1001U8S.PDF?Dockey=P1001U8S.PDF>

⁶⁸ Ibid.

⁶⁹ EPA. 1991. Nonroad Engine and Vehicle Emission Study Report. <https://nepis.epa.gov/Exe/ZyPDF.cgi/P100AI9E.PDF?Dockey=P100AI9E.PDF>

⁷⁰ California Air Resources Board. 2006. Airport Ground Support Equipment Inventory Data. https://ww3.arb.ca.gov/msprog/ordiesel/documents/off_rd_inventory_assump_gse_corrected.pdf

nationwide GSE population has not been undertaken, although population regression formulas allow us to make a rough guess of what the nationwide total might be.

There is a sizable opportunity to mitigate scope 3 emissions at our nation's airports by replacing fossil powered GSE equipment and vehicles and other passenger transport vehicles with zero emission alternatives. As noted above various tools have been developed and a partial, but dated, inventory has been extrapolated to estimate total population for standard GSE categories, but not for passenger transport. There are no existing mandates or incentives driving the aviation industry to inventory scope 3 emissions or the equipment and vehicles producing the emissions. Also, there is no single agent at the airport level that owns the problem. Typically, airport authorities lease gates to airlines who then operate independently and often through a collection of subcontractors that operate the variety of GSE equipment and vehicles that service the aircraft between LTO. The subcontractor model is also applied to passenger transport between terminals and parking, etc., and transport to rental cars, hotels, etc. are independently operated. The next section addresses a two-step policy framework that first uses a grant program to obtain the needed scope 3 inventories and then provides investment tax credits to rapidly replace fossil powered GSE and passenger transport vehicles with zero emission alternatives.

Results: Policy Recommendations to Reduce Scope 3 Emissions at U.S. Airports

Given the analysis from the section above it is clear that opportunity exists to inventory scope 3 emissions and then implement policy mechanisms that reduce scope 3 emissions. The policy framework to accomplish this goal will first establish a grant program to help fund inventory activities necessary to gain a comprehensive understanding of the scope 3 emissions. The second plank of the policy framework will establish an investment tax credit program to incentivize

rapid replacement of fossil powered GSE and passenger transport vehicles with zero emission electric alternatives and charging infrastructure.

Zero Carbon Ground Operations Grant Program - As described above, there has not been a full industry wide accounting of GSE equipment and vehicles and passenger transport vehicles, therefore it has been difficult to quantify scope 3 emissions at the operating level. No mandate exists that requires a comprehensive accounting of scope three emissions and no one entity at the airport operational level has ownership or control of the emitting equipment and vehicles. These inventories are also costly and time-consuming. The ZCGO grant program provides funds to the local airport authority to conduct a comprehensive inventory. Completing the inventory qualifies operational entities, such as airlines and fleet operators, to participate in the companion ZCGO investment tax credit program. This financial assistance from USG incentivizes all parties to cooperate on the inventory in order to access the investment tax credits. The inventory database also provides USG the means to manage the investment tax credit requests from eligible tax payers.

The scope of the grant program will include 77 eligible airports. The eligibility is based on the inclusion of an airport or airline in the FAA online database called Aviation System Performance Metrics (ASPM). ASPM compiles data on the 77 largest airports in the United States, which includes several metrics for use by aviation stakeholders and the general public.⁷¹ The ASPM 77 airports list is a collection of our nations large and medium hub airports and represent a significant majority of all U.S. domestic air traffic, totaling almost 820 million

⁷¹ FAA. 2019. Aviation System Performance Metrics (ASPM). [https://aspmhelp.faa.gov/index.php/Aviation_System_Performance_Metrics_\(ASPM\)](https://aspmhelp.faa.gov/index.php/Aviation_System_Performance_Metrics_(ASPM))

enplaned passengers in 2018.⁷² The ASPM 77 represents 82% of all domestic U.S. air travel and the total U.S. systemwide domestic scheduled service passengers reached an all-time record high of 1.0 billion passengers in 2018.⁷³ It is also worth noting that the total scheduled passengers record number was an increase of 4.8% since 2017, further underscoring how flight demand is outpacing current emissions reductions efforts.

Under the new FAA ZCGO inventory grant program, the ASPM airports will further be divided into subgroups for the grant award payment scheme. The complete grant award table in Appendix C delineates the inventory grant award for individual airports. Inventory Group 1A consists of the nation's top 7 CORE 30 airports (a subset of the ASPM 77), which handle over 250 million passengers or roughly 25% of all passenger traffic in the United States. These airports have the largest facilities, and subsequently the largest GSE fleets and scope 3 emissions in the ASPM 77 airports. Inventory Group 1B will consist of the 14 next largest airports which account for over 280 million passengers or roughly 28% of all passenger traffic in the United States. Inventory Group 1C accounts for the next 9 airports and roughly 100 million passengers or 10% of all U.S. passengers. Groups 1A-1C encompass 29 of the CORE 30 airports. Group 2 comprises the remaining 47 airports and is further delineated into subgroups 2A and 2B with none of the remaining airports representing more than 1% of total 2018 enplaned passengers. The chart below represents the grant maximum award matrix for the ASPM 77.

⁷² Bureau of Transportation Statistics. 2019. 2018 Traffic Data for U.S Airlines and Foreign Airlines U.S. Flights. <https://www.bts.dot.gov/newsroom/2018-traffic-data-us-airlines-and-foreign-airlines-us-flights>

⁷³ Ibid.

<u>Inventory Grant Award Subgroup</u>	<u>Maximum Federal Grant Award</u>
Inventory Grant Group 1A	\$800,000
Inventory Grant Group 1B	\$650,000
Inventory Grant Group 1C	\$500,000
Inventory Grant Group 2A	\$400,000
Inventory Grant Group 2B	\$250,000

The total funding distribution for the inventory grant is estimated to be \$32,750,000. For the purposes of administering the inventory grant and providing technical assistance, Congress will fund the newly created grant program at \$50 million, incorporating administrative overhead and management oversight. The grant program will be located within the FAA Office of Environment and Energy. Additional details of the grant program are provided in Appendix C.

Zero Carbon Ground Operations Investment Tax Credit - The ZCGO investment tax credit will be the second policy mechanism that will influence market behavior and drive the aviation industry towards significantly reducing scope 3 emissions.

Traditionally, in the United States, federal and state governments have issued tax credits to influence industry behavior and drive change. The investment tax credit (ITC) is a mechanism that allows individuals or companies to deduct a certain percentage of investment related costs from their tax liability. One of the greatest successes of an investment tax credit specific to industry is the Solar ITC, which was enacted in 2006. The Solar ITC is the single most important policy mechanism in driving solar industry growth and since the credit went into effect the

industry has grown by 10,000%.⁷⁴ This growth has created hundreds of thousands of jobs and generated billions of dollars in the U.S. economy as a direct result of solar industry growth, while simultaneously substantially reducing emissions impacts.

The ZCGO ITC will be deployed in a similar manner to the Solar ITC, with the same goal of influencing industry behavior changes, specifically reducing scope 3 emissions at airports. ZCGO GSE and transportation fleets will replace, over time, polluting fossil fuel powered GSE and transportation fleets. The ZCGO investment tax credit will have three components for qualifying ground operations technologies, outlined in Appendix D. They are:

1. Aircraft Activity Engine-Off LTO – Under the ZCGO ITC Engine-off LTO tug vehicles will be included. Airports and airlines have experimented with different strategies to reduce fuel consumption during aircraft movement on the tarmac from gate to LTO. When the NAS is experiencing delays due to a number of factors, wait times on the tarmac for aircraft can increase fuel usage and emissions. Some airlines have tried to taxi with only one engine on, which has shown an increase in maintenance costs on the engine that remains off due to irregular engine usage. Additionally, there are aircraft landing systems companies that are in the preliminary stages of developing electric taxiing technology but this is still years from deployment. Even if successful it is not clear that aircraft manufactures will incorporate this technology into the aircraft design because of the weight and safety concerns of flying with large batteries. Incentivizing the investment in certified taxiing alternatives that reduce aircraft fuel burn will reduce emissions from LTO activities. Airports and airlines would be able to take advantage of the ZCGO tax

⁷⁴ Solar Energy Industry Association. 2019. Solar Investment Tax Credit. <https://www.seia.org/initiatives/solar-investment-tax-credit-itc>

credit to purchase new technologies like tow bar-less eTugs that can tow aircraft from the gate to the runway for takeoff. ZCGO ITC breakdowns can be found in Appendix D.

2. Ground Support Equipment – GSE fleets make up a significant portion of scope 3 emissions at airports. Incentivizing the transition to ZCGO will require an expeditious shift from fossil fuel GSEs to reduce emissions. Some airports have transitioned their fleets away from old diesel fleets to new low carbon fuels like compressed natural gas because of a desire to reduce EPA criteria pollutants but this does not reduce CO₂ emissions from GSE. There are several airports that have started to deploy electric GSE fleets but the change is expensive requiring significant investment. Airlines and airports will move more quickly to ZCGO GES fleets with the availability of government financial assistance. Currently, the only federal government financing mechanism to address this change is the Voluntary Airport Low Emissions (VALE) Program. The VALE program was designed to help airports meet state-related air quality responsibilities under the Clean Air Act.⁷⁵ The VALE program is a good first step but like several other programs discussed, the VALE program was designed to focus on EPA criteria pollutants which does not include CO₂. Additionally, VALE program siphons money away from two other airport funding sources, Airport Improvement Program (AIP) funds and Passenger Facility Charges (PFCs), which means there is competition for these funds for other quality of experience upgrades at airports that are more passenger focused and enjoy more public support than the conversion of GSE fleets to EV. The ZCGO ITC will incentivize airports and airlines to purchase new EV GSE and phase out

⁷⁵ FAA. 2019. Voluntary Airport Low Emissions Program. <https://www.faa.gov/airports/environmental/vale/>

fossil fuel based GSE. There are also significant operation and maintenance cost reductions with EV GSE which is explained in detail in Appendix E.

3. Fixed Gate Support – Fixed gate support would also be covered by the ZCGO. Fixed gate support equipment is designed to help the aircraft operate with engines off at the gate. Traditionally, aircraft run their onboard auxiliary power units (APU) (or plug into a mobile GSE APU) to operate air conditioning and electronic systems while waiting at the gate for passenger turnover and refueling. Running the onboard APU, which is a smaller jet engine located in the tail of the plane, also causes fuel burn and generates emissions. Fixed gate support equipment includes a number of different technologies that can reduce this fuel consumption by the aircraft or GSE. Examples include preconditioned air units for aircraft parked at the gate and fixed electrical ground power for electronic systems. Fixed gate support improvement will be covered under the ZCGO ITC.

In addition to the aircraft ground operations component to the ZCGO ITC, there will also investment tax credits for airport passenger operations. The airport passenger operations segment has three components. A full breakdown of the ZCGO ITC scheme for airport passenger operations can be found in Appendix D. The three components of the ZCGO ITC for airport passenger operations are:

1. On-Airport Shuttles – On-Airport shuttles and buses are integral components of functioning major metropolitan airport. Many of these bus and shuttle fleets, which ferry passengers between terminals, to parking garages, and rental car facilities are fossil fuel internal combustion engine vehicles. These fleets can be replaced by EVs, reducing GHG emissions. The ZCGO ITC will support the purchase of these vehicles and their associated charging infrastructure.

2. Off-Airport Shuttles – Off-Airport shuttles are also an important component of airport operations. These vehicles ferry passengers to off-airport facilities such as long-term parking, hotels, and public transit centers that allow passengers to travel to and from the airport. These vehicles would be covered by the ZCGO ITC but to a lesser extent than the on-airport vehicles.
3. Regional Shuttles – In an effort to address regional GHG impacts of the airport longer range regional shuttles are included in the ZCGO ITC so regional shuttle companies can take advantage of the financial incentive to replace their vans and buses with EV technology. The investment tax credit incentive for the regional shuttles is lower than on-and-off airport shuttles because they may not be dedicated to airport shuttle service.

The overall goal of the ZCGO ITC is to incentivize the replacement of all airport GSE and vehicles with EVs or electric gate support services.

Congressional Strategy

The purpose in crafting policy is to get it enacted into law to achieve the desired outcome, in this case the Low Carbon Airport of Tomorrow. Advancing the ZCGO Inventory Grant Program and ITC requires a congressional strategy that will allow the bill to be considered and taken seriously. The legislation will have to attract bipartisan support. The primary bill sponsors in the House of Representatives will ideally be a Democrat (majority) representing one of the top 7 CORE 30 airports identified in ZCGO Inventory Grant Group 1A, such as Atlanta, Los Angeles, Chicago, Denver, New York or San Francisco metropolitan areas. The Republican (minority) representative would most likely be from Texas in the Dallas-Fort Worth metropolitan area, also in group 1A. Choosing representatives from areas that represent major stakeholder airports as champions of the legislation would lend credibility to the purpose of the bill. On the Senate side,

a Democratic senator from Washington state and a Republican senator from Georgia would be ideal bill sponsors because they represent major aviation industry stakeholder groups, including Boeing and the Atlanta Hartford-Jackson International Airport which is the largest airport in the United States, global hub for Delta Airlines, and Textron GSE, one of the world's largest manufactures of GSE equipment.

After establishing the primary bill sponsors, the legislation would need to be circulated widely with aviation stakeholder groups. The groups that would need to endorse the legislation in order for it to pass through Congress would be Airports Council International-North America, Airlines for America, Airport Workers United, Aerospace Industries Association, and individual major airports, airline and equipment manufactures, and applicable environmental organizations. One of the key components of legislative success is developing a coalition of stakeholders who represent as many diverse view points on the underlying issues as possible.

Once stakeholders' endorsements are secured, the bill sponsors must conduct a strong whip operation to gain bill cosponsors and support from the committees of jurisdiction. The ZCGO inventory and ITC legislation would come with a large Congressional Budget Office (CBO) score of over \$800 million. While the CBO score would be high, tax credit schemes are much more politically tolerable to Republican members, which is why bipartisan support can be achieved. Had the policy mechanism incorporated an emissions reduction target mandate, Republican and industry support would be highly unlikely. Since the bill would have to different components that are actually quite different activities, the legislation would be referred to more than one committee. In the House, the legislation would be referred to the House Committee on Ways and Means, responsible for tax legislation and thus the ITC, and the House Transportation and Infrastructure Committee, which has jurisdiction over the FAA, for the grant program. It is

also possible that the bill could be referred to the to the Energy and Commerce Committee, which has jurisdiction over the EPA. On the Senate side, the bill would be referred to the Senate Finance Committee and the Senate Commerce, Transportation, and Science Committee.

The legislation also has a unique factor working in its favor. Every state in the country has an airport or industry that can benefit from the policy. Because of that unique fact, the political support from stakeholders would be strong. Developing a nationwide coalition of stakeholder groups would give ownership of the issue and policy to all members of Congress, providing them with the political capital necessary to support passage of the policy. The legislation also may not move on its own accord, but the inclusion of the bill in a larger FAA reauthorization, which typically takes place every five years, could be a very realistic possibility to legislate The Low Carbon Airport of Tomorrow.

Conclusion

Climate change is an existential threat to the United States and all countries around the globe. If the United States and global community are to truly address the problem, there will need to be rapid decarbonization of all industrial and transportation sectors, and aviation is the most difficult sector to decarbonize. In flight operations must be addressed with alternative low carbon fuel and major efforts are underway in the US and globally. The ground operations component of aviation emissions has largely been overlooked as part of a broad emissions reduction policy framework. This capstone report details why and how ground operations emissions can be reduced in a substantial way through smart policy making and thoughtful consideration of stakeholder input. Methodology already exists to inventory emissions from ground operations, and technology is already being sporadically deployed in the field, but in the absence of emission reduction mandates cost considerations and cheap fuel prices, unburdened by a price on carbon,

are limiting that deployment. Incentivizing ZCGO GSE and fleet transition to EVs will substantially reduce emissions and create pathways for all airports to become carbon neutral. CO2 emissions from US commercial aviation is currently about 182 MMT/year, nominally ground operations including LTO is about 10% of the total or 18 MMT/year. Full implementation of the ZCGO policy would eliminate approximately 95% (17.3 MMT/year) of ground operation CO2 emissions, assuming renewable electric energy is used to power a new GSE and transportation fleet. This would be achieved at a cost of about \$46/metric ton of CO2 removed using USG funding. A significant reduction in other air pollutants would also be achieved.

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Appendix

APPENDIX A:

Estimated GSE Population

Aviation Emissions Policy Gap Analysis Roadmap

APPENDIX B:

Zero Carbon Ground Operations Grant Program

Supplemental S-1 Air Freight Under the Grant and ITC Program

Inventory Grant Program Cost

APPENDIX C:

Zero Carbon Ground Operations Investment Tax Credit Program

Investment Tax Credit Matrix

Supplemental S-2 LTO Emissions Under the ITC Program

APPENDIX D:

Example Baggage Tractor EV Switching Cost

Note 1: Each component of each Appendix is footnoted separately. Footnotes are numbered consecutively within a component.

Appendix A Estimated GSE Population

Summary of Technical Support for Development of Airport Ground Support Equipment Emission Reductions

Prepared by:

Sierra Research, Inc. for the Office of Mobile Sources

U.S. Environmental Protection Agency Contract No. 68-C7-0051

December 31, 1998

GSE Population Estimates: Ideally, GSE population data by equipment type would be compiled and maintained through a national database so that accurate population estimates for any given airport, airline, or equipment type could be readily developed. However, no such database exists and no standard GSE tracking procedures have been developed across airports. Therefore, alternative mechanisms for estimating GSE population must be derived. Two possible approaches involve so-called “top-down” and “bottom-up” estimation. Under the top-down approach, aggregate (i.e., national or state-specific) GSE populations are estimated and allocated to individual airports on the basis of some activity indicator. For example, scrappage algorithms can be applied to annual GSE sales data to estimate aggregate GSE populations. These GSE can then be allocated to individual airports through the use of an activity indicator such as the number of aircraft landing and take-off (LTO) cycles. Such an approach was employed in the U.S. Environmental Protection Agency’s (EPA’s) 1991 Nonroad Engine and Vehicle Emissions Study (NEVES). Alternatively, under a bottom-up approach, GSE populations are estimated for individual airports and aggregated as necessary. In the absence of comprehensive airport-specific data, such an approach typically involves the statistical analysis of known GSE population data for a given sample of airports in order to relate observed GSE populations to one or more explanatory parameters that are readily available for all airports (e.g., LTO cycles). Once such a relationship has been defined, it is a relatively simple matter to apply the regression equation to other airports and develop airport-specific GSE population estimates.

Both approaches are theoretically sound, but both also have inherent weakness and potentially large uncertainties. Generally, however, the bottom-up approach tends to more readily incorporate airport-specific information into the derived population estimates. Moreover, uncertainties with potential top-down approach sources of error, such as the use of standard scrappage algorithms, are inherently addressed in the derived bottom-up regression relations. For these reasons and given that a small sample of airport-specific GSE population data are available to undertake the necessary regression analysis, the bottom-up approach generally reflects a more robust GSE population estimation approach. The current best estimate bottom-up regression equation approach is presented in GSE Information Series 1 selection entitled *Basis for GSE Population Estimates*. Basically, the approach is based on aircraft LTO cycles as the predictive GSE population parameter and the resulting regression equation is expressed algebraically as follows:

$$\text{GSE} = 0.0226 (\text{LTO}_{\text{nswwb}}) + 0.0054 (\text{LTO}_{\text{nswnb}}) + 0.0022 (\text{LTO}_{\text{sw}}) + 0.0008 (\text{LTO}_{\text{prop}})$$

where:

“GSE” represents the calculated GSE population,

“LTO_{nswwb}” indicates the number airport LTO cycles accumulated by wide-body jets, exclusive of those operated by Southwest Airlines,

“LTO_{nswnb}” indicates the number airport LTO cycles accumulated by narrow-body jets, exclusive of those operated by Southwest Airlines,

“LTO_{sw}” indicates the number airport LTO cycles accumulated by all jets operated by Southwest Airlines, and

“LTO_{prop}” indicates the number airport LTO cycles accumulated by non-jet aircraft.

As described in GSE Information Series 1, the regression equation yields a national GSE population estimate of about 45,000 units. This estimate is consistent with several estimates derived over the last several years using alternative approaches, but considerably lower than the estimate derived using the top-down approach employed for the NEVES (about 85,000 units).

Although the regression equation is based on a significant sample of observed GSE population* and the relationships with the selected predictive parameters (i.e., the various LTO cycle parameters) are significant at over 99 percent confidence, the variability observed across airlines and airports is, nevertheless, significant (correlation coefficients for component regressions are generally around 0.80). Therefore, a review of the ability of the regression equation to accurately forecast individual airport GSE populations is important in assessing the absolute utility of the population predictions.

* In total, GSE populations for 35 individual airlines at 10 airports, comprising nearly 2,500 GSE, are incorporated in the regression analysis. Together, these airline/airport combinations account for about 9 percent of national LTO cycles.

Estimated 2018 GSE Units

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11/15/2019

ATADS ASPM77 Total 2018 LTO's = 33,555,400

US 2018 Fleet

Narrow Body and Regional Jet = 68%

Wide Body Jet = 16%

Total = 84%

$$LTO_{nswnb} = 0.0054$$

$$\text{GSE Narrow Body \& Regional Jet} = (33,555,400) \times (0.68) \times (0.0054) = 123,215$$

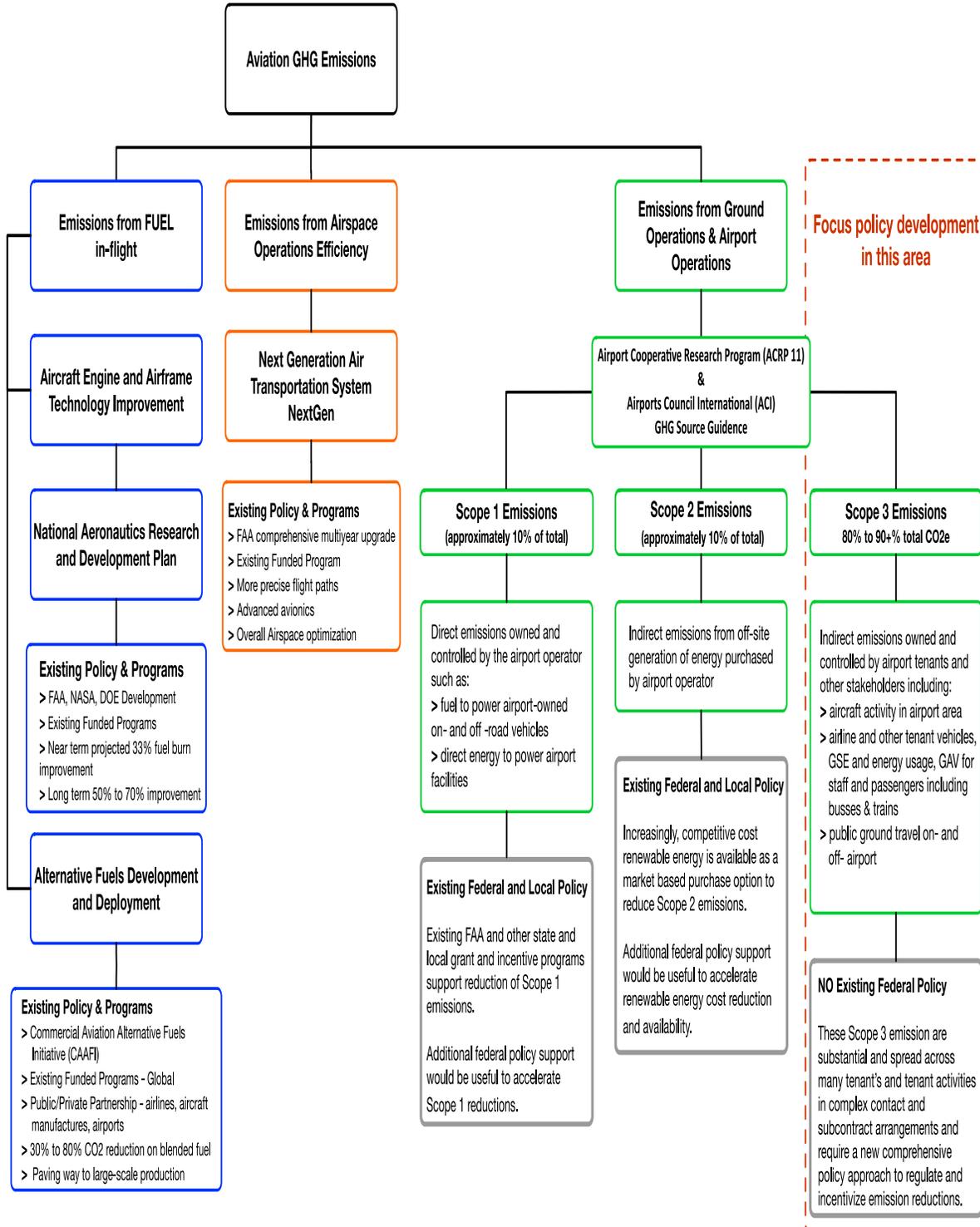
$$LTO_{nswwb} = 0.0226$$

$$\text{GSE Wide Body} = (33,555,400) \times (0.16) \times (0.0226) = 121,336$$

$$\text{Total Estimated 2018 GSE} = 244,551$$

***Note:** The regression coefficients used in this estimate are from work done by EPA under Contract No. 68-C7-0051 in 1998 and may no longer be representative of the industry but are likely close. The inventory grant program outlined in Appendix B will provide comprehensive inventory reporting for each of the ASPM 77 Airports.*

Aviation Emissions Policy Gap Analysis Roadmap



Appendix B
Ground Operations Inventory Grant Program

Zero Carbon Ground Operations (ZCGO) Grant Program	
Implementing Sector	Federal
Lead Agency	Federal Aviation Administration
Category	Financial Incentive for Zero Carbon Ground Operation Emissions
Related Statute	The FAA Modernization and Reform Act of 2012 Title 49, United States Code, 49 USC §47136a, Zero-Emission Airport Vehicles and Infrastructure. ¹
Incentive Type	Grant Program for Inventories, Planning, and Implementation
Administrator	Federal Aviation Administration Airport Improvement Program (AIP) Grants
Eligible Facilities ²	<p>Group 1 – CORE 30 Airports of the Aviation System Performance Metrics (ASPM) 77 Airports</p> <p style="padding-left: 40px;">Group 1A – CORE 30 Airport with greater than 25 million enplaned passengers annually</p> <p style="padding-left: 40px;">Group 1B - CORE 30 Airport with greater than 15 million but less than 25 million enplaned passengers annually</p> <p style="padding-left: 40px;">Group 1C – Remaining CORE 30 Airports</p> <p>Group 2 – Remainder of the ASPM 77 Airports</p> <p style="padding-left: 40px;">Group 2A – Airports with greater than 5 million enplaned passengers annually</p> <p style="padding-left: 40px;">Group 2B – Airports with less than 5 million enplaned passengers annually</p>
Expiration Date	January 31, 2025
Grant Eligible Categories for Group 1 and Group 2	<p>A) Inventory³ of GSE, FGS, Engine-Off LTO, On-Airport Shuttles, Off-Airport Shuttles, Regional Shuttles</p> <p>B) Preliminary Implementation Planning, Timeline to Full Zero Carbon Ground Operations (ZCGO) for Inventory Categories</p> <p>C) Preliminary Planning for Infrastructure Upgrades and Modifications to Meet ZCGO, and Preliminary Cost Estimates</p>
Group 1 Grant	<p>Group 1A - \$800,000</p> <p>Group 1B - \$650,000</p> <p>Group 1C - \$500,000</p>
Group 2 Grant	<p>Group 2A - \$400,000</p> <p>Group 2B - \$250,000</p>
Spending Authority	\$50,000,000

¹ Title 49 establishes a pilot program that allows the FAA to award Airport Improvement Program (AIP) grants for the acquisition and operation of zero emissions vehicles (ZEVs) at an airport including the construction or modification of infrastructure to facilitate the delivery of fuel and services necessary for the use of such vehicles.

² Air Freight – Ground operations of Dedicated Cargo Operators are not eligible for the inventory grant program, see Appendix B Supplemental S-1 below for rationale.

³ National Academies of Sciences, Engineering, and Medicine 2009. *Guidebook on Preparing Airport Greenhouse Gas Emissions Inventories*. Washington, DC: The National Academies Press. <https://doi.org/10.17226/14225>.

Appendix B - Supplemental S-1

Consideration of Air Freight Services Under the ZCGO Grant Program

The air freight industry consists of a complex distribution network linking manufacturers and shippers to freight forwarders, off-airport freight consolidators, and airport sorting and cargo handling facilities where shipments are loaded on and unloaded from aircraft.⁷⁶

Typically, air freight cargo relates to time sensitive, valuable or perishable freight carried over long distances. This is particularly suitable in supporting “just-in-time” production and distribution strategies with low inventory levels. Increasingly, all manner of consumer and business commodities are purchased through e-commerce with overnight delivery fulfillment by air cargo. Also, a niche market exists for emergency situations where the fast delivery of supplies prevails over cost issues.

The Federal Aviation Administration (FAA) forecasts that steady U.S. and world economic growth will drive modest annual increases of about 3% in air cargo shipments over the next two decades,⁷⁷ while Boeing notes that e-commerce could spur additional demand for worldwide shipments.⁷⁸

Most outbound air cargo packages are consolidated at off-airport facilities and arrive at airports on bulk pallets or in special containers known as unit load devices. It is estimated that about 75% of all air cargo by weight travels on bulk pallets.⁷⁹ While the air travel time for an air cargo supply chain is usually about half a day, the ground processing can take about 5 days (two and a

⁷⁶ *Security of Air Cargo Shipments, Operations, and Facilities*

Bart Elias, *Specialist in Aviation Policy* January 24, 2018, *Congressional Research Service*

⁷⁷ *Federal Aviation Administration, FAA Aerospace Forecast: Fiscal Years 2017-2037*, https://www.faa.gov/data_research/aviation/aerospace_forecasts/media/FY2017-37_FAA_Aerospace_Forecast.pdf.

⁷⁸ *Boeing, World Air Cargo Forecast 2016-2017*, <http://www.boeing.com/commercial/market/cargo-forecast/>.

⁷⁹ Andy Pasztor, Keith Johnson, and Daniel Michaels, “Focus on Cargo Security Steps,” *Wall Street Journal*, November 1, 2010

half day at the airport of origin and two and a half day at the airport of destination). Thus, flight operations account for less than 10% of an air cargo transport chain.⁸⁰

The air freight market is serviced by three predominant types of operations:

- **Dedicated cargo operators** maintaining a fleet of cargo-only aircrafts and offering regular scheduled services between the airports they service. They also offer charter operations to cater to specific needs.
- **Combination services** where an airline company will maintain a fleet of both specialized and passenger aircrafts able to carry freight in their bellyhold. Most of the cargo operations involve long haul services.
- **Passenger operators** that will offer the freight capacity in the bellyhold of their aircrafts. For these operators, freight services are rather secondary and represent a source of additional income, usually less than 5% of total revenues. However, low cost airlines usually do not offer air cargo services since their priority is a fast rotation of their planes and often service airports that do not generate cargo volumes.

About 22 billion pounds of freight cargo were shipped on domestic flights in 2016. Of this, FedEx transported about 11.6 billion pounds, while UPS carried about 6.3 billion pounds.⁸¹ Collectively, these two carriers transported about 81% of all domestic air cargo in 2016, and were by far the largest two operators in the U.S. air cargo industry.

In 2018 the U.S. commercial aircraft fleet (widebody, narrow body, and regional jets) consisted of 7,356 aircraft. Of this fleet approximately 13% of aircraft (950) were operated by dedicated cargo operators such as FedEx (9.3%), UPS (3.4%), and a collection of other dedicated cargo operators making up less than one percent of the fleet.⁸² On the basis of flight departures 6.11% of all departures were cargo flights.⁸³

Air Freight Ground Operations

Domestic air freight services provided by combined and passenger operators will be covered under the proposed Zero Carbon Ground Operations (ZCGO) policy Investment Tax Credit and Grant Programs. Ground operations for these flights are nominally serviced with the same equipment used for passenger flight operations.

However, ground operation services for dedicated cargo operators, like FedEx and UPS, differ substantially from passenger flight operations. With the exception of peak operating hours at hub

⁸⁰ *Air Transport*, Dr. John Bowen and Dr. Jean-Paul Rodrigue https://transportgeography.org/?page_id=1765

⁸¹ *CRS analysis of Bureau of Transportation Statistics, Air Carriers: T-100 Domestic Market (U.S. Carriers) data.*

⁸² *Analysis of Bureau of Transportation Statistics, Air Carriers: T-100 Domestic Market (U.S. Carriers) data.*

⁸³ *Analysis of Bureau of Transportation Statistics, Air Carriers: T-100 Domestic Market (U.S. Carriers) data, 2018 USCarrier_Cargo Traffic_20191103125540 and 2018 USCarrier_Passenger Traffic_20191103125540-2*

air freight operations, such as the FedEx Memphis Super Hub which is highly automated, flight turnaround time is not as acute as passenger flight operations. Planes often sit on the tarmac for hours between flights. Bulk pallets and unit load devices require specialized ground operation equipment dis-similar to passenger flight operations.

Unlike commercial airport operators, which are typically an authority operating as a sub division of a municipal government, dedicated cargo operators have operating income and financing capability that allows them to constantly pursue highly efficient operations to remain competitive. The substantially lower operating cost, energy consumption and maintenance, of EV ground operation equipment should be a great incentive to move to zero emission EV equipment. They have the wherewithal and purchasing power to get the suppliers of their specialized equipment to deliver zero emission EV upgrades.

For these reasons the Zero Carbon Ground Operations (ZCGO) policy proposal does not ask the tax payer to underwrite dedicated cargo operators with investment tax credits or inventory grants.

Appendix B Table B-1 ZCGO Grant Program Cost

Appendix B
Table B-1

ZCGO Inventory Grant Program - ASPM 77 Airports									
2018 Rank	Airport	2018 Enplaned Passengers (millions)	% of Total Enplaned Passengers	Core 30 as of March 2019	Inventory Grant Group 1A	Inventory Grant Group 1B	Inventory Grant Group 1C	Inventory Grant Group 2A	Inventory Grant Group 2B
1	Atlanta	51.84	6.32%	X	\$ 800,000				
2	Los Angeles	42.58	5.19%	X	\$ 800,000				
3	Chicago O'Hare	39.85	4.86%	X	\$ 800,000				
4	Dallas/Fort Worth	32.78	4.00%	X	\$ 800,000				
5	Denver	31.34	3.82%	X	\$ 800,000				
6	New York JFK	30.49	3.72%	X	\$ 800,000				
7	San Francisco	27.77	3.39%	X	\$ 800,000				
8	Seattle	23.98	2.93%	X		\$ 650,000			
9	Las Vegas	23.59	2.88%	X		\$ 650,000			
10	Orlando	23.16	2.82%	X		\$ 650,000			
11	Newark	22.75	2.78%	X		\$ 650,000			
12	Charlotte	22.26	2.72%	X		\$ 650,000			
13	Phoenix	21.60	2.64%	X		\$ 650,000			
14	Houston Bush	21.14	2.58%	X		\$ 650,000			
15	Miami	20.66	2.52%	X		\$ 650,000			
16	Boston	19.98	2.44%	X		\$ 650,000			
17	Minneapolis	18.32	2.24%	X		\$ 650,000			
18	Fort Lauderdale	17.58	2.15%	X		\$ 650,000			
19	Detroit Metro	17.41	2.12%	X		\$ 650,000			
20	Philadelphia	15.26	1.86%	X		\$ 650,000			
21	New York LaGuardia	15.06	1.84%	X		\$ 650,000			
22	Baltimore	13.30	1.62%	X			\$ 500,000		
23	Salt Lake City	12.22	1.49%	X			\$ 500,000		
24	San Diego	12.17	1.48%	X			\$ 500,000		
25	Washington Dulles	11.58	1.41%	X			\$ 500,000		
26	Washington Reagan	11.35	1.38%	X			\$ 500,000		
27	Chicago Midway	10.66	1.30%	X			\$ 500,000		
28	Tampa	10.35	1.26%	X			\$ 500,000		
29	Portland	9.80	1.20%				\$ 500,000		
30	Honolulu	9.49	1.16%	X			\$ 500,000		
31	Dallas	7.81	0.95%					\$ 400,000	
32	Nashville	7.79	0.95%					\$ 400,000	
33	Austin	7.70	0.94%					\$ 400,000	
34	St. Louis	7.59	0.93%					\$ 400,000	
35	Houston	7.04	0.86%					\$ 400,000	
36	San Jose	7.02	0.86%					\$ 400,000	
37	Oakland	6.66	0.81%					\$ 400,000	
38	New Orleans	6.57	0.80%					\$ 400,000	
39	Raleigh/Durham	6.24	0.76%					\$ 400,000	
40	Sacramento	5.90	0.72%					\$ 400,000	
41	Kansas City	5.78	0.70%					\$ 400,000	
42	Santa Ana	5.19	0.63%					\$ 400,000	
43	San Antonio	4.83	0.59%						\$ 250,000
44	Cleveland	4.68	0.57%						\$ 250,000
45	Indianapolis	4.63	0.57%						\$ 250,000
46	Pittsburgh	4.62	0.56%						\$ 250,000
47	Fort Myers	4.60	0.56%						\$ 250,000

48	Cincinnati	4.24	0.52%						\$ 250,000	
49	San Juan	3.99	0.49%						\$ 250,000	
50	Columbus	3.96	0.48%						\$ 250,000	
51	Kahului	3.56	0.43%						\$ 250,000	
52	Milwaukee	3.45	0.42%						\$ 250,000	
53	Hartford	3.27	0.40%						\$ 250,000	
54	West Palm Beach/Palm Beach	3.26	0.40%						\$ 250,000	
55	Jacksonville	3.13	0.38%						\$ 250,000	
56	Burbank	2.68	0.33%						\$ 250,000	
57	Albuquerque	2.64	0.32%						\$ 250,000	
58	Anchorage	2.60	0.32%						\$ 250,000	
59	Buffalo	2.51	0.31%						\$ 250,000	
60	Ontario	2.49	0.30%						\$ 250,000	
61	Omaha	2.45	0.30%						\$ 250,000	
62	Memphis	2.20	0.27%	X					\$ 250,000	
63	Charleston	2.19	0.27%						\$ 250,000	
64	Providence	2.11	0.26%						\$ 250,000	
65	Oklahoma City	2.07	0.25%						\$ 250,000	
66	Reno	2.04	0.25%						\$ 250,000	
67	Richmond	2.04	0.25%						\$ 250,000	
68	Boise	1.94	0.24%						\$ 250,000	
69	Long Beach	1.91	0.23%						\$ 250,000	
70	Louisville	1.87	0.23%						\$ 250,000	
71	Spokane	1.87	0.23%						\$ 250,000	
72	Norfolk	1.84	0.22%						\$ 250,000	
73	Kona	1.81	0.22%						\$ 250,000	
74	Tucson	1.75	0.21%						\$ 250,000	
75	Lihue	1.64	0.20%						\$ 250,000	
76	Grand Rapids	1.63	0.20%						\$ 250,000	
77	El Paso	1.59	0.19%						\$ 250,000	
		819.67				\$ 5,600,000	\$ 9,100,000	\$ 4,500,000	\$ 4,800,000	\$ 8,750,000
Grant Distribution		\$ 32,750,000				17.10%	27.79%	13.74%	14.66%	26.72%

U.S. Airports, ranked by 2018 System* Scheduled Enplanements on U.S. and Foreign Airlines

BUREAU OF TRANSPORTATION STATISTICS
U.S. Department of Transportation

Appendix C
Ground Operations Investment Tax Credit Program

Zero Carbon Ground Operations (ZCGO) Investment Tax Credit (ITC) Program	
Implementing Sector	Federal
Lead Agency	Federal Aviation Administration
Category	Financial Incentive for Zero Carbon Ground Operation (ZCGO) Emissions
Incentive Type	Corporate Investment Tax Credit available to Owner, Operator, Finance Entity of Eligible Components
Administrator	U.S. Internal Revenue Service
Eligible Facilities ¹	Aviation System Performance Metrics (ASPM) 77 Airports
Expiration Date	Varies by Authorized Category/Component
Applicable Categories	D) Engine-Off LTO E) GSE F) FGS G) On-Airport Shuttles H) Off-Airport Shuttles I) Regional Shuttles
Eligible Components	1) Vehicles 2) Charging Stations 3) Infrastructure 4) Equipment 5) Energy Storage
Incentive Amount	A-1 50% ITC through 2035 A-2 and A-3 100% ITC through 2035 B-1 and B-4 50% ITC through 2030 B-2 and B-3 100% ITC through 2030 C-4 50% ITC through 2030 C-2 and C-3 100% ITC through 2030 D-1 50% ITC through 2030 D-2 and D-3 100% ITC through 2030 E-1, E-2, and E-3 30% ITC through 2030 F-1, F-2, and F-3 20% ITC through 2030
Spending Authority	\$750,000,000
Component Requirements	GSEE ² , FAA, DOT, NEMA, and building codes as applicable

¹ Air Freight – Ground operations of Dedicated Cargo Operators are not eligible for the ITC program, see Appendix B Supplemental S-1 for rationale.

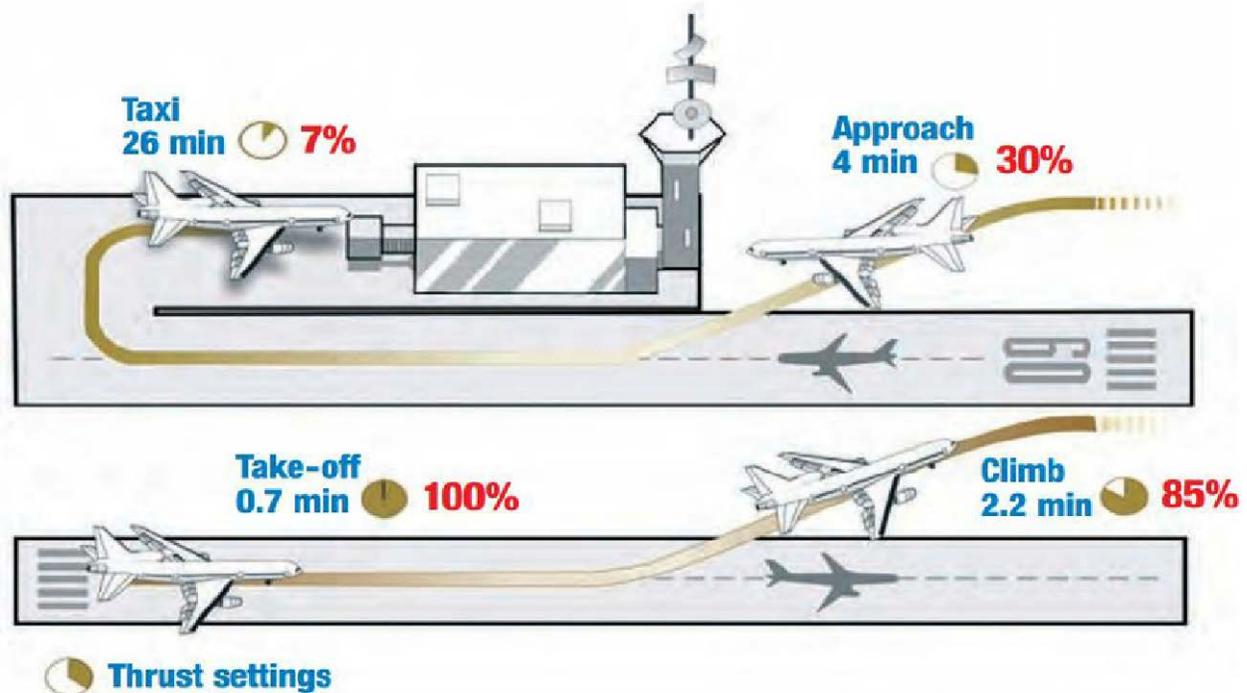
² The Ground Support Equipment and Environment (GSEE) Technical Group of the International Air Transport Association (IATA) focuses on the technical, functional and safety aspects of ground support equipment (GSE) as well as the impact GSE has on the environment. The task force continually reviews and develops the policies, strategies and guidelines as published in the IATA Airport Handling Manual (AHM). The GSEE reports to the Ground Operations Group (GOG). Through participation in the GSEE there is the opportunity to influence the ground operations industry. Main areas of activity:

- Technical standards and specifications for all types of GSE
- The interfaces between aircraft and GSE
- Aircraft and GSE design modifications to address ground operations needs
- Environmental guidelines for GSE

Appendix C - Supplemental S-2 Consideration of LTO Operating Mode Emissions Under the ZCGO ITC Program

The LTO cycle is defined as all aircraft activity below a height of 3000 ft above field elevation (AFE). For departures, the LTO cycle comprises taxiing out from the terminal to runway, hold on the taxiway, the takeoff roll, initial climb and climb-out to 3000 ft AFE. For arrivals this includes approach to runway from 3000 ft AFE, landing roll and taxi into the terminal (Watterson et al., 2004; ICAO, 2007)⁸⁴. The 3000 ft AFE boundary for the LTO cycle is dictated by regulatory standards and approximates a representative atmospheric mixing height (ICAO, 2007). The LTO cycle is illustrated in the following graphic:

LTO Operating Mode Time and Thrust



ICAO Landing Take-off Cycle, Source ICAO

Times-in-mode

Emissions during a particular phase of the LTO cycle are proportional to the amount of time spent in that phase of operation - the 'time-in-mode' (TIM). The standard ICAO certification LTO cycle is generally not representative of operations at all airports, for example high altitude AFE operation may require higher thrust to achieve lift. Also, TIMs vary by aircraft size category. Researchers have estimated general TIM variations on the order of 10% (Watterson et

⁸⁴ Watterson, J., Walker, C., Eggleston, S., 2004. Revisions to the Method of Estimating Emissions from Aircraft in the UK Greenhouse Gas Inventory. Netcen, Oxford.

al., 2004)⁸⁵, and deviations of 10 to 20% for takeoff and climb-out and 15 to 20% for approach (Patterson et al., 2009)⁸⁶.

Thrust Settings and Fuel Flow

Fuel flow to the engine is approximately linearly proportional to engine thrust setting (Wey et al., 2006)⁸⁷, which is defined here as a percentage of maximum rated thrust. Indicated thrust by LTO cycle phase, graphic above, can vary by aircraft size category and local airport configurations. Nominal standard thrust settings are tabulated in the ICAO Engine Emissions Databank corresponding to the default ICAO LTO cycle (Herndon et al., 2009)⁸⁸. Empirical evidence from Wey et al. (2006), suggests a suitable uncertainty range of 10% for the ICAO fuel flow indices.

Investment Tax Credit Policy Application

Approximately 70% of aircraft emissions is CO₂, with the remaining 30% comprising a mix of nitrous gases, water vapor, sulfates and other particulate matter.⁸⁹ Approximately 90% of these emissions take place at an elevation above 3,000 feet. The remaining 10% take place through taxiing, landing and take-off (LTO) cycle.⁹⁰ A breakdown of LTO cycle emissions is shown in the following table, LTO Operating Mode Emissions. CO₂ emissions from approach, take-off, and climb, about 20%, are being addressed through elements of Next-Gen and with the development and deployment of low-carbon aviation fuels. However, about 80% of CO₂ emissions from LTO is attributable the taxi/ground idle phase of the cycle. Eventually taxi/ground idle phase emissions will be addressed by the deployment of low-carbon aviation fuels, which could take several decades to fully address fuel demand. In the near-term implementation of fixed gate services (FGS), new categories of EV engine-off LTO ground support equipment (GSE), and new on-aircraft technologies for electric taxiing could be addressing these emissions immediately.

⁸⁵ Ibid. Watterson, J., Walker, C., Eggleston, S., 2004. Revisions to the Method of Estimating Emissions from Aircraft in the UK Greenhouse Gas Inventory. Netcen, Oxford.

⁸⁶ Patterson, J., Noel, G.J., Senzig, D.A., Roof, C.J., Fleming, G.G., 2009. Analysis of departure and arrival profiles using real-time aircraft data. *Journal of Aircraft* 46 (4), 1094e1103.

⁸⁷ Wey, C.C., Anderson, B.E., Hudgins, C., Wey, C., Li-Jones, X., Winstead, E., Thornhill, L.K., Lobo, P., Hagen, D., Whitefield, P., Yelvington, P.E., Herndon, S.C., Onasch, T.B., Miake-Lye, R.C., Wormhoudt, J., Knighton, W.B., Howard, R., Bryant, D., Corporan, E., Moses, C., Holve, D., Dodds, W., 2006. Aircraft Particle Emissions eXperiment (APEX). NASA.

⁸⁸ Herndon, S.C., et al., 2009. Aircraft hydrocarbon emissions at Oakland International Airport. *Environmental Science and Technology* 43 (6), 1730e1736.

⁸⁹ FAA Office of Environment and Energy. 2015. Aviation Emissions, Impacts & Mitigation A Primer www.faa.gov/regulations_policies/policy_guidance/envir_policy/media/primer_jan2015.pdf

⁹⁰ Ibid.

LTO Operating Mode Emissions*

LTO Operating Mode	Time in Mode (minutes)	Operating Thrust	Fuel Burn (kg)	Proportion of LTO Emissions
Approach	4.0	30%	4.71	12.41%
Taxi/ground idle	26.0	7%	30.59	80.65%
Take-Off	0.7	100%	0.05	0.12%
Climb	2.2	85%	2.59	6.82%
total	32.9		37.93	100.00%

* International Civil Aviation Organization - ICAO, (n.d.). Local air quality: <http://www.icao.int/environmental-protection/Pages/local-air-quality.aspx>

Fixed Gate Services – FGS refers to replacing mobile GSE and on-aircraft auxiliary power units (APU) with electric gate services powered from the grid. One of the simplest things to do is plug electricity into the aircraft to run avionics and air conditioning at the gate, thus on a net basis lowering CO2 emissions.

The proposed investment tax credit policy, table titled *Zero Carbon Ground Operations (ZCGO) Investment Tax Credit (ITC) Program*, addresses FGS as Applicable Category C. Figure 1 – Investment Tax Credit Matrix shows the eligible components, level of tax credit, and timing of the program. The proposed ZCGO Grant Program also covers inventory and planning activities for FGS.

Engine-off LTO e-Tug Taxi Vehicles – A new class of EV Tug vehicles is being introduced that will collect up the aircraft at landing and deliver the aircraft to the gate and then back to the take-off runway. The picture below illustrates the concept and the TaxiBot tug, several GSE equipment OEM’s are introducing similar tugs.

IAI developed, with Airbus and TLD, this innovative new towbarless towing device concept – the TaxiBot (Taxiing Robot)⁹¹. TaxiBot is a semi-autonomous system that enables airplane taxiing without engines running, controlled by the pilot and without shortening nose landing gear (NLG) life time. Features are said to include:

- Can provide EV APU to the aircraft
- Pushback operation and procedures performed by the TaxiBot operator
- Immediate taxiing after pushback eliminating bottlenecks in the gate area
- Taxiing with engines stopped. Engines start shortly before take-off with respect to required warm-up time

⁹¹ <https://www.taxibot-international.com>

- Pilot is in control at all times (after Pushback) using airplane tiller and brake pedals (transparent to pilot as in regular taxiing)
- Taxiing at 23 knots, same as current airplane taxi speed

A proprietary TaxiBot-aircraft NLG interface mechanism provides pilot steering capability, using the airplane's existing controls in the cockpit. Taxiing speed is controlled by the pilot using the aircraft brakes.



The TaxiBot system provides the pilot with the same handling characteristics as if taxiing with engines. In most cases no modification to aircraft is required and minor if any modifications to airports infrastructure are required.

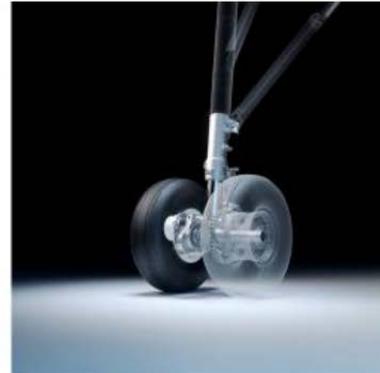
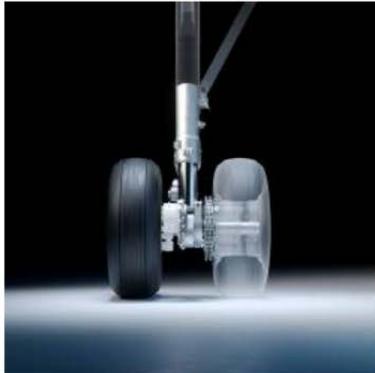
The proposed investment tax credit policy, (*Zero Carbon Ground Operations (ZCGO) Investment Tax Credit (ITC) Program*), addresses Engine-off LTO as Applicable Category A. Figure 1 – Investment Tax Credit Matrix shows the eligible components, level of tax credit, and timing of the program. The proposed ZCGO Grant Program also covers inventory and planning activities for this category of GSE.

On-aircraft Electric Taxiing – This electric taxiing approach is being developed by Safran and Airbus with expectations of introducing this on the Airbus 320 in 2022. The Auxiliary Power Unit (APU) generator provides power to electric motors located inside the wheels of the main landing gear⁹². The system enables the aircraft to reverse and move around on the ground entirely under its own power, without needing to use its main engines, see illustration below.

⁹² <https://www.safran-landing-systems.com/systems-equipment/electric-taxiing-0>

Safran believes their electric taxiing system can lead to savings of as much as 4% in the total fuel consumption, saving an average of \$250,000 per aircraft per year, with some airlines seeing savings of as much as \$500,000. This level of saving should be sufficient motivation for airlines to adopt this technology, it therefore is NOT covered under either the ZCGO Grant Fund or ITC program.

Electric taxiing



Appendix D – Example Baggage Tractor EV Switching Cost

EnergyType	Purchase Cost	EV Premium Cost Factor	Energy Cost	EV Energy Cost Savings	Maintenance Cost	EV Maintenance Cost Savings
Gasoline	\$ 17,000	1.76	\$ 59,481	90.6%	\$ 126,139	55.27%
Diesel	\$ 22,000	1.36	\$ 27,386	79.6%	\$ 97,826	42.33%
LPG	\$ 19,000	1.58	\$ 49,072	88.6%	\$ 107,816	47.67%
CNG	\$ 21,000	1.43	\$ 65,058	91.4%	\$ 125,802	55.15%
Electric	\$ 30,000	1.00	\$ 5,574	0.0%	\$ 56,418	0.00%

Switching from conventional fossil energy powered baggage tractor to EV incurs a capital cost premium ranging from 36% to 76%, energy cost savings ranges from 80% to 91%, and maintenance cost savings range from 47% to 55%.

*Source information from Table 3. Life Cycle Costs for Baggage Tractors
 Technical Support for Development of Airport Ground Support Equipment Emission Reductions,
 Prepared by: ^[SEP]Sierra Research, Inc. for the Office of Mobile Sources^[SEP] U.S. Environmental
 Protection Agency Contract No. 68-C7-0051
 December 31, 1998*

Assumptions: 16 year equipment life; 6 year engine replacement interval for gasoline, LPG, and CNG; 8 year engine rebuild interval for diesel; 5 year battery life for electric; \$2,500 unit cost for all rebuilds; \$4,500 unit cost for all battery replacements, equipment used 8 hours per day for 350 days per year; idle is 40 percent of operating day; gasoline use is 3.2 gallons per hour at \$0.75 (after tax credits) per gallon; diesel use is 1.7 gallons per hour at \$0.65 (after tax credits) per gallon; LNG use is 3.3 gallons per hour at \$0.60 per gallon; CNG use is 3.5 gallons per hour at \$0.75 per gallon (including the cost of refueling facility operation and amortization); electric use is 8.33 kilowatts per operating hour; maintenance costs are \$1.90 per hour for gasoline and diesel; maintenance costs are \$1.50 per hour for LPG and CNG under a reduced maintenance scenario or \$1.90 per hour under a “same maintenance” scenario; maintenance costs are \$0.63 per hour for electric under a reduced maintenance scenario or \$1.90 per hour under a “same maintenance” scenario.