United States

2021 Aviation Climate Action Plan

Contents

I. Introduction

Objective and Commitment to Action

The United States believes that addressing the climate crisis through enhanced ambition is a defining priority of our time. This Aviation Climate Action Plan provides a whole-of-government approach and policy framework for the aviation sector to contribute to broader, economy-wide objectives.

To achieve ambitious climate goals, the United States will implement a suite of policy measures to foster innovation and drive change across the entire U.S. aviation ecosystem, namely the airlines, manufacturers/suppliers, airports, energy companies, airline customers, and various levels of government. This plan builds on individual and sector-wide commitments announced by the U.S. aviation industry.

Our vision is that emissions will be decreased through:

- The introduction of new, more efficient aircraft by airlines into their operational fleets and retirement of older, less efficient aircraft.
- Development of new, more energy efficient aircraft and engine technologies by the original equipment manufacturers (OEMs).
- Improvements in aircraft operations throughout the National Airspace System (NAS) by the U.S. Government (USG) and by airlines flying more optimal trajectories for reduced fuel use and contrail impacts.
- Production of Sustainable Aviation Fuels (SAF) by the energy sector.
- Electrification and potentially hydrogen as solutions for short-haul aviation.
- Advancements in airport operations across the United States.
- International initiatives such as the airplane CO_2 standard and the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA).
- Domestic policies and measures to help meet emissions targets.
- Support for research into climate science related to aviation impacts.

These actions will not only help us meet ambitious climate goals, but they will also help improve the quality of life for those living near airports and under flight paths through reductions in community noise and pollutants that degrade air quality. In addition to their environmental benefits, these actions will also spur U.S. economic and job growth.

Recent natural disasters have also underscored the need to gird America's—and the world's—aviation infrastructure against the impacts of a changing climate. Unprecedented heat "domes" and wildfires in the western U.S., record rainfalls in the eastern part of the country, and a spate of hurricanes, severe storms, and impacts on coastal areas where many of the country's airports are located, necessitated the evacuation of control towers and airports, and provided a harbinger of future events.[1] As part of this climate strategy, the USG will seek to strengthen the climate resilience of aviation infrastructure across the United States and with partners around the globe.

[1] "Newark Airport Temporarily Halts Flights After Severe Flooding," N.Y. Times (Sept. 2, 2021), https://www.nytimes.com/2021/09/02/nyregion/newark-airport-flights-flooding-halted-ida.html.

Recognition of COVID-19 Impacts

The passenger aviation sector experienced a severe downturn in 2020. As the COVID-19 global pandemic locked down cities and states, passenger air travel—both domestic and international—ground to a halt. Although demand for air cargo remained robust, the pandemic had a crippling effect on passenger aviation globally. The year 2020 saw layoffs, bankruptcies, and an unprecedented drop in commercial aviation. In the United States, passenger air traffic in 2020 fell by 60% to its lowest level since 1984,[2] and the scheduled U.S. passenger airlines collectively lost $46 billion before taxes in 2020.[3] It's unclear when the sector will fully recover, and it's unclear what a "full recovery" truly means, though aviation now has the opportunity to restructure, adapt, and recover sustainably, putting the need to address the climate crisis at the core of that effort.

Although the COVID-19 pandemic has had a major impact on the aviation sector in the United States and around the world, it can come back stronger and cleaner—with a fleet that is both newer and greener, flies more efficient routes, uses sustainable aviation fuels, and operates from environmentally responsible airports in a more resilient national airspace system—as travelers begin to reconnect with loved ones and help strengthen the economy. The actions described in this document take into account a range of drivers of change in the aviation industry, including the track record of industry innovation, the impacts of the COVID-19 global pandemic, and the global climate crisis.

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[2] U.S. DOT Bureau of Transportation Statistics, "Full Year 2020 and December 2020 U.S. Airline Traffic Data," Release Number: BTS 18-21, *available at*: https://www.bts.gov/newsroom/full-year-2020-and-december-2020-us-airline-traffic-data, last retrieved: July 18, 2021.

[3] U.S. DOT Bureau of Transportation Statistics, "U.S. Airlines 2020 Net Profit Down $35 Billion from 2019," *available at*: www.bts.gov/newsroom/us-airlines-2020-net-profit-down-35-billion-2019, last retrieved: July 18, 2021.

II. Climate Goal and Approach

To be effective, a goal should be clear, achievable, and ambitious with specific actions and milestones that can be taken to achieve it. The goal outlined below contributes to the broader objective to achieve net-zero GHG emissions economy-wide by 2050.

U.S. Aviation Climate Goal:
Net-Zero GHG Emissions* from the U.S. Aviation Sector** by 2050

* Aviation GHG emissions include life cycle carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4) emissions. Aircraft engines produce negligible amounts of nitrous oxides and methane, so this plan has a focus on aviation combustion CO_2 emissions and well-to-tank life cycle GHG emissions (CO_2, N_2O, and CH_4). The U.S. Aviation 2050 Goal is based on emissions that are measurable and currently monitored. Research is ongoing into the climate impacts of aviation-induced cloudiness and the indirect climate impacts of aviation combustion emissions (see section 7 for details on the climate impacts of aviation non-CO_2 combustion emissions).

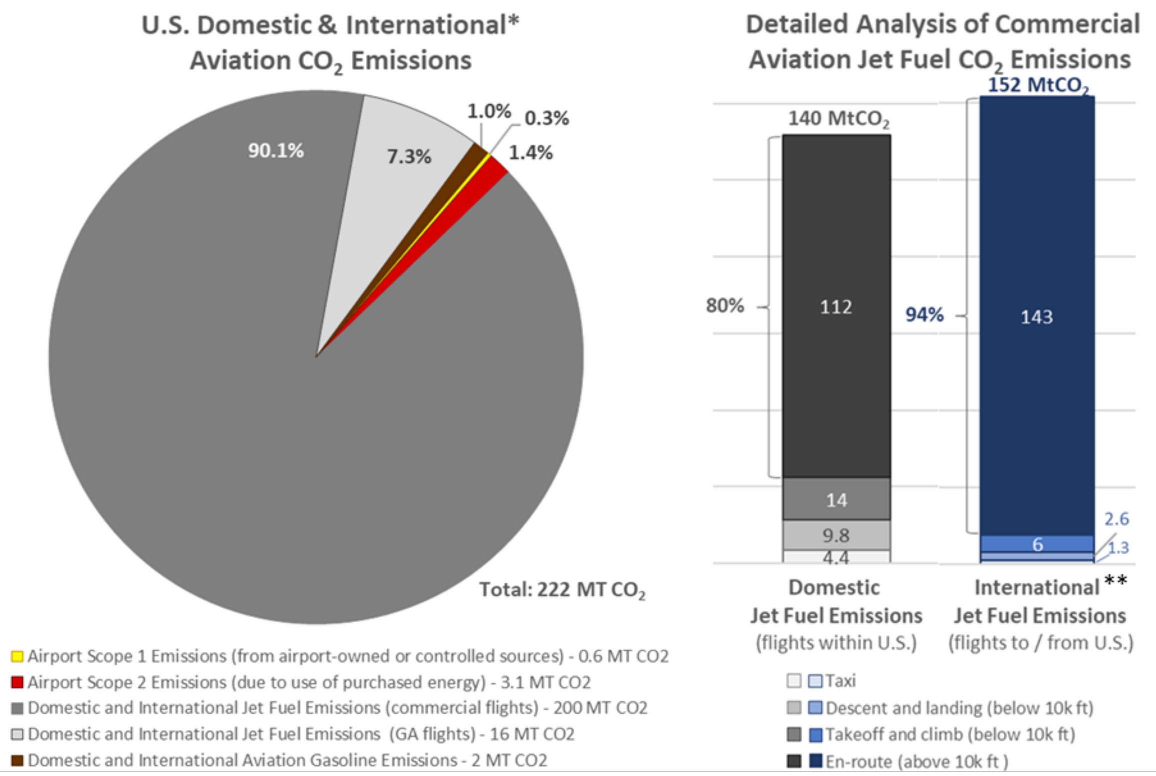
** This U.S. aviation goal encompasses CO_2 emissions from (1) domestic aviation (i.e., flights departing and arriving within the United States and its territories) from U.S. and foreign operators, (2) international aviation (i.e., flights between two different ICAO Member States) from U.S. operators, and (3) airports located in the United States.

Recognizing that the decarbonization of the aviation sector is extremely challenging, the ability of the U.S. aviation sector to reach net-zero emissions by 2050 will depend on a number of factors including the sector's rate of growth, success in scaling up the production of SAF with significant life cycle emissions reductions, the introduction of new aircraft and engine technologies to reduce the amount of fuel required to move people and goods, and operational efficiency improvements. This plan also recognizes a role for the use of high-integrity emissions offsets by airlines, embedded in national accounting systems to address any remaining in-sector emissions until the sector is only using fuels with zero net life cycle GHG emissions.[4]

The U.S. aviation goal of net-zero GHG emissions by 2050 was supported by analyses of current and future domestic and international aviation CO_2 emissions conducted by the Federal Aviation Administration (FAA).

[4] SAF are drop-in fuels for aviation created from renewable or waste materials. Since they are drop-in compatible with the existing fleet, SAF are hydrocarbon fuels and thus emit CO_2 when combusted in the aircraft engine. The extent to which any particular SAF provides a climate benefit depends on the SAF's life cycle emissions profile, taking into account the production, transportation, and combustion of the SAF, as well as indirect effects associated with these. Accordingly, the goals outlined in this Plan consider the life cycle emissions of aviation fuel with an accounting of the GHG emissions from all aspects—direct and indirect—of fuel production and transportation as well as the use of the fuel by the aircraft.

As a starting point, it is informative to consider the sources of U.S. aviation sector CO_2 emissions. As shown in Figure 1, the combustion of jet fuel from domestic and international aviation[5] accounts for more than 97% of U.S. aviation CO_2 emissions,[6] with the remaining emissions coming from airport operations and fuel use from aviation gasoline used by piston engines. Further, 80% of domestic aviation emissions and 94% of international aviation emissions come from en-route operations. The CO_2 emissions of U.S. domestic flights are roughly comparable to the CO_2 emissions of international flights. With these data in mind, the approach outlined in this document focuses on jet fuel and the aircraft using it.



* CO_2 emissions from (1) domestic aviation (i.e., flights departing and arriving within the United States and its territories) from U.S. and foreign operators and (2) international aviation (i.e., flights between two different ICAO Member States) from U.S. operators (only). Airport scopes 1 and 2 added for this specific analysis (figure).

** International aviation to / from the United States, regardless of the operator of the flights i.e., including both U.S. and foreign operators.

Definition: General Aviation (GA) based on the scope of the FAA Aerospace Forecast derived from the General Aviation and Part 135 Activity Survey (GA Survey). Includes general aviation activity (Parts 91, 125, 133, 135, and 137) from fixed wing (piston, turboprop, turbojet), rotorcraft (piston and turbine), experimental, special light-sport and other aircraft.

Figure 1. Analysis of U.S. Aviation CO_2 Emissions in 2019[7]

[5] In the context of Figure 1, domestic flights are those that take place within the United States and its Territories. International flights are those to and from the U.S. and its Territories. In both cases, the data includes operations by U.S. and foreign operators.

[6] Not including the life cycle emissions associated with production and distribution of fuels, also referred to as well-to-tank emission.

[7] Airport scope 1 and 2 emissions are from the ACI 2021 Long-Term Carbon Goal Study for Airports (Fig 23). Jet fuel and aviation gasoline emissions based on the FAA Aerospace Forecast (Federal Aviation Administration, FAA Aerospace Forecast, Fiscal Years 2021-2041, 111, Table 23). Detailed analysis of commercial aviation jet fuel emissions based on AEDT analysis. International jet fuel emissions include U.S., international, and foreign airspace.

While U.S. aviation has seen increased traffic in terms of passengers over the past 30 years, aviation's share of U.S. CO_2 emissions has remained relatively constant. In 2019, civil aviation's share of U.S. CO_2 emissions was about 2.7% of total domestic emissions.[8] As shown in Figure 2, the aircraft in the national airspace are operating much more efficiently—moving more passengers using the same amount of energy. Since 1991, traffic by U.S. airlines, measured in enplanements, has increased by 89% and as measured in Revenue Ton Miles has increased by 133%. In 2018, the U.S aviation sector carried about 32% more passengers than in the year 2000, while using almost the same amount of fuel, producing similar emissions. The fact that the sector carried more passengers, while generating roughly the same emissions is in large part a result of the fuel efficiency improvements of the fleet over time, but this improvement alone is not enough to address the sector's emissions and to achieve net-zero emissions. Today's fleet of aircraft has an average fuel efficiency of 57.5 passenger-miles per gallon of fuel.[9]

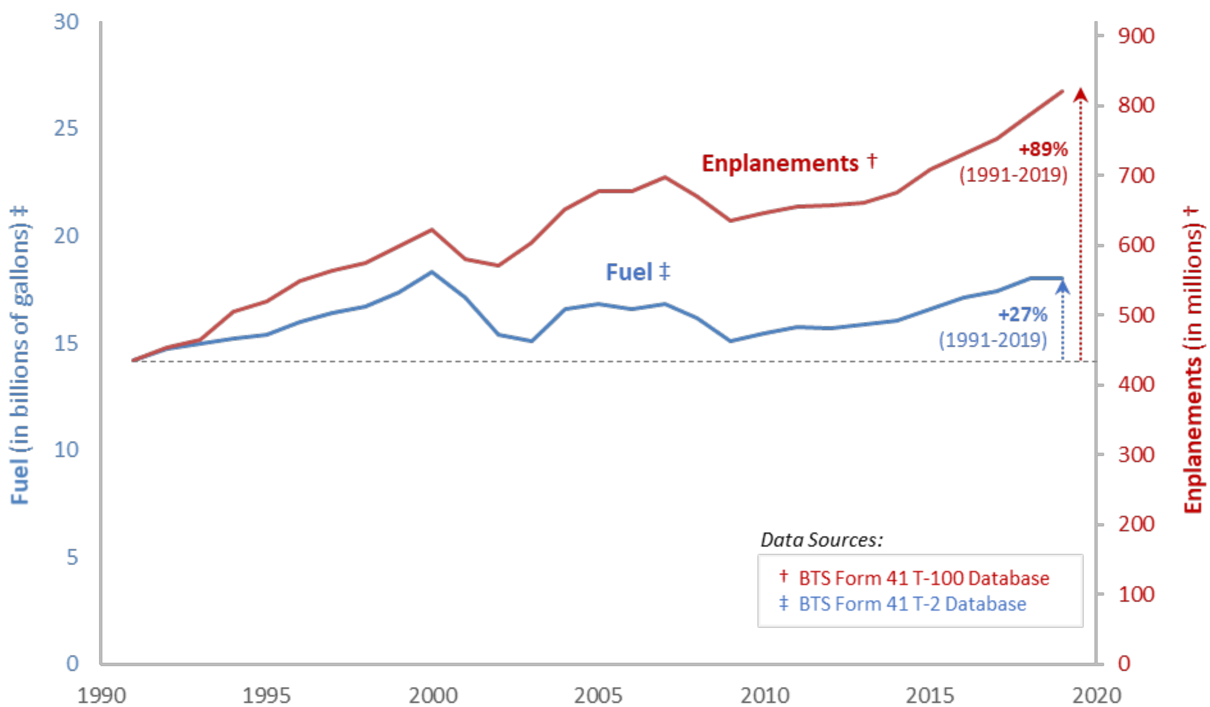
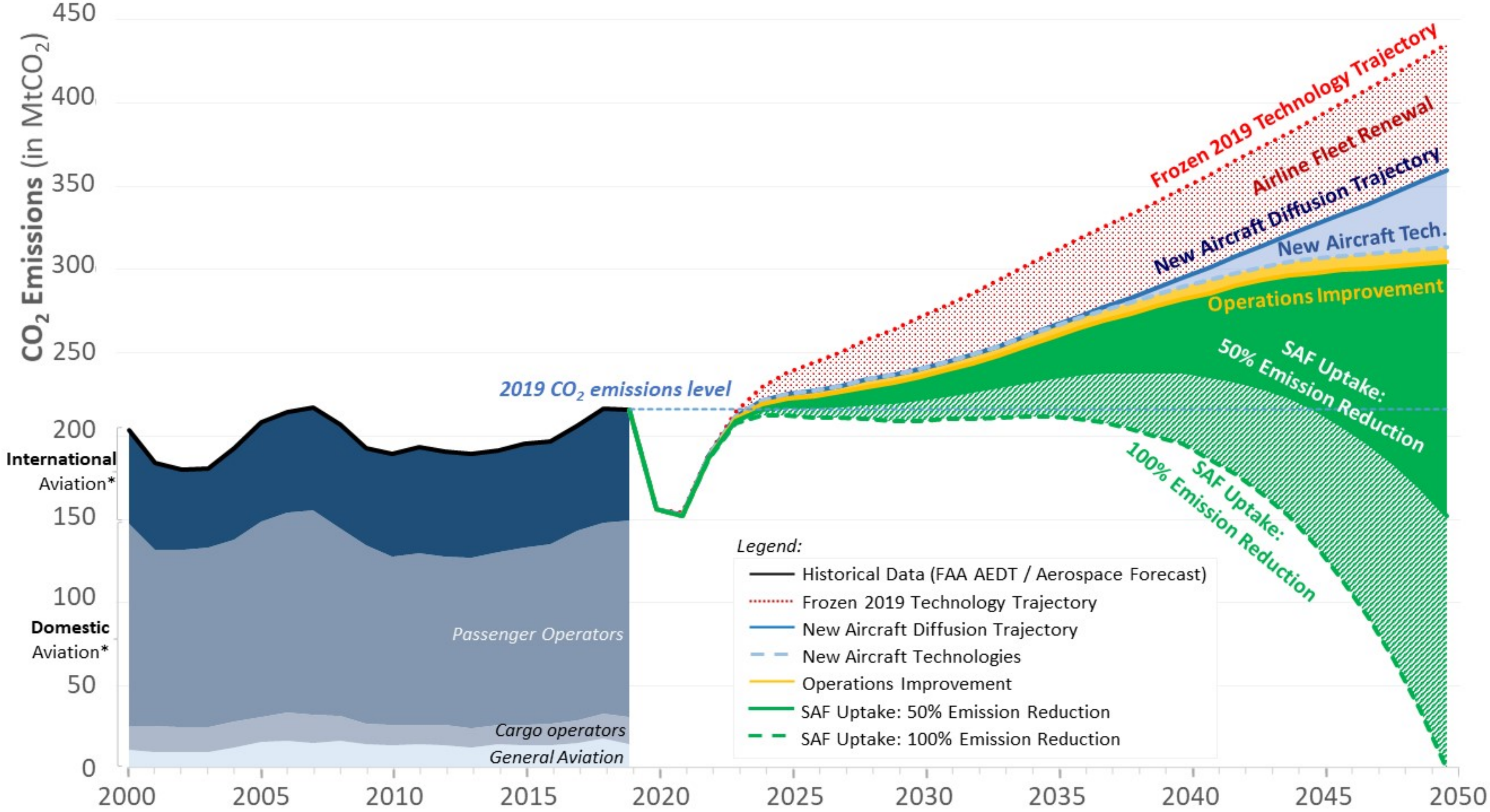


Figure 2. Historical U.S. Revenue Passengers Enplaned (i.e., enplanements) and Aircraft Fuel Use[10]

As the economy recovers from the COVID-19 pandemic, aviation demand is projected to return to pre-pandemic levels and then continue to grow. Figure 3 provides the CO_2 emissions that would accompany this growth, [11] as computed from the FAA Aerospace Forecast,[12] alongside how the emissions could be

[8] United States Environmental Protection Agency (EPA), "Inventory of U.S. Greenhouse Gas Emissions and Sinks," *available at*: www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks, last retrieved: July 18 2021.
[9] United States, "United States Efforts to Address Aviation's Climate Impact," A40-WP/531, ICAO 40th General Assembly, Executive Committee, *available at*: www.icao.int/Meetings/a40/Documents/WP/wp_531_en.pdf, last retrieved: July 18 2021.
[10] U.S. Department of Transportation – Bureau of Transportation Statistics, Air Carrier Summary Data, Form 41 and 298C Schedule T1: U.S. Air Carrier Traffic & Capacity Summary by Service Class for 1991-2019 (Aug. 2, 2019). *Available at:* http://www.transtats.bts.gov/.
[11] CO_2 emissions calculated based on 3.16 and 3.10 $kgCO_2/kg$ fuel for jet fuel and aviation gasoline, respectively. CO_2 emissions are reduced by Emissions Reductions from SAF based on ratios of lifecycle values for SAF vs. conventional fuels.
[12] The forecast traffic growth is from the FAA Aerospace Forecast data (2021-2041) with extrapolation to 2050.



* Note: Domestic aviation from U.S. and Foreign Carriers. International aviation from U.S. Carriers.

Figure 3. Analysis of Future Domestic and International Aviation CO_2 Emissions[13]

[13] Analysis conducted by BlueSky leveraging R&D efforts from the FAA Office of Environment & Energy (AEE) regarding CO_2 emissions contributions from aircraft technology, operational improvements, and SAF.

reduced to a net-zero level in 2050. The future emissions analysis considers how various measures can be combined to reach net-zero emissions, namely, aircraft technology, operations, and SAF. These projections are presented for in-sector reductions; however, we recognize that high-integrity offsets, (i.e., reductions from other sectors, accounted for against sectoral and national totals) might be needed to achieve net-zero emissions. The contributions from the various measures are discussed below and in the following chapters.

The two trajectories of Figure 3 capture expected actions by the airlines to use new aircraft and engine technologies that are currently being produced by the OEMs. The **Frozen 2019 Technology Trajectory** illustrates a scenario that captures projected growth in traffic but assumes the technology across the fleet remains unchanged, and therefore, the fleet-wide fuel efficiency remains at the 2019 levels. The **New Aircraft Diffusion Trajectory** accounts for the airlines' continued acquisition of new aircraft with improved fuel efficiency. This includes a wide variety of new aircraft types, including the Boeing 737 MAX and Airbus A320 NEO aircraft, which have recently entered the fleet and aircraft like the Boeing 777X, which are expected to enter the fleet in the coming years. The difference between these two trajectories shows the contribution of expected fleet renewal to the aviation CO_2 emissions reduction.[14]

The time between now and 2030 will be critical to achieving the 2050 net-zero goal. Throughout this plan, there are specific references to 2030 goals that will put the industry on a trajectory toward the 2050 goal. The United States intends to review progress against the goals in this document on an annual basis and will develop roadmaps and milestones as required to aid in tracking progress. Finally, the overall document will be updated every three years.

The measures shown in Figure 3 provide a roadmap for how U.S. aviation could reach net-zero levels through coordinated actions by U.S. industry and the USG. These measures are discussed in greater depth below and in the chapters that follow.

1. New Aircraft Technologies: The development and introduction of new aircraft and engines by aircraft and engine OEMs will be critical to reducing future CO_2 emissions as aviation demand continues to grow. With investments by industry and the USG, new aircraft could be introduced with a step-change improvement in fuel efficiency. With investments by the USG and industry in the near-term, new narrow-body aircraft could enter the fleet in the 2030s and new wide-body aircraft in the 2040s. The fuel efficiency improvements of these new aircraft will be a direct result of research and development (R&D) investments made over the next five years, as it typically takes at least seven years for a technology to go from flight demonstration to an entry into service on a new aircraft. Through the Sustainable Flight National Partnership (SFNP), described in Chapter 1, the USG will work with industry to demonstrate a suite of aircraft technologies by 2030 to achieve a 30% improvement in fuel efficiency compared to today's best-in-class vehicles. This achievement will be key to ensuring that we are able to slow the growth of CO_2 emissions in the future, and potentially achieve significant reductions.

2. Operational Improvements: As demand for aviation grows, so does congestion and air traffic management (ATM) related fuel burn inefficiency. Without continued investment in infrastructure and trajectory-based ATM tools, excess fuel burn per flight will increase. While the NAS is already highly efficient, there are opportunities for improvements in all phases of flight to reduce fuel burn. This

[14] The removal of aircraft from the U.S. fleet could have indirect effects on aviation emissions from other countries. For example, these aircraft could be used to replace less efficient aircraft in other countries, they could simply be added to other fleets, or they could be removed from service and their components recycled.

includes ongoing improvements during surface, takeoff, cruise, and landing operations from continued investments in infrastructure and development of operational concept improvements. Furthermore, operational improvements for the entire integrated gate-to-gate flight path domain with consideration of pre- and post-flight events, can yield efficiencies in regional and NAS-wide operations. Improvements in trans-oceanic routes could be especially beneficial. As with any changes to the aviation system, any operational procedure changes would need to continue to ensure the safety of all aircraft operations and account for local environmental factors, such as noise and pollutants affecting air quality. This is covered in Chapter 2.

3. SAF Uptake: SAFs produced from renewable and waste feedstocks will be critical to aviation's ability to meet the net-zero goal.[15] While the SAF production industry is still in an early stage of development, through various measures including the "SAF Grand Challenge" and the September 2021, White House led commitment to increase the production of SAF to at least 3 billion gallons per year by 2030 described in Chapter 3, it is possible for the industry to grow to the point that sufficient SAF is available to meet aviation's demand for jet fuel. The data in Figure 3 reflect the focus of the USG on SAF that provide at least a 50% reduction in life cycle emissions. As there is uncertainty on what the actual life cycle emissions reductions from these fuels will be, the range depicted in Figure 3 covers 50% to 100% reduction in emissions from SAF use.

4. International leadership: Since its inception in 1944, the United States has supported the efforts of the International Civil Aviation Organization (ICAO), whose more than 10,000 Standards and Recommended Practices (SARPs), developed through consensus-based, technical-expert processes, undergird the safety and security of the global aviation system and have been crucial to aviation's global development. Chapter 4 discusses opportunities to broaden and deepen U.S. leadership at ICAO to enable greater ambition in tackling international aviation emissions, including emissions from U.S. carriers' international flights. It examines the potential for U.S. leadership in the context of ICAO's CORSIA, ICAO's CO_2 standard for aircraft, and ICAO's work toward a long-term emissions goal for international aviation. These efforts will result in increased climate ambition at the ICAO Assembly and the development of ambitious international standards to reduce CO_2 emissions through the use of aircraft technologies, aviation fuels, and emissions offsets.

5. Airport Initiatives and Climate Resilience: The United States will continue to provide incentives to reduce emissions from airports through funding and development of guidelines for best practices. While the contribution from airports to the aviation sector's CO_2 emissions is relatively modest (less than 2% for scope 1 and 2 emissions), airports are taking actions and seizing opportunities to reduce their contribution to climate change and enabling other actors in the sector to achieve reductions. Airports are also playing a leading role in efforts to gird the nation's aviation infrastructure against the impacts of climate change, and increase the sector's resilience to those impacts. This is covered in greater depth in Chapter 5. An integral part of the U.S. plan to address the climate impacts of aviation is to ensure that the FAA, as the government agency tasked with operating the NAS, is also a leader on addressing climate, sustainability, and resilience throughout its programs and activities. These efforts are described in additional detail in Chapter 6.

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[15] This document focuses on technologies that could substantially reduce the emissions from the commercial fleet of aircraft. As such, it does not focus on the use of electricity nor hydrogen, which could be used in small, short-haul aircraft. While the electrification of these aircraft would only have a small impact on GHG emissions, the use of electrification as a means to power general aviation could have considerable air quality benefits as many small, short-haul aircraft are powered by leaded aviation gasoline.

6. Non-CO_2 Climate Impact Initiatives: There is agreement in the research community that aircraft operations affect the climate through non-CO_2 emissions, as well as Aviation Induced Cloudiness (AIC). However, the relative importance of these non-CO_2 climate impacts is still a subject of discussion within the community. The United States is taking actions to improve our understanding of the full range of impacts from aviation while developing new technologies to reduce a wide range of emissions over the full aircraft mission. A point of emphasis over the next five years will be on identifying technologies and tools to enable industry to cost effectively reduce the climate impacts of industry via changes in AIC. This is discussed in Chapter 7.

7. Additional Domestic Policies: Getting the entire U.S. aviation sector on a trajectory toward net-zero emissions by 2050 will require a suite of policies to incentivize innovation, deployment, implementation, and competition to grind down the costs of the changes that will be needed. Chapter 8 identifies potential policies that could be used to deliver these incentives. Recognizing that in principle it is possible to develop and deploy SAFs that have zero life cycle emissions, but that whether these can be done in sufficient quantity to power all of aviation by 2050 remains an open question, Chapter 8 also examines options for closing the gap. These include offsets that come from outside the aviation sector or from capturing CO_2 from the atmosphere and sequestering it in the ground. A set of concluding remarks complete the document.

Community Co-Benefits through Improved Air Quality and Reduced Noise

In addition to its impacts on climate change, aircraft operations have impacts on human health and welfare via noise pollution and emissions that degrade air quality. These impacts are felt in communities near airports as well as much further away in the communities that surround our metropolitan areas. The actions outlined in this document will not only put us on a course to achieve net-zero GHG emissions by 2050, but they will also reduce the impacts of noise and air quality on airport communities.

New aircraft and engine technologies, supported by the actions in Chapter 1, provide reductions in noise in addition to fuel burn. Advances in engine combustor designs are yielding reductions in emissions of non-volatile particulate matter (a.k.a., soot or black carbon) as well as nitrogen oxides (NO_X or $NO+NO_2$), lessening the impact of aviation on air quality. Some of the airspace modernization efforts and advanced operational procedure concepts described in Chapter 2 could be used by airspace designers to change the distribution of flight paths around airports providing noise relief to communities and lessening exposure to pollutants that degrade air quality. By focusing on reductions in fuel burn from en-route operational improvements, openings could emerge to actually increase fuel use closer in to the airport to enable operations that mitigate noise for communities. SAF, supported by the actions in Chapter 3, not only provide life cycle GHG emissions reductions, but they have also been shown to reduce emissions of non-volatile particulate matter (a.k.a. soot or black carbon) without any change in nitrogen oxide emissions. Further, these fuels have no sulfur content, thus their use will also eliminate aircraft sulfur oxide emissions, another pollutant that degrades air quality. Finally, electrification of small, general-aviation aircraft could prove transformational in our efforts to reduce lead emissions from aircraft that use leaded aviation gasoline (a.k.a., avgas).

Finally, as highlighted in different areas of this plan, industry collaboration is necessary to achieve a sustainable, decarbonized aviation sector. The engagement of the full ecosystem of aviation stakeholders will be critical to advance technological innovation, create new job opportunities, and contribute to the Administration’s economy-wide goal of net-zero emissions by 2050. New and recent commitments by airlines, aircraft manufacturers, fuel providers, and airports—in concert with government investment—will significantly reduce emissions by 2030 and put us on the pathway to a net-zero aviation sector.

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1. Aircraft and Engine Technology Development

The evolution of modern, more efficient airframes and engines has historically produced the most significant aviation emissions reductions; the Sustainable Flight National Partnership (SFNP) will continue to drive emissions reductions in the future.

Background / Context

Historically, advances in aircraft technology have been the primary factor in mitigating aviation's environmental impacts. Advancements in technology over the past 50 years have resulted in a 70% improvement in fuel efficiency. Most gains in fuel efficiency and emissions over the last five decades have come from enhancements in engine and airframe technologies and design. However, there is a continued need for improved fuel efficiency given the projected growth of aviation and the need to make SAF go as far as possible. This comes with a challenge, as continued improvements in aircraft technology that result from exploring novel designs and technologies often pose large financial risks for manufacturers. In addition, aircraft have an operational life of decades, affecting the pace of fleet renewal by aircraft operators and thereby affecting the ability of manufacturers to rapidly recoup significant investments in developing new technologies. Continued USG investment to help mitigate these risks and incentivize industry to invest in and develop cleaner technologies is critical to ensure success and will allow the U.S. aviation manufacturing industry to grow while decreasing total emissions.

Figure 4 shows the aircraft development scenario that accounts for the introduction of new narrow-body aircraft in 2035 to replace the current generation and new wide-body aircraft in 2040 to replace the current generation. In both cases, it may be possible for the next generation of these planes to achieve further fuel efficiency improvements of 30% compared to current best-in-class aircraft. The fuel efficiency improvements of these new aircraft will be a direct result of R&D investments by the USG and industry that will be made over the next five years. The relatively long lead time between the introduction of these new aircraft and the "New Aircraft Tech." wedge growing in size provides a measure of the penetration rate of these aircraft into the fleet.

Summary of Actions

- Utilize the SFNP to conduct ground and flight tests to demonstrate aircraft and engine technologies and designs that can deliver a step-change improvement in environmental performance.
- Pursue ambitious international standards that incentivize the most effective technologies to safely limit the growth of, and ensure reductions in, aircraft emissions.

Current Activity

Emission reduction technologies are regulated at the aircraft and engine level as a part of airworthiness certification. These environmental standards are harmonized internationally through ICAO. Today, standards exist at the airplane level for CO_2 and noise, and at the engine level for nitrogen oxides (NO_x), non-volatile particulate matter (nvPM) mass and particle number, carbon monoxide (CO), and unburned hydrocarbons (UHC). While these standards are not technology-forcing, they ensure that new technologies are incorporated into the aircraft fleet and that there is a level playing field internationally. The standards also serve as a benchmark for environmental goal setting in USG R&D programs.

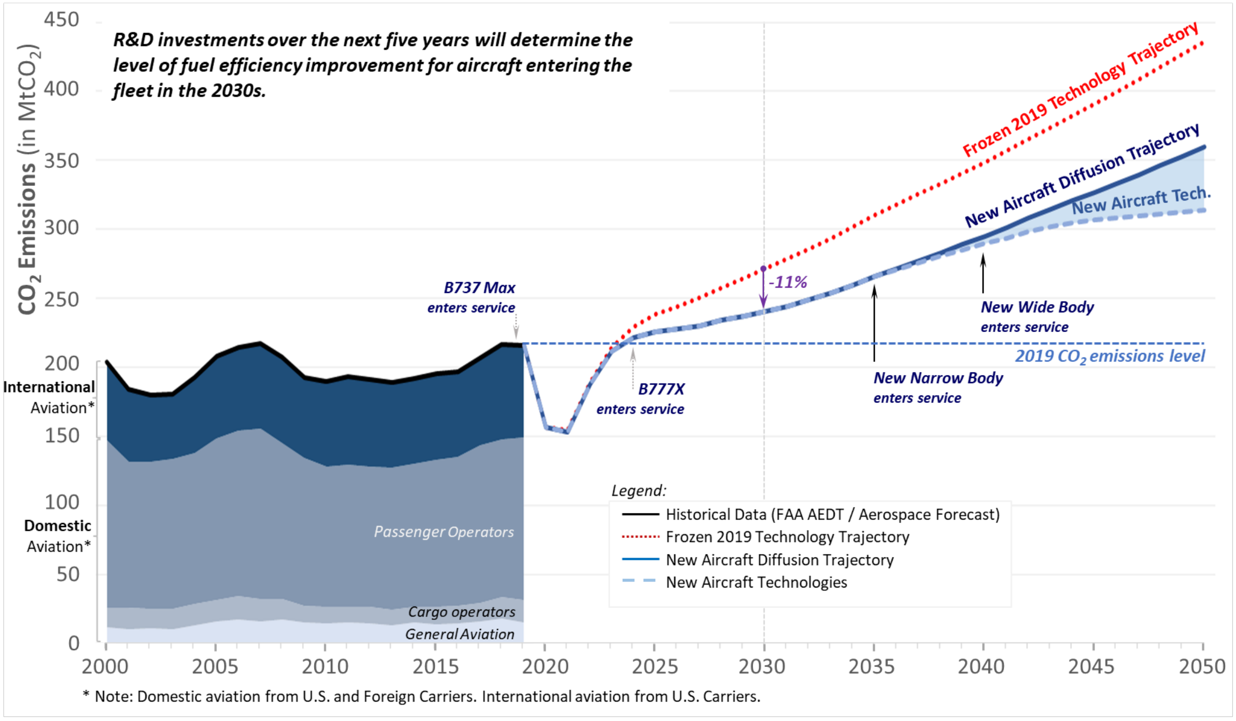

Figure 4. Analysis of Future Domestic and International Aviation CO_2 Emissions: New Aircraft Development Scenario

The USG is leading a number of efforts and collaborating with the aviation industry to mature new technology (i.e., increase the Technology Readiness Level (TRL)) to increase fuel efficiency and reduce emissions. The FAA's Continuous Lower Energy, Emissions, and Noise (CLEEN) Program is a public-private partnership to develop certifiable aircraft and engine technologies that reduce fuel burn, engine emissions, and noise. With the support of the CLEEN program, industry is able to expedite the integration of advanced technologies into current and future aircraft. The CLEEN Program, established in 2010, has matured technologies for adoption into the existing fleet and continues to develop additional technologies that will enter into service in the coming years as opportunities arise for their adoption into new aircraft and engine designs.[16] Additionally, the FAA is directing aircraft technology innovation research at universities around the country through the Aviation Sustainability Center (ASCENT Center of Excellence) to advance and expand industry's technical knowledge base broadly.[17]

The National Aeronautics and Space Administration (NASA) conducts foundational research and as well as ground and flight demonstration of sustainable aviation technologies across a wide variety of programs including the Advanced Air Vehicles Program (AAVP), Integrated Aviation Systems Program (IASP), Transformative Aeronautics Concepts Program (TACP), and the Airspace Operations and Safety Program (AOSP). These programs include research on new vehicle technologies and safe and efficient airspace operations with the potential to significantly reduce aviation's impact on the environment.[18] NASA also invests in high-risk, high-payoff research to explore longer term zero-emissions aviation

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[16] Additional information on the CLEEN Program is available at https://www.faa.gov/about/office_org/headquarters_offices/apl/research/aircraft_technology/cleen/.
[17] Additional information on ASCENT is available at https://ascent.aero/topic/Aircraft-Technology/.
[18] Additional information on NASA Aeronautics Research Mission Directorate programs is available at https://www.nasa.gov/aeroresearch.

technologies, often in collaboration with universities. Lastly, U.S. Department of Defense (DOD) and U.S. Department of Energy (DOE) are making investments in gas turbine efficiency and battery and energy storage technologies that could help make civil aviation more fuel efficient and reduce CO_2 emissions.

The USG's research programs have delivered and continue to deliver significant advancements in aircraft technology and are critical to enabling the U.S. aviation sector to achieve environmental targets in the future. Investments in technology support standard setting as the R&D proves out technologies as being fuel efficient, quieter, and safe for use in aviation. Standard setting could ensure that leading-edge technologies will be used in new aircraft entering the fleet. The USG, industry, and academia will continue to work together to explore and advance vehicle concepts and enabling technologies that drive environmental improvements.

Proposed Actions

While developments in aircraft and engine technology require longer timescales than other measures to realize their environmental benefits, significant improvements in fuel efficiency through the introduction of new and improved technologies are needed to reduce aviation's climate impact and make our limited supplies of SAF go further.

To achieve this goal, the USG is pursuing a sustained major technology development initiative, the SFNP, under which NASA and the FAA will work with industry, to accelerate the maturation of aircraft and engine technologies that enable a step-change reduction in fuel burn and CO_2 emissions (i.e., 25-30% lower fuel burn) by 2030.

NASA's investments under the SFNP include a suite of integrated, large-scale aircraft and propulsion flight and ground technology demonstrations, including ultra-efficient wings (such as transonic truss-braced wings), small-core gas turbines, electrified and hybrid electric aircraft propulsion systems, and new manufacturing techniques such as high-rate composite manufacturing to enable rapid production of such new aircraft. With these technology development efforts, the SFNP will set the stage for a step-change improvement in environmental performance (i.e., 25-30% lower fuel burn and 10-15 decibel noise reduction relative to best-in-class aircraft today). This fuel-burn reduction can be achieved with commensurate reductions in conventional pollutants from aircraft engines. The SFNP will be key for U.S. industry decision making for the product launch of new aircraft. The SFNP includes a large flight demonstrator platform to demonstrate a new aircraft architecture and associated technologies. This flight demonstrator will not only serve as an initial demonstration platform for key airframe/configuration technologies but will serve as an ongoing test bed for additional technologies in the future. FAA R&D is focused on engine propulsor technologies, low-emissions combustion, and aircraft technologies that enable future operational concepts. At the FAA, these technology development efforts will be executed primarily under the CLEEN Program and the ASCENT Center of Excellence.

This partnership will build upon a long and proven history of successful cooperation between FAA, NASA, and industry on R&D to explore and accelerate the maturation of technologies to improve fuel efficiency and reduce noise and engine emissions. USG investments in public-private partnerships under the SFNP will reduce the technical risks associated with these transformative technologies and enable industry to take the lead to the next level of environmental performance in their products. By demonstrating these technologies in the late 2020s, SFNP will support the introduction of a clean-sheet, narrow-body aircraft in the market in the early 2030s with a step-change improvement in environmental performance.

The narrow-body aircraft family initially targeted by the SFNP is of considerable importance, accounting for 55% of future global market value ($3.7 trillion), 40% of CO_2 emissions from commercial operators globally, and 60% of domestic population exposure to significant noise. Although the initial focus is on a narrow-body aircraft, the technologies demonstrated by the SFNP are generally applicable to the next generation of wide-body designs in the 2040s. Narrow-body and wide-body aircraft together account for more than 80% of global market value, global CO_2 emissions from commercial operators, and domestic population exposure to significant noise. In addition, some of the technologies may be candidates for retrofitting on existing aircraft.

NASA has started exploration of technologies such as all-electric aircraft architectures and hydrogen propulsion as well. These technologies are most likely to first be introduced as small aircraft and are decades away from adoption, to the degree they are viable, in large commercial aircraft. While there is a potential that autonomous all-electric flight vehicles could be used for "last-mile" freight deliveries and passenger movements over short distances, further investigation is needed to understand the potential life cycle emissions tradeoffs, and whether flights would result in additional or reduced emissions.

In addition to the above technology maturation initiatives for the next generation, narrow-body and wide-body aircraft, the USG continues to actively support ICAO in the development of global aviation environmental standards. The United States strives for international consensus to develop global SARPs that drive aircraft and engine manufacturers to integrate technologies to reduce CO_2 emissions, reduce noise around airports and decrease engine emissions that impact local air quality. This approach is part of the USG efforts to address environmental justice issues around airports. The USG is pursuing the development of new SARPs that would further reduce fuel burn and noise simultaneously in the coming years. The SFNP can help benchmark what may be possible when considering new global environmental standards. Additional background, details, and actions related to International Leadership are presented in Chapter 4.

2. Operational Improvements

Efficiencies can be gained through every phase of flight, helping to reduce fuel burn and emissions from aviation; improvements in trans-oceanic flights could provide substantial benefits.

Background / Context

Air traffic management (ATM) improvements and related infrastructure upgrades have contributed to a highly efficient global air transport system. ICAO estimated horizontal flight efficiency levels between 94% and 98% globally based on 2017 traffic, while the Civil Air Navigation Services Organization (CANSO) suggested a range of 92% to 94% in 2008.[19,20] These studies note that the ATM system will always have some inherent level of inefficiency due to necessary operating constraints and interdependencies, such as safety, capacity, weather, noise, and airspace fragmentation. Airspace modernization efforts—including the Next Generation Air Transportation System (NextGen) in the United States—are developing and introducing innovative technologies that will result in a safer, more efficient, and more predictable system, which may potentially contribute to reduced fuel burn, emissions, and noise. However, it will be a challenge to maintain and improve upon current efficiency levels as demand for airspace increases and modernization efforts focus on safely accommodating that demand.

Figure 5 shows the operations improvement scenario that accounts for potential improvements during surface, takeoff, cruise, and landing operations from continued investments in infrastructure and development of operational concept improvements.

Summary of Actions

- Continue to operationalize NextGen to realize the full potential of modernized infrastructure and systems, including through the transformation of the NAS to trajectory-based operations.
- Enhance data quality and information distribution to enable operators to fly more fuel-efficient trajectories, especially during the cruise phase of flight, in U.S.-controlled airspace.

Current Activity

Many of NextGen's planned infrastructure improvements are complete, having deployed advanced navigation, surveillance, communication, automation, and information infrastructure across the U.S. NAS. Performance based navigation (PBN) procedures have been rolled out across the NAS, leveraging satellite-enabled technology to create precise, repeatable, predictable, and efficient 3-D flight paths. Automatic-Dependent Surveillance – Broadcast (ADS-B) has improved surveillance of aircraft, providing higher accuracy and faster update rates for situational awareness of aircraft position using modernized aircraft equipage. Data communications have revolutionized the way air traffic controllers and pilots communicate, saving time and enabling complex route instructions not possible before. These improvements have improved air traffic efficiency in the United States and are estimated to have generated $1.2 billion, or approximately 476 million gallons, in fuel savings from 2010 through 2019.[21]

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[19] ICAO, "Destination Green, the Next Chapter, 2019 Environmental Report," 138-44, *available at*: www.icao.int/environmental-protection/Documents/EnvironmentalReports/2019/ENVReport2019_pg138-144.pdf.

[20] CANSO, "ATM Global Environment Efficiency Goals for 2050," *available at*: https://issuu.com/canso/docs/atm_global_environment_efficiency_goals_for_2050?e=1305071%2F9383178.

[21] U.S. FAA, "Performance Reporting," www.faa.gov/nextgen/reporting/.

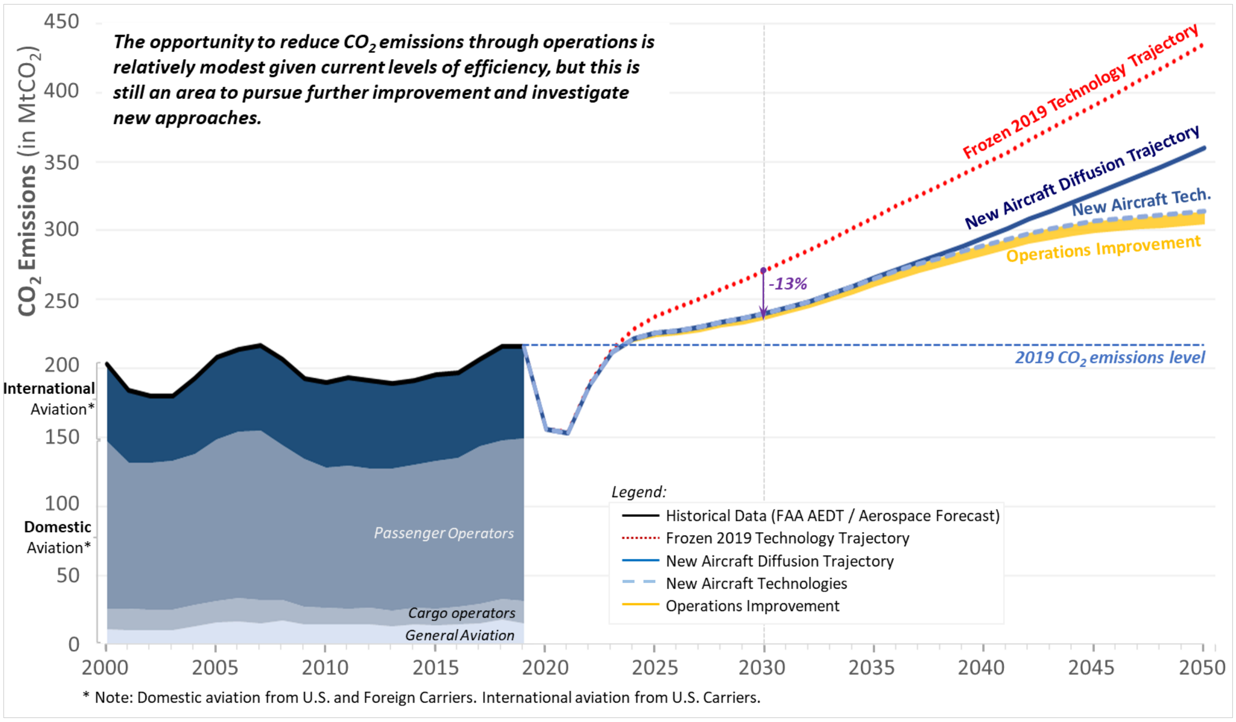

Figure 5. Analysis of Future Domestic and International Aviation CO_2 Emissions: Operations Improvement Scenario

FAA is operationalizing NextGen, leveraging the modernized infrastructure to realize the full operational potential of the system. This includes transformation of the NAS to TBO. TBO is an ATM method for strategically planning, managing, and optimizing flights throughout the operation by using time-based management, information exchange between air and ground systems, and the aircraft's ability to fly precise paths in time and space. The vision for TBO will be accomplished through improved ATM strategic planning initiatives along with the predominant use of time-based management using precise and repeatable paths defined by PBN procedures and routings. NASA is focused on partnering with FAA and industry in development, demonstration, and transfer of technologies to enable TBO and PBN. The suite of capabilities will deliver opportunities for reduced noise, fuel, and emissions. It will allow airlines to request the most fuel and emissions optimum flight profile from FAA, and automate the operator and FAA route request negotiation.

Together, time-based management and PBN comprise a four-dimensional trajectory (latitude, longitude, altitude, and time) that airspace users negotiate with the Air Navigation Service Providers to identify a solution that best accommodates both their needs. The trajectory includes a path between origin and destination with predicted crossing time estimates at key points along the path that are much more accurate than the estimates used today for strategic planning. The trajectory facilitates integration across air traffic control domains, enables the FAA to plan while accounting for user objectives, and allows for more collaborative and flight-specific solutions in response to airspace constraints. This represents a great improvement over today's strategic planning initiatives and tactical flow management techniques and addresses many of today's operational shortfalls.

TBO is expected to provide efficiency benefits by allowing flights to absorb delays caused by merging and sequencing in a more fuel-efficient manner over the full trajectory. For example, delays that are typically absorbed via low-altitude vectoring in the current system will be shifted upstream, and absorbed via more efficient means such as speed-control, vectors at higher altitudes, or ground delays at the origin airport, where the aircraft can stay on the ground with no, or markedly lower, fuel burn (see Chapter 6, Airport Initiatives, below).[22] Additionally, TBO is necessary for accommodating anticipated growth in demand for aviation, which could result in increased congestion and excess fuel burn per flight if these capabilities are not developed and implemented.

Proposed Actions

The foundation of the future vision for air traffic services in the United States is a fully-shared information environment. In this paradigm, broader data distribution, information connectivity, delivery of actionable information to decision-makers, and persistent situational awareness will enable improved performance of the NAS by distributing decisions and allowing stakeholders to best manage their operations. This mode of operation could contribute to fuel efficiency by allowing operators to more regularly fly their preferred, optimal trajectory, while taking full advantage of weather conditions including prevailing winds. Additionally, a more connected, data-rich aviation ecosystem could enable exploration of more complex operational opportunities to reduce aviation environmental impacts, such as avoiding the formation of contrails in a manner that reduces the climate impacts of aviation. Generally, improvements in the cruise portion of flight will be the most valuable given that the majority of fuel is consumed in this flight phase. NASA's Airspace Operations and Safety Program, working in partnership with the FAA NextGen Office, will develop the digital framework, concepts for operation, and technologies for this digitally-enabled, service-oriented future airspace.

Operations in oceanic airspace may also be an important target for environmental efficiencies since it is a sector that: (a) is dominated by large, long-haul aircraft, and (b) could especially benefit from enhanced availability of information and operational flexibility. In oceanic airspace, radar and ground-based ADS-B surveillance are not available, so aircraft currently must navigate using separation standards and track systems that may limit access to the most fuel-efficient trajectories. The FAA is evaluating enhancements in surveillance technology that can support reduced separation between aircraft and improved accommodation of altitude, speed, and route-change requests, thereby providing safety and efficiency benefits in oceanic Flight Information Regions.

NASA will develop a service-oriented architecture for the future NAS to deliver digitally auto-negotiated operational improvements for the entire integrated gate-to-gate flight path domain with consideration of pre- and post-flight events. These improvements can yield efficiencies on regional and NAS-wide operations. In addition, technologies will be developed for identification of the most optimum high-altitude trajectory for reduced climate impacts accounting for contrail formation. The capabilities will utilize fusion of data amongst all stakeholders for shared situational awareness, and machine learning and artificial intelligence algorithms to deliver solutions to the users for optimum aircraft operations.

Continued investment by the USG in airspace modernization research and technology development, in collaboration with industry, is critical to achieving the safety and efficiency goals of the future NAS.

[22] U.S. FAA, "TBO Benefits," https://www.faa.gov/air_traffic/technology/tbo/benefits/.

3. Sustainable Aviation Fuels

Sustainable Aviation Fuels will be critical to the long-term decarbonization of aviation. Through a range of policy instruments, including the SAF Grand Challenge, the USG will work with industry to rapidly scale up SAF production with the goal of meeting the fuel needs of U.S. aviation by 2050.

Background / Context

Jet fuel is a critical component of the safe, reliable, and efficient global air transportation system that businesses and individuals rely on today. Jet fuel provides a unique combination of properties that enable aircraft to safely carry hundreds of passengers and tons of freight for thousands of miles at high speeds. Some of these properties include remaining in liquid form at the very low temperatures of flight, not vaporizing at the low atmospheric pressures experienced in the upper atmosphere during cruise flight, tolerating relatively high engine temperatures without breaking down and clogging fuel lines, and providing considerable energy both in terms of energy per unit mass and per unit volume. Further, refining crude oil into petroleum jet fuel is a mature, cost-effective industrial process with relatively low production costs. While jet fuel's properties play a key role in enabling today's aviation system, they also make it a difficult sector to decarbonize because they are hard to replace.

In the transportation sector, several approaches to decarbonization are under consideration to replace petroleum-based fuels including electrification, hydrogen fuel, and sustainable liquid fuels. Current battery technologies are limited by their energy density and would only be able to power a relatively low-speed aircraft that would carry a small number of passengers over a few hundred miles. While these technologies have the potential to play an important role in decarbonizing short-distance flights in the coming decades, they are not expected to provide a solution for the medium- and long-haul flights that generate most of the aviation sector's carbon emissions by 2050. A recent report of international experts convened by ICAO stated that "all-electric propulsion systems are not likely even for business jets by the 2037 timeframe."[23] To understand the challenge of electrifying aviation, it helps to consider that, at takeoff, the engines of a wide-body jet are generating power levels comparable to a nuclear reactor or coal power plant.[24] Cryogenic hydrogen has also been proposed as an option to power commercial aircraft, but hydrogen's low energy per unit volume limits its potential viability to shorter ranges due to the amount of space needed to store the fuel. Even more problematic is the lack of a global distribution network to get the fuel to the airports that would need to supply it. Airbus is working to develop a hydrogen-powered regional aircraft that could enter into service in the 2035 timeframe, but they have also stated that larger commercial aircraft would be operating on liquid fuels through 2050.[25] This timeline is insufficient to meet the U.S. goal of net-zero emissions by 2050. Simply put, there is no realistic option that could replace liquid fuels in the commercial aircraft fleet in the coming decades. Even with significant investments in electrified aircraft propulsion technology and/or cryogenic hydrogen powered aircraft, it will take many years for technology to mature to the point of adoption,

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[23] ICAO, "Independent Expert Integrated Technology Goals Assessment and Review for Engines and Aircraft," 118 (2019). *Available at* https://store.icao.int/en/independent-expert-integrated-technology-goals-assessment-and-review-for-engines-and-aircraft-english-printed.

[24] Commercial aircraft have maximum power between roughly 30 and 300 MW, for single-aisle to wide-body jets, respectively. Commercial nuclear reactors typically produce 1,000 MW but their output can be as small as 500 MW.

[25] "Airbus Gears Up For Hydrogen Jet As Fuel of Future Edges Closer To Reality," Financial Times (Sept. 26, 2021). https://www.ft.com/content/87941b8d-0460-4b54-a861-d6ebc6da29e8.

leaving the aviation industry dependent upon liquid hydrocarbon fuels for the foreseeable future. While there may be a role for hydrogen on shorter-range flights and more broadly in the years beyond 2050, we do not expect hydrogen-powered aircraft to make a significant contribution toward achieving net-zero aviation emissions by 2050.

In September 2021, the Administration committed to scaling up SAF production to at least 3 billion gallons per year by 2030. At the same time, members of Airlines for America pledged to work with the USG and other stakeholders toward a rapid expansion of the production and deployment of commercially viable SAF to make three billion gallons of SAF available to U.S. aircraft operators in 2030. Alongside this commitment, several airlines provided individual commitments.[26]

Rigorous standards have been developed by ASTM International to ensure the safety of liquid hydrocarbon fuels under the demanding conditions of flight operations.[27] These standards cover not only jet fuel production from conventional petroleum, but also alternative jet fuel pathways that could use renewable and waste feedstocks to produce a liquid hydrocarbon fuel that can be safely used in today's jet engines. Thus far, ASTM International has approved seven alternative jet fuel pathways for blending with conventional jet fuel and the co-processing of renewable feedstocks with conventional petroleum in today's refineries.[28] More approvals are anticipated in the coming years.

These pathways use technologies that can convert wastes, residues, biomass, sugar, oils, and gaseous sources of carbon into a fuel that can be used by today's fleet of aircraft.

Sustainable Aviation Fuels

SAF are "drop-in" liquid hydrocarbon fuels with the same performance and safety as conventional jet fuels produced from petroleum, are fully fungible with the existing fuel supply, and can be used in the same infrastructure, engines, and aircraft. SAF can be created from either renewable or waste materials and for purposes of this action plan and U.S. policy, SAF reduce life cycle GHG emissions by at least 50% relative to conventional jet fuel. Since they are drop-in compatible with the existing fleet, SAF are hydrocarbon fuels and thus emit CO_2 when combusted in the aircraft engine. The extent to which any particular SAF provides a climate benefit depends on the SAF's life cycle emissions profile, taking into account the production, transportation, and combustion of the SAF, as well as indirect effects associated with these. Finally, some types of SAF reduce emissions that impact air quality and contribute to the formation of contrails, which also impacts climate change.

While there is a great deal of interest in using SAF, SAF production and availability is limited today. High conversion costs and limited feedstock and production infrastructure have inhibited SAF expansion. Expanding SAF availability and maximizing SAF's benefits requires addressing key challenges and risks across the supply chain.

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[26] *See* Press Release, White House "FACT SHEET: Biden Administration Advances the Future of Sustainable Fuels in American Aviation," (Sept. 9, 2021), https://www.whitehouse.gov/briefing-room/statements-releases/2021/09/09/fact-sheet-biden-administration-advances-the-future-of-sustainable-fuels-in-american-aviation/.

[27] ASTM D1655: Standard Specification for Aviation Turbine Fuels. ASTM D7566: Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons.

[28] For more information on the fuel qualification process as well as a full list of approved fuels, please visit https://www.caafi.org/focus_areas/fuel_qualification.html.

Figure 6 shows the SAF Uptake Scenarios depicting potential emissions reductions from SAF use. Two bands are shown in the figure corresponding to life cycle GHG emissions reductions of 50% and 100%. Projections through are based on a near-term global SAF production survey.

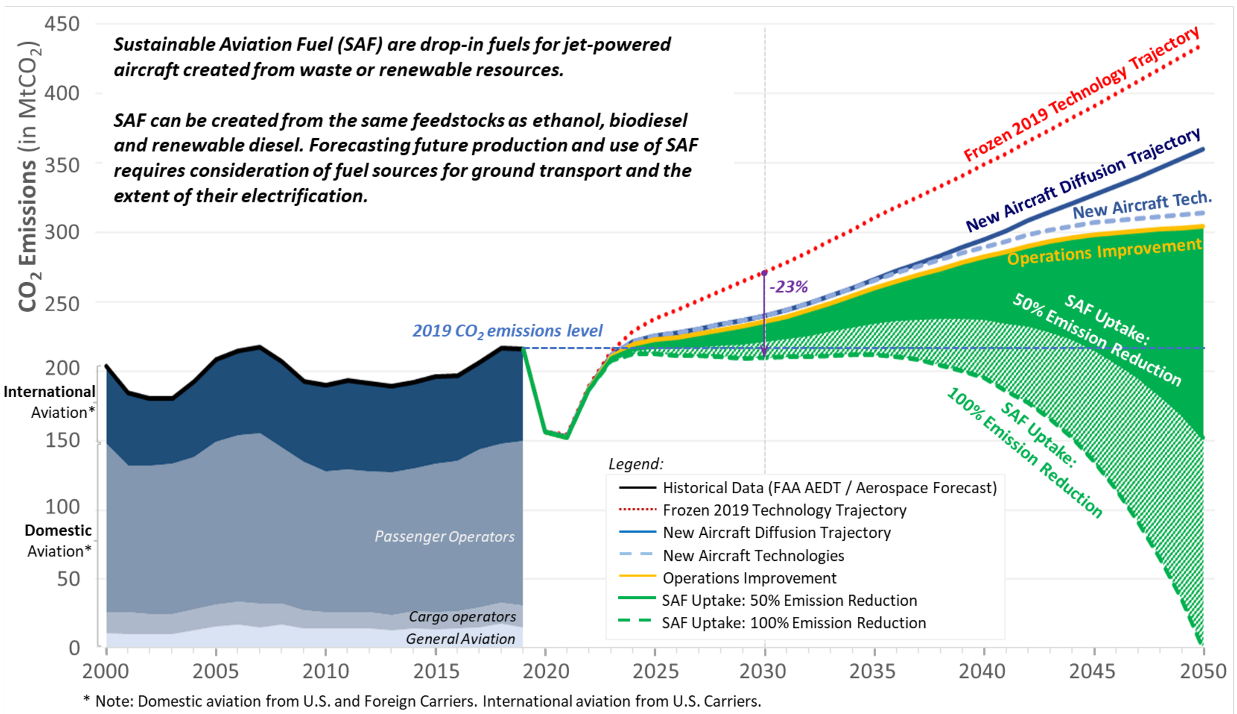

Figure 6. Analysis of Future Domestic and International Aviation CO_2 Emissions: SAF Uptake Scenario

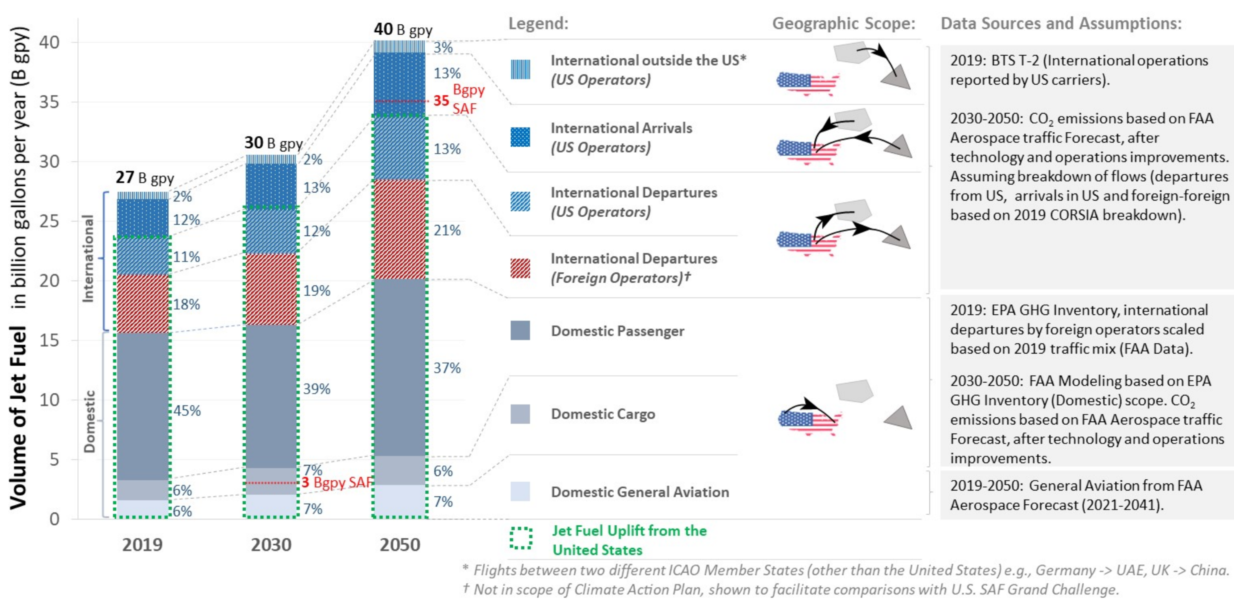

Figure 7. Potential demand for jet fuel in gallons per year (gpy) across domestic operations (by U.S. and Foreign Carriers), international departures from foreign carriers and international operations by U.S. carriers. Red text indicates SAF Grand Challenge volumetric production goals.

Trends for 2025 to 2050 are based on the goals of the SAF Grand Challenge with roughly 90% percent of U.S. SAF production capacity available to meet 2050 U.S. domestic and international aviation fuel demand from U.S. carriers and the remainder going to meet demand from foreign carriers departing the U.S. or towards exports, see Figure 7. Under the high-end scenario, sufficient SAF would be produced to meet domestic and international fuel demand, although the climate benefits of this SAF would depend, as noted above, on the life cycle benefits.

Summary of Actions

- Continue to support critical USG programs on research, development, demonstration, and deployment of feedstock systems, conversion, testing, analysis, and coordination on SAF directly with industry and through the Commercial Aviation Alternative Fuels Initiative (CAAFI).
- Develop a multi-agency roadmap to implement the SAF Grand Challenge to reduce cost, enhance sustainability and expand production and end use of SAF to a level of 35 billion gallons of SAF per year by 2050.
- Obtain enactment of proposed Sustainable Aviation Fuel tax credit proposed in the Build Back Better Agenda to help cut costs and rapidly scale domestic production of SAF.
- Catalyze bulk purchases of SAF by military and other end users.

Current Activity

The USG has a long history of support for SAF research, development, demonstration, and deployment. CAAFI is a public-private partnership founded in 2006 by the FAA with industry to support development and deployment of SAF. Strong partnerships exist among multiple USG agencies. The USG's SAF programs have delivered significant advancements that have positioned the SAF industry for growth. USG led research, development, demonstration, and commercial deployment support is playing a critical role in reducing production costs, maximizing sustainability benefits, developing supply chains, and expanding commercial production infrastructure. Ongoing R&D efforts are focused on work across the entire SAF supply chain and development space.

The FAA supports testing to ensure fuels are safe for use; analysis to understand the economics, environmental impacts, and potential production; and plays a significant role in coordination among industry, federal agencies, and with the international community. The FAA works with academia through the ASCENT Center of Excellence. With the help of ASCENT, FAA is leading technical work to set international standards to account for life cycle GHG emission reductions within ICAO's CORSIA as well as doing the testing that is required within the ASTM fuel approval process. The FAA also facilitates coordination of a broad range of SAF stakeholders through CAAFI. A major area of work for the FAA going forward will be working with industry to gain approval for the use of 100% SAF in today's fleet of aircraft. This is a key barrier that must be overcome to decarbonize aviation.

USDA supports programs in feedstock supply chain systems; environmental, economic, and social analysis; and funds commercialization support, providing financial assistance for the development of SAF production infrastructure via grants and loan guarantees.

The DOE SAF portfolio includes R&D, pre-pilot, pilot, and demonstration scale conversion activities for biochemical, thermochemical, and hybrid processes; biomass, industrial/power exhaust gas and all types of waste feedstocks research; and analysis of all aspects of sustainability and life cycle GHG emissions, as well as techno-economics.

DOE ARPA-E are supporting six projects as part of the Systems for Monitoring and Analytics for Renewable Transportation Fuels from Agricultural Resources and Management (SMARTFARM) program. These projects will develop technologies that bridge the data gap in the biofuel supply chain by quantifying feedstock-related GHG emissions and soil carbon dynamics at the field-level.

DOD, NASA, and the U.S. Environmental Protection Agency (EPA) also have programs supporting SAF. Renewable jet fuels may qualify for tradable credits under the EPA Renewable Fuel Standard program. NASA research and development of advanced combustors includes tests with various SAF to assess performance and emissions. NASA also characterizes SAF emissions with on-wing exhaust measurements.

SAF is a key focus area for the federal multi-agency Biomass Research and Development Board, which is tasked with implementing a federal strategy—the Bioeconomy Initiative—to develop bioenergy, bioproducts, and biofuels.

The government as a whole has procurement power that can be used to support the sustainable aviation industry as federal employees return to travel. The General Services Administration is publishing a Request for Information (RFI) on the Options to Increase Sustainability of Future Federal Air Travel. In this RFI the agency is seeking market research information about airlines' commercial sustainability capabilities and offerings to inform the Government's efforts to reduce the sustainability impacts of employee travel.

Various airlines have advanced pilot projects and programs to demonstrate the use of SAF, or invite their customers to use SAF on a voluntary basis. While the SAFs selected must meet ASTM standards, there are no mandatory governmental standards for calculating the environmental benefits or disbenefits of SAF. Given the high production costs of SAF, it is expected that any producers who meet the criteria of the Renewable Fuel Standard will participate in the program, but it is currently an opt-in program for aviation fuel. Similarly, other opt-in, state-level programs also exist such as California's Low Carbon Fuel Standard. These programs have their own compliance provisions designed to ensure the environmental benefits of SAF. However, because producers can qualify for multiple programs, there is a risk that SAF reductions could be double-counted. At the international level, with U.S. leadership, ICAO's CORSIA, has established and is developing further sustainability criteria and mechanisms aimed at ensuring the environmental credibility of SAF used to show compliance with CORSIA obligations. While CORSIA only addresses international aviation's CO_2 emissions, it could provide a foundation on which to build domestic policies and programs to ensure the environmental effectiveness of SAF used by U.S. airlines beyond their CORSIA obligations.

Expanding SAF availability and maximizing SAF's benefits requires robust standards that give industry confidence to invest in producing SAFs with increasing environmental benefit, while also addressing key challenges and risks across the supply chain. To help overcome these obstacles, the United States is developing USG-formulated standards, and conducting USG-led research, development, demonstration, and commercial deployment support. These efforts are playing a critical role in reducing production costs, maximizing sustainability benefits, developing supply chains, and expanding commercial production infrastructure.

Proposed Actions

The USG has identified the development and deployment of SAF as a key aviation climate priority. The USG has established a multi-agency effort lead by the U.S. Department of Transportation (DOT), DOE, and USDA to implement the "SAF Grand Challenge" to reduce cost, enhance sustainability, and expand production and use of SAF that achieves a minimum of a 50% reduction in life cycle GHGs compared to conventional fuel. In addition, the challenge will adopt the goal of supplying at least 3 billion gallons of SAF per year by 2030 and, by 2050, sufficient SAF to meet 100% of aviation fuel demand, which is currently projected to be around 35 billion gallons per year. Through the SAF Grand Challenge, DOE, DOT, and USDA, working with other agency partners, intend to accelerate the research, development, demonstration, and deployment needed for innovative solutions and technologies and develop a policy framework that can enable an ambitious government-wide commitment to scale up the U.S. production of SAF.

The SAF Grand Challenge will include development of a multi-agency roadmap within the first year identifying agency roles and an implementation plan to leverage USG activities in research, development, demonstration, deployment, commercialization support, and policy in order to:

- **Reduce the cost of SAF** through critical activities that drive down cost of production across the supply chain; expand the feedstock and conversion technology portfolio; leverage and repurpose existing production infrastructure; reduce risk to industry; and provide incentives for production.
- **Enhance sustainability of SAF** by maximizing the environmental co-benefits of production; demonstrating sustainable production systems; developing low land-use change feedstock crops; reducing the carbon intensity of SAF supply chains; ensuring robust standards that guarantee environmental integrity through rigorous life cycle analysis; and, enabling approvals of higher blend levels of SAF.
- **Expand SAF supply and end use** through support for regional feedstock and fuel production development and demonstration; outreach, extension, and workforce development; new infrastructure and commercialization support through federal programs; implementation of supporting policies that are enacted for SAF; enabling approvals of diverse SAF pathways; and, continued outreach and coordination with military and industry end users.

Well-designed economic incentives, including blender's tax credits and investment tax credits, can help bridge the cost gap between SAF and petroleum jet fuel. That is why President Biden proposed a Sustainable Aviation Fuel tax credit as part of the Build Back Better Agenda. This credit will help cut costs and rapidly scale domestic production of sustainable fuels for aviation. The proposed tax credit requires at least a 50% reduction in life cycle GHG emissions and offers increased incentive for greater reductions. Catalyzing and coordinating purchases by military, other governmental, industry, and other consumers can help aggregate demand for SAF that meets ambitious standards for life cycle emission reductions. The USG will need to ensure that the life cycle benefits of SAF are properly accounted for in national emissions reporting. It will also be important to provide these purchasers and other consumers with guidance to assist them in evaluating SAF environmental integrity claims.

4. International Leadership and Initiatives

Continuing a long tradition of leadership on noise and environmental standards in ICAO, the United States is providing technical and policy leadership on climate in ICAO.

Background / Context

The USG has historically demonstrated strong international leadership in addressing aviation's climate impact through its technical contributions to the ICAO Committee on Aviation Environmental Protection (CAEP). Additionally, the USG played an instrumental role in encouraging global consensus on a single market-based measure to address international aviation CO_2 emissions, ICAO's CORSIA and in facilitating agreement in ICAO on a first-ever CO_2 emissions standard for civil aircraft. The ICAO General Assembly provides an opportunity for the organization to define its climate activities, from the continued support and implementation of CORSIA to the establishment of a long-term aspirational climate goal. USG efforts both bilaterally and multilaterally provide a critical opportunity to demonstrate leadership and increase the overall climate ambition for international aviation.

The USG is also active in a range of bilateral initiatives with key aviation partners around the globe. These open a suite of opportunities for U.S. leadership in strengthening climate ambition through technical and economic cooperation, including under bilateral air services agreements.

ICAO Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)

In 2016, ICAO Member States reached agreement on CORSIA, a global market-based measure to address international aviation's CO_2 emissions. In the simplest terms, CORSIA requires aircraft operators purchase emissions offsets or use CORSIA Eligible Fuels (CEF) to reduce international CO_2 emissions above a defined baseline. There are two types of CORSIA Eligible Fuels, Sustainable Aviation Fuels created from renewable or waste feedstocks, and Lower Carbon Aviation Fuels, created from fossil feedstocks. As an international program, CORSIA enables the development of harmonized standards for both emissions offsets and CEF to ensure their robustness and sustainability and creates a marketplace for their use. This harmonization establishes global certainty for all stakeholders involved. The USG has played a leadership role in the development of all aspects of CORSIA and continues work ensuring CORSIA's environmental integrity.

Summary of Actions:

- Continue to provide technical leadership to ICAO/CAEP and its Working Groups.
- Undertake rulemaking to implement CORSIA to the extent possible under existing authority.
- Negotiate internationally to maintain the environmental integrity of CORSIA, enhance CORSIA's ambition, strengthen ICAO's aircraft CO_2 emissions standard, and adopt medium- and long-term global goals that drive aviation climate action world-wide.
- Pursue mutually-beneficial climate protection provisions in aviation bilateral and multi-lateral agreements.

Current Activity

The United States has been a leader in aviation emission standards since the 1970s when the first aviation emissions and noise standards were developed in the United States. This continued to the international realm when the United States provided technical leadership to ICAO on environmental standards when the first international standards were established, and that international leadership has continued under CAEP since its inception in 1983. CAEP is a committee of ICAO's thirty-six member governing Council that assists in formulating new policies and international SARPs related to aircraft noise and emissions. CAEP is responsible for the development of SARPs to implement the first CO_2 standard for civil aircraft along with the SARPs implementing ICAO's CORSIA. Within CAEP, the United States contributes to all technical working groups and maintains a leadership position in a majority of them. U.S. participation in CAEP ensures that the United States can drive international standards to maximize environmental benefits, while ensuring they are technically feasible and economically reasonable.

The United States provides policy leadership in ICAO through its membership in ICAO's Council and its participation in the triennial meetings of ICAO's Assembly. In these capacities, the United States has played a key role in the adoption of the suite of ICAO Assembly Resolutions establishing environmental standards such as CORSIA and ICAO's CO_2 standard, as well as ICAO's climate-related work plan.

The USG also collaborates bilaterally with a wide range of countries on environmental efforts related to aviation. This engagement is done through specific technical agreements that relate to specific technical work and through bilateral air transport agreements.[29]

Proposed Actions

Continued U.S. leadership in ICAO, including the Council, the Assembly, and CAEP is a fundamental cornerstone of USG efforts to mitigate aviation's global GHG emissions. Technically feasible but ambitious SARPs developed by CAEP will help reduce in-sector emissions. Global implementation of CORSIA and strengthening of CORSIA's ambition can help catalyze development and use of high-quality SAF and ensure the integrity and transparency of emission reductions from other sectors that are used to help aviation bridge the gap between its in-sector emissions and its climate mitigation goals.

The United States has actively supported development of a global market-based measure to help international aviation to address its climate impact. After years of constructive, multilateral negotiations, ICAO agreed in 2016 to establish CORSIA as the global market-based measure to address international aviation CO_2 emissions. The United States was instrumental in developing a global consensus on CORSIA and led the development of the SARPs that are being implemented globally. The United States initially implemented the emissions monitoring, reporting, and verification (MRV) requirements of CORSIA through a voluntary program administered by the FAA that covers more than 98% of applicable emissions from U.S. international operators. The FAA intends to extend its voluntary MRV program as an interim measure and pursue rulemaking to fully implement CORSIA to the extent possible under existing authority.

As it implements CORSIA for U.S. airlines, the USG is also collaborating with international partners at ICAO to ensure CORSIA's global success. As the international aviation sector recovers from the impacts

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[29] For example, a listing of FAA's bilateral agreements related to aviation safety can be found at https://www.faa.gov/aircraft/air_cert/international/bilateral_agreements/.

of COVID-19, the USG will constructively support the ICAO Council and negotiate at the ICAO Assembly to ensure CORSIA maintains a robust of level of environmental integrity, strengthens its ambition commensurate with the climate challenge, and is not altered to introduce destructive market distortions.

As ICAO moves to address the need for a global long-term climate goal for international aviation emissions, FAA will continue to provide technical support through CAEP, and the Departments of Transportation and State will provide leadership in the ICAO Council and Assembly.

The United States supports the development of ambitious new international CO_2 standards at ICAO. We believe the standard setting process used by ICAO CAEP to develop the first airplane CO_2 standard serves as a useful basis for future SARPs. This was the first time ICAO modeled a differentiated response from existing airplanes and future new types. As mentioned above in section 1, the new technologies being developed under SFNP are intended for future airplane types. Many of these technologies cannot be retrofitted onto existing types. Therefore, the United States intends to examine how standards could reflect what is technologically feasible for both existing and future airplane types.

The United States also pursues mutually beneficial bilateral technical work on aviation's climate impact with partners around the world. The Departments of Transportation and State, which are responsible for America's bilateral air transport agreements, will evaluate the potential for advancing efforts to address the climate crisis through these agreements. Further, the FAA has formal agreements with bilateral partners to facilitate cost sharing and collaboration on climate-related research, the exchange of aviation operation databases to support aviation environmental modeling tools, as well as exchange of employees for training opportunities and best practice demonstrations. The USG intends to continue, extend, renew, and institute new agreements with bilateral partners to continue to support research, technical tool development, and training, and increased ambition in reducing GHG emissions, extending the use of SAF, and strengthening the resilience of aviation infrastructure.

5. Airport Initiatives

While their CO_2 emissions are relatively small in comparison to those from the combustion of jet fuel, airports are playing an important role in addressing climate change.

Background/Context

The operational and economic challenges from climate change to the NAS are daunting. However, as noted in the introduction to this publication, USG considers the environment—and specifically addressing climate change—a national priority. For example, President Biden on January 27, 2021 signed Executive Order 14008, "Tackling the Climate Crisis at Home and Abroad," and directed "each federal agency to develop a plan to increase the resilience of its facilities and operations to the impacts of climate change."[30] The FAA is now working to implement its Climate Action Plan in collaboration with other federal partners, so it can better coordinate with airports to ensure resilience. Second, to meet current GHG reduction goals noted in the introduction section, FAA is taking several actions to assist airports to lower their GHG emissions. Specifically, the FAA's Office of Airports (ARP) administers several grant programs that address GHG emissions. It is also developing a plan regarding infrastructure resilience. Both of these actions are discussed in this chapter.

Airports increasingly are aware of their GHG emissions and the need to work to mitigate these impacts. In fact, in June 2021, the Airports Council International, representing airports worldwide, established a global goal for achieving net-zero carbon emissions by 2050, recognizing that specific actions and timelines will be developed on an individual airport bases subject to specific conditions. The United States welcomes this initiative by the world's airports and the FAA is committed to supporting U.S. airports in achieving this ambitious target.

In most cases, while new investments are needed to assess energy use and to purchase more advanced equipment to lower emissions, such investments are cost effective over short time horizons. As discussed below, FAA has several Congressionally-authorized grant programs to assist airports in reducing their GHG emissions. If additional resources were to become available, there would be significant opportunities within these programs to scale up funding for emissions reduction projects, including the electrification of ground support equipment.

Regarding resilience, according to the 2017 National Climate Assessment, 13 of the nation's 47 largest airports have at least one runway with an elevation within the reach of a moderate to high storm surge. Climate change is leading to an increase in the intensity and frequency of severe weather events, higher temperatures, and more frequent heat waves that will severely impact some airports, including ground access links. Therefore, while severe weather is already the largest cause of flight delays, more substantial delays and supply chain interruptions to operations systemically have significant cost and policy implications for airports and the FAA. Activities on resilience conducted by FAA are outlined below.

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[30] Executive Order 14008, Tackling the Climate Crisis at Home and Abroad, 86 Fed. Reg. 7,619, 7,625-6 (Jan. 27, 2021). See also Executive Order 14030, Climate-Related Financial Risk, (reinstating Executive Order 13690 of January 30, 2015, Federal Flood Risk Management Standard, to address current and future flood risk and ensure that projects funded with taxpayer dollars last as long as intended) 86 Fed. Reg. 27,967, 27969-70 (May 25, 2021).

Summary of Actions:

- Continue to fund grants for authorized emission reduction programs and develop guidelines for other programs authorized but not funded or implemented.
- Develop a resilience framework through research and potential grant funding.

Current Activity:

The following programs are authorized and funded by FAA:

Voluntary Airport Low Emissions (VALE) Program. This program addresses emission reductions at commercial airports in areas that are in “non-attainment” or “maintenance” under the Federal Clean Air Act. Typical projects include gate electrification, charging stations for electrical ground support vehicles, geothermal systems, and solar hot water systems.

Zero Emission Vehicle (ZEV) Program. This program provides grants for any airport in the National Plan of Integrated Airport Systems to replace or convert on-road vehicles for zero-emission vehicles.[31] Presently, only electric powered vehicles and their charging infrastructure have been funded. Fuel cell vehicles and their charging infrastructure are also eligible.

Energy Efficiency Program. The program provides funding for energy assessments to identify and implement energy reduction measures to reduce energy consumption across all airport operations. Typical projects include light-emitting diode (LED) lighting or other energy efficiency measures.

Sustainability Program. This program provided funding for development of sustainability plans as stand-alone documents. This program has since been eligible for inclusion in Airport Master Plans addressing a broad array of environmental and energy activities (e.g., recycling, green construction and operations, energy efficiency, renewable energy, water quality, and climate resilience).

Resilience Research. FAA is continuing to conduct research using case studies, including at airports, to develop a resilience framework to augment several ARP programs, including its Sustainability Program.

Proposed Actions

The following programs are authorized, and will be implemented or reinitiated by FAA.

Environmental Mitigation Pilot Program. This pilot program is for environmental mitigation projects that measurably reduce or mitigate aviation impacts on noise, air quality, or water quality at or within five miles of an airport.

Energy Supply, Redundancy, and Microgrids Program. This program can be used to: (1) improve reliability and efficiency of the power supply; (2) prevent power disruptions; (3) acquire and install electrical generators; (4) separate the main power supply; and (5) construct or modify facilities to install a microgrid.

Deployment of Zero-Emission Technology Program. This program will augment the ZEV program by facilitating the deployment of zero-emission airport vehicles, technology, and related infrastructure.

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[31] For a description of the NPIAS system of airports, see: https://www.faa.gov/airports/planning_capacity/npias/.

Sustainability Program. FAA is considering reinitiating this program with an emphasis on resilience planning to address climate and extreme weather risks to airports in relation to sustainability.

6. FAA Leadership on Climate, Sustainability, and Resilience

Background/Context

An integral part of the U.S. plan to address the climate impacts of aviation is to ensure that the FAA, as the government agency tasked with operating the NAS in the United States, is also a leader on addressing climate, sustainability, and resilience throughout its programs and activities. The FAA maintains more than 9,000 properties, structures and facilities across the United States that will experience different effects from climate change, from flooding to wildfires, each requiring targeted or specific solutions while supporting the continued round-the-clock operation of the NAS. Increasing resilience of FAA's infrastructure and reducing their environmental footprint, along with taking climate into account across the FAA's programs is a top priority.

Current Activity

In support of Executive Orders 13990 and 14008 on climate change,[32] the FAA is taking action to address the climate crisis by bolstering adaptation and increasing resilience of FAA facilities, FAA agency operations, and infrastructure to the impacts of climate change. The FAA is developing an in-depth strategy to prioritize this effort, with ambitious milestones and targets, in line with President Biden's Executive Orders to increase the sustainability and resilience of federal agencies. Consistent with the elements laid out in this plan, the agency is also increasing action to reduce carbon emissions from the aviation sector.

Proposed Actions

- Establish climate, sustainability, and resilience as an agency priority initiative with measurable targets and timelines, in line with Executive Orders and related agency requirements.
- Reduce climate impacts from FAA facilities and operations by lowering the agency's carbon footprint, with specific and measurable milestones and targets.
- Increase the resilience of critical FAA facilities and assets, with specific and measurable milestones and targets.
- Update agency policies and orders related to sustainability, energy/water efficiency, and waste reduction, to reflect best practices and ensure long-term implementation

[32] Executive Order 13990, Protecting Public Health and the Environment and Restoring Science To Tackle the Climate Crisis, 86 Fed. Reg. 7,037 (Jan. 20, 2021); Executive Order 14008, Tackling the Climate Crisis at Home and Abroad, 86 Fed. Reg. 7,619 (Jan. 27, 2021).

7. Non-CO_2 Impacts of Aviation on Climate

Aircraft combustion emissions also have non-CO_2 impacts on the climate. The primary concern is the impact of aviation induced cloudiness.

Background / Context

Aircraft engines emit water vapor and a variety of other gases and particulate matter into the atmosphere, in addition to CO_2. These non-CO_2 combustion emissions can directly or indirectly impact climate. All of the non-CO_2 effects of aviation are short lived, and the largest impact is due to AIC. Other non-CO_2 aviation climate impacts are due to nitrogen oxides (NO_X), water vapor, sulfates, and soot emissions. In addition, non-CO_2 engine emissions also affect local air quality and there are trade-offs between air quality and climate impacts. The United States is taking action to improve the level of scientific understanding for non-CO_2 climate impacts of aviation emissions to support future policy decisions.

Climate Impacts of Aviation Non-CO_2 Combustion Emissions

The non-CO_2 combustion emissions from aviation include water vapor (H_2O), unburned hydrocarbons (UHC), carbon monoxide (CO), nitrogen oxides (NO_X or $NO+NO_2$), sulfur oxides (SO_X) and non-volatile particulate matter (nvPM, a.k.a., black carbon or soot). These emissions undergo complex interactions amongst themselves and with the changing background atmosphere. The impact of these emissions on climate has been examined for several decades. Emissions identified as potentially affecting climate include radiatively and/or chemically active species such as nvPM, NO_X, UHC, CO, SO_X and H_2O. Direct emissions of gases (e.g., CO_2, H_2O, soot particles), byproducts (e.g., O_3, stratospheric H_2O), and perturbed methane (CH_4) tend to have a warming effect, while particles like sulfates generally have a cooling effect. Gaseous emissions of SO_X and NO_X evolve and partially transform into volatile nitrate and sulfate aerosols, which contribute to climate change as do the semi-volatile organic particles that form from gaseous UHC emissions.

Persistent linear contrails produced in the wake of aircraft contribute to net climate warming. Contrail-induced cirrus clouds (aviation induced cloudiness or AIC) also affect the solar and terrestrial infrared radiative budget of the atmosphere. Recent estimates indicate that the AIC warming effect could be comparable or even higher than those due to aviation CO_2 although large uncertainties still remain. Further complicating the situation, some forms of aviation induced cloudiness may have a cooling effect.

There is a wide range of spatial and temporal scales associated with atmospheric perturbations due to non-CO_2 aviation emissions. Contrails have an impact over an area measured in miles and a time span measured in hours whereas the impacts of NO_X on methane has a global impact that lasts decades.

Summary of Actions:

- Improve the scientific understanding of the impacts of non-CO_2 aircraft emissions to enable the development of cost-beneficial solutions to address both air quality and climate impacts.
- Develop decision support tools that could be used by industry to cost-effectively mitigate the overall climate impacts of aviation via contrail mitigation.

Current Activity

The FAA is currently funding research to improve its understanding of the non-CO_2 climate impacts of aircraft. The FAA funded research uses the latest scientific models and realistic emissions scenarios to quantify impacts of various short-lived climate forcers. In addition, this research examines the trade-offs between fuel efficiency and NO_x emissions that manifest as trade-offs between air quality and climate impacts. The research utilizes algorithms to improve detection of contrails and AIC from satellite data, as well as the climate impact of higher-altitude stratospheric emissions. With this information, the FAA will be better prepared to address such trade-offs in the context of existing engine emissions regulations and identify other data gaps.

Proposed Actions

The climate impact of AIC could be comparable to that of aviation CO_2. However, the nature of the impacts of CO_2 and AIC have important differences. If aviation activity were to stop tomorrow, the warming caused by contrails and AIC would also immediately stop, while the CO_2 that results from aviation activity will continue to warm the planet for centuries. In addition, the estimates of warming impact of AIC still have large uncertainties unlike the impact of CO_2. As noted previously, not all contrails contribute to warming. Even with these challenges, it is critical to develop approaches to reduce or eliminate warming due to AIC, as part of the broader action to address aviation's climate impact.

Recent studies have demonstrated that it is possible to develop contrail avoidance approaches optimizing the climate impact of short-lived climate forcers and fuel burn. A methodology to facilitate the avoidance of warming contrails with little fuel burn penalty, is another opportunity to reduce aviation's overall climate impact. Such a methodology could be combined with SAF and engine technologies to ensure reductions in both CO_2 and warming due to AIC. Therefore, the FAA is pursuing research to develop targeted approaches to predict and avoid warming contrails. As a part of this, ASCENT researchers will work to identify approaches and decision support tools that could be used by industry to cost-effectively mitigate the overall climate impacts of aviation via contrail mitigation.
FAA funded research is investigating the suitability of forecast meteorological conditions to predict the likelihood of persistent warming contrails one day ahead, a few hours before the flight, and in real-time during a flight. Using the evaluated meteorological fields, the FAA intends to fund development of a tool that will predict warming contrails, which when combined with flight-routing optimizations, can be used to avoid the formation of warming contrails with little or no fuel burn penalty. The performance of such a tool will be evaluated with contrails identified using the satellite data globally. The FAA will also support aircraft flight measurements of contrails and industry partners to evaluate and validate the performance of the tool such that the tool can be used more widely.

The FAA intends to collaborate with NASA, the National Oceanic and Atmospheric Administration, DOE, DOD, and other government agencies and industry stakeholders on various components of this research including evaluation of numerical weather prediction models, satellite data evaluation, aircraft campaigns, and validation methodologies. Such a comprehensive approach will be necessary to improve confidence in the usability and efficacy of this decision support tool for operational contrail mitigation.

8. Policies and Measures to Close the Gap

The Aviation sector is a challenge to decarbonize. The use of robust offsets including carbon capture can support the sector's goals by leveraging emissions reductions elsewhere.

Background/Context

Getting the entire U.S. aviation sector on a trajectory toward net-zero emissions by 2050 will require a suite of policies to incentivize innovation, deployment, and implementation, as well as competition to lower the costs of the changes that will be needed. In principle, it is possible to develop and deploy SAFs that have zero life cycle emissions. However, it is not assured that these fuels can be produced in sufficient quantity—and used at 100% blends in the aircraft—to power all of U.S. aviation entirely by zero-life cycle SAF by 2050. That's why, with a view to closing the emissions gap and enabling us to meet our 2050 goal, the United States is examining a broad range of options, including reductions that come from outside the aviation sector, such as processes that capture and sequester atmospheric CO_2. CORSIA provides a limited amount of access to such options to help close the gap for U.S. aviation emissions from international flights; these types of options could also be considered to help close the gap for emissions from domestic flights. In doing so, it will be essential to ensure environmental effectiveness, transparency, durability, and accountability.

Summary of Actions:

- Examine policy options that incentivize innovations in low-emissions aviation, including new and breakthrough technologies.
- Examine policy options that help close the gap for emissions from domestic flights, by providing access to and use of emission reductions that come from outside the sector.

Current Activity:

The aviation industry has a built-in incentive to improve the efficiency of fuel use, since aviation fuel costs money. As Figure 8 illustrates, the industry has steadily moved more people per unit of fuel use over the last three decades.

Notwithstanding these improvements in the efficiency of flight, there are few if any incentives currently to drive down total emissions. While many U.S. airlines use carbon offsets, or invite their customers to use carbon offsets, on a voluntary basis, these efforts are generally not harmonized across industry, and there are no broadly applicable standards to ensure accurate accounting and avoid double-counting and double-claiming within and across sectors. Globally, CORSIA has established specific criteria and requirements aimed at ensuring the environmental credibility of offsets used to show compliance with CORSIA obligations. While CORSIA addresses only the CO_2 emissions of flights between countries, it could provide a reference for potential policies and programs to help close the emissions gap for flights within the United States.

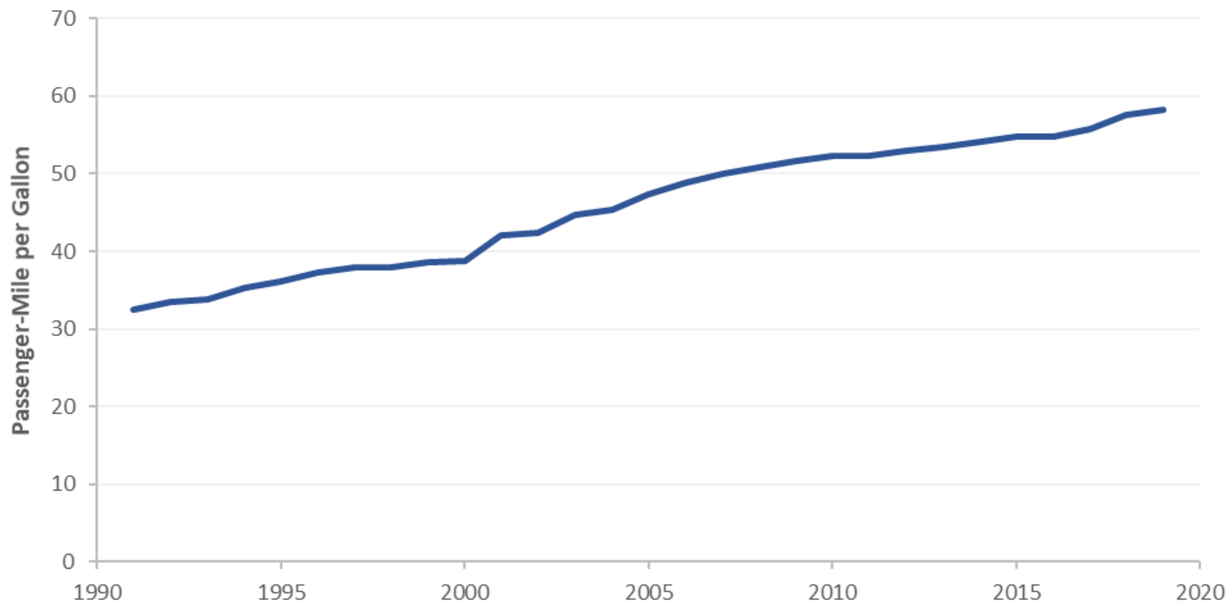

Figure 8. Historical trend in fuel burn for new jet aircraft (1990-2019).[33]

Proposed Actions

The United States has established a goal of net-zero emissions for U.S. aviation by 2050, recognizing that a whole-of-government approach is crucial to the achievement of that goal, and also recognizing that no single approach—aircraft technologies, operations, or SAF—will be sufficient to achieve it. With a view to closing the emissions gap, the United States will undertake extensive consultations with stakeholders on options for policies and programs and will assess existing legal authorities with a view to advancing additional tools in support of the goal.

In Conclusion

The United States is committed to making significant efforts to achieve the ambitious climate goals in this Aviation Climate Action Plan. Working in partnership with the U.S. aviation, agriculture, and energy industries, these goals are achievable, and will result in significant progress in addressing aviation's climate impact. Through this effort, we will drive innovation in aviation technologies, further streamline operations, and spur a massive increase in SAF deployment with a corresponding increase in the U.S. economic benefits and jobs. The United States looks forward to this challenge and will leverage the resources necessary to carry out the actions throughout this plan.

[33] U.S. Department of Transportation – Bureau of Transportation Statistics, Air Carrier Summary Data, Form 41 and 298C Schedule T2 for 1991-2019 (July 29, 2019). *Available at:* http://www.transtats.bts.gov/.

Appendix: Glossary of Terms

AAVP	Advanced Air Vehicles Program	NASA program to study, evaluate, and develop technologies and capabilities for future aircraft systems with a focus on fuel burn, noise, emissions, and safety.
ADS-B	Automatic Dependent Surveillance – Broadcast	Aircraft surveillance technology using satellite/GPS technology instead of radar to identify and monitor aircraft.
AIC	Aviation Induced Cloudiness	Clouds induced by aviation activity that includes contrails.
AOSP	Airspace Operations and Safety Program	NASA program to study, evaluate, and develop ATM and aircraft technologies to enable NextGen advanced automation and safety tools.
ATM	Air Traffic Management	Agencies and systems supporting safe, efficient, and orderly navigation of airports and airspace by aircraft (e.g., air traffic control and flow/capacity management).
CAAFI	Commercial Aviation Alternative Fuels Initiative	Coalition of airlines, aircraft and engine manufacturers, energy producers, researchers, international participants, and USG agencies working to develop and deploy alternative jet fuels for commercial aviation.
CANSO	Civil Air Navigation Services Organization	Representative body of air navigation service provider companies and agencies, assisting with the development of policies in regulatory and industry bodies.
CLEEN	Continuous Lower Energy, Emissions, and Noise	Public-private partnership administered by the FAA in cooperation with the aviation industry to develop certifiable aircraft and engine technologies that improve fuel efficiency and reduce noise and emissions.
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation	Market-based mechanism developed by ICAO to help the international aviation industry reach its goal of carbon neutral growth after 2020.
DOD	Department of Defense	Executive department of the USG charged with coordinating and supervising all military agencies and functions of the USG.

DOE	Department of Energy	Cabinet-level department of the USG with responsibilities including energy security, conservation, environmental impact, and production.
DOT	Department of Transportation	Cabinet-level department of the USG concerned with transportation, including the FAA.
EPA	Environmental Protection Agency	Independent executive agency of the US federal government tasked with environmental research and regulation.
FAA	Federal Aviation Administration	Agency of the USG regulating all aspects of civil aviation, including ATM, regulations/standards, personnel, airports and aviation research.
GGE	Gasoline-Gallon Equivalents	Amount of alternative fuel containing the equivalent energy of one liquid gallon of gasoline.
GHG	Greenhouse Gas	Gas that absorbs and emits radiant energy within the thermal infrared range, causing the greenhouse effect.
IASP	Integrated Aviation Systems Program	NASA program to mature advanced aeronautics technology through systems-oriented flight test and integrated development.
ICAO	International Civil Aviation Organization	Agency of the United Nations supporting regulatory development and standardization for international civil aviation.
NAS	National Airspace System	Collective term for the technology, systems, regulations, and infrastructure for aviation in the United States (e.g., airports, navigational aids, ATM infrastructure, and support personnel).
NASA	National Aeronautics and Space Administration	Independent agency of the US federal government responsible for the civilian space program, aeronautics research, and space research.
NextGen	Next Generation Air Transportation System	FAA modernization program for the NAS, including infrastructure and ATM technologies.
NO_X	Nitrogen Oxides	Nitrogen oxide (NO) and nitrogen dioxide (NO_2) gases, which are a component of aircraft engine exhaust.
nvPM	Non-volatile particulate matters	Aerosol pollutants that are found in aircraft exhaust. Sometimes referred to as soot or black carbon.
OEM	Original Equipment Manufacturer	Manufacturers and suppliers of physical hardware employed in the NAS, including aircraft and ATM hardware.

PBN	Performance Based Navigation	Aircraft navigation procedures with specifications requiring accuracy, integrity, availability, continuity, and functionality capabilities.
SAF	Sustainable Aviation Fuels	Liquid hydrocarbon fuels created from renewable or waste feedstocks that are fully fungible with existing fuel supply infrastructure, engines, and aircraft. For purposes of this this action plan and U.S. policy, SAF reduce life cycle GHG emissions by at least 50% relative to conventional jet fuel.
SARP	Standards and Recommended Practices	International regulatory guidance documents to facilitate standardized state-level regulatory development.
SFNP	Sustainable Flight National Partnership	NASA program to support development of next-generation narrow body aircraft through technology development and integrated system testing.
TACP	Transformative Aeronautics Concept Program	NASA program to provide research and testing resources to enable development of technologies for aviation transformation.
TBO	Trajectory-Based Operations	ATM concept that enhances strategic planning and flow management in the NAS through advanced time-based traffic management and PBN route definitions.
TRL	Technology Readiness Level	Nine-level scale developed by NASA to estimate the level of maturity of a technology from basic research through full integrated system operation.
USDA	United States Department of Agriculture	Executive department of the USG charged with regulating activities related to farming and food, including production of feedstocks used to manufacture certain SAF products.
USG	United States Government	Collective term for agencies and entities within the U.S. Government.
VALE	Voluntary Airport Low Emissions	FAA program to encourage and support airport modernization and environmental impact reduction through increased electrification and enhanced monitoring.
ZEV	Zero-Emission Vehicle	A vehicle that does not emit exhaust gas or other pollutants from the onboard source of power.