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Sustainable Product Life Cycle

Boeing increasingly looks at every stage of the product life cycle through a sustainability lens

We continue to evolve our approach so that our next generation of products consider the full breadth of sustainability including environmental, health, safety and human factors improvements by targeting the following seven areas:



Demand/Sales. Customers continue to demand higher-efficiency, lower emissions products. Globally, airlines and governments are increasingly accountable to emerging sustainability standards, which requires that they evaluate the life cycle of aircraft they operate.

Cascade: Boeing’s data modeling and visualization tool quantifies the potential of four strategies to cut emissions, including fleet renewal, operational efficiency, renewable energy and future aircraft introduction.

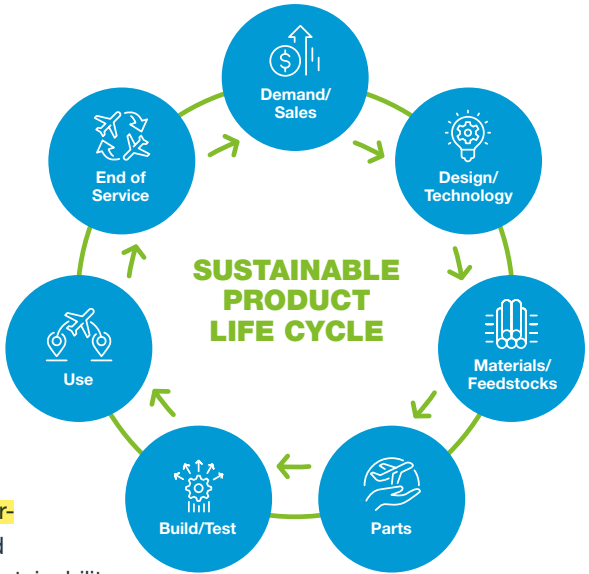


Design/Technology. Boeing evaluates new product designs and technologies to determine if they are safe and sustainable by conducting an environmental life cycle assessment. We strive to evaluate new aircraft design concepts, materials and technologies early in the development process to assess how much we can reduce the risks and expenses associated with its environmental footprint. We aim to examine whether more sustainable approaches exist for new product design, considering everything from selecting materials and parts to improving manufacturing processes and in-service operations to recycling the plane.

SAF-Compatible Commercial Airplanes: Boeing is collaborating with suppliers to achieve our goal that all commercial airplanes we deliver by 2030 will be compatible with SAF.



Materials/Feedstocks. Boeing examines coatings that improve our planes’ aerodynamics, fuel efficiency and longevity, in part by using more parts that can be repurposed. Lighter composite materials permit us to design more fuel-efficient aircraft like our primarily composite 787 Dreamliner. Boeing simultaneously supports research into regenerative feedstocks that can replace constituents that are nonrenewable resources. For example, the bio-based regenerative feedstocks from forestry waste and pine root oil that we are researching at Villanova University may one day be integrated into the epoxy resins used in our interior parts, enabling us to reduce the feedstock-related emissions from extraction and refining compared to petrochemical-based feedstocks. Meantime, we recycle the metals used in manufacturing our aircraft back into our supply chain, reducing reliance on virgin materials.



“Across Boeing Defense, Space & Security, we believe that operational effectiveness and sustainability are two sides of the same coin. A more sustainable, lower cost, energy efficient defense enterprise is a more operationally effective one.

That’s why we have a history of partnering with our customers to pioneer the use of sustainable aviation fuels and are leveraging digital design and production to reduce our carbon footprint throughout the life cycle of our products”

Ted Colbert, president and CEO of Boeing Defense, Space & Security

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Parts. Boeing aims to reduce carbon emissions and waste from parts, components and systems procured from suppliers. We reduce carbon emissions from the movement of millions of airplane spare parts by consolidating shipments, eliminating single-use packaging and redesigning warehousing networks to regional hubs. In addition, we use additive manufacturing to 3D print some of our own parts. Doing so allows us to change the designs of some parts in a way that can lessen their environmental impact by creating lighter consolidated parts that use less raw material, fewer machining processes and leave less waste. [See Page 64 for more information.](#)

Supplier Collaboration: In 2021, Boeing co-founded an industry effort through the International Aerospace Environmental Group to establish a voluntary sectoral framework for ESG engagement, including assessment and awareness, throughout the aerospace manufacturing industry.

Used Serviceable Material Offerings: Boeing Service business provides access to recertified used parts from retired aircraft called used serviceable material.



Build/Test. Reducing waste from operations while boosting the use of renewable energy and digital technologies can help our manufacturing and other work sites reduce their environmental impact while building and testing a product. Boeing cuts waste to landfill, water, energy and hazardous chemicals. Read more about how we do so on [Page 52](#). For example, when testing aircraft, Boeing uses blended sustainable aviation fuels.

Sustainable Operations: Since 2020, Boeing has maintained workplace net-zero GHG emissions at manufacturing sites and other facilities (Scope 1 and Scope 2) and in its business travel (Scope 3, Category 6) by expanding conservation and renewable energy use while securing carefully selected, third-party-verified offsets for the remaining GHG emissions.

ecoDemonstrator: To accelerate innovation for current and future airplane sustainability, our 10-year-old ecoDemonstrator flying test bed program takes promising technologies out of a lab and tests them in an operational environment.



Use. Boeing provides solutions for customers to lower their carbon footprints while they are using our aircraft. For example, armed with real-time data, flight crews can make adjustments to optimize fuel use, and thus minimize the carbon footprint of each flight. Digital tools empower our airline customers to conserve fuel, track emissions and enhance their operations' overall efficiency, while defense customers can conserve fuel and lower emissions with platform-agnostic digital systems with maintenance, supply chain and flight planning recommendations based on analytics.

Government Services: As our tools ingest flight, maintenance and supply data, our analytics produce results that drive efficiency across the system. Read more on [Page 37](#).



End of Service. Up to 90 percent of the parts and materials in Boeing aircraft can be reused and recycled across aerospace and other industries. We manage and recertify used parts for aircraft, and engine platforms for our customers.

Remanufactured: Boeing remanufactures aircraft, such as the 115 AH-64D Apache for government customers, which includes upgrading configurations with the latest technology and keeping valuable materials in a closed loop.



Boeing Converted Freightier Fleet Renewal: Boeing's passenger-to-freighter programs provide airlines an economical way to replace less efficient, older-generation freighters with more efficient freighters created from repurposed passenger aircraft.

Innovation and Clean Technology

Our company and our industry recognize finding solutions to climate change as an urgent challenge of our time. We are united in our goal to ensure billions of passengers can continue to fly every year to connect with friends and family, discover new places and cultures, engage in commerce and care for those in need.

Achieving this objective requires a portfolio of innovative solutions and partnerships that allows our sector to decarbonize. We are focused on four key areas: fleet renewal, operational efficiency, renewable energy and advanced technology. In 2022 we set ambitious 2030 targets related to our products, and throughout this section we share progress toward those goals and essential partnerships that will help us achieve them.

More about the governance of this strategy can be found in the Approach & Governance Section on [Page 13](#) of this report.



Sharing Cascade at the opening of the Boeing Research & Technology Sustainability Research Center in Tokyo, CSO Chris Raymond explains how the modeling tool projects the multiple paths to net-zero carbon emissions for commercial aviation. (Boeing photo)

The Cascade effect

Boeing debuted The Boeing Cascade Climate Impact Model (Cascade) at the Farnborough International Airshow in 2022. This web application uses digital technical data pulled from across the world to visualize how introducing various sustainable aviation options would impact global emissions. Cascade uses life cycle modeling to accurately quantify how choices in the four key areas impact the atmospheric concentrations of carbon dioxide.

Cascade is a way to visualize the climate impact of global commercial aviation while creating scenarios to calculate what kind of positive impacts our levers to decarbonize aviation would have on carbon emissions: fleet renewal, operational efficiency, renewable energy and new aviation technologies like hybrid, electric or hydrogen airplanes.

Why it matters: It's a data-driven way for our stakeholders to make informed decisions about how to reach the commercial aviation industry's net-zero 2050 ambition.

[Learn more about Cascade](#)

“Cascade helps airline operators, industry partners and policymakers see when, where and how different energy carriers and life cycle emissions affect their sustainability goals. The tool shows how incremental changes can cut emissions in commercial aviation.”

Neil Titchener, program leader, Cascade



Neil Titchener, program leader, Cascade. (Boeing photo)

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Four Strategies to Advance Sustainable Aerospace Together



Fleet
Renewal



Operational
Efficiency



Renewable
Energy



Advanced
Technology

Cross-sector global partnerships required

Fleet Renewal

New airplanes provide significant efficiency gains — historically each generation reduces fuel use and emissions 15%-25%. Deploying the latest generation of airplanes is one of the most significant contributions to CO₂ emissions reduction available over the next decade. Boeing will continue to invest in efficiencies that reduce fuel use and carbon emissions. [More detail on the sustainability of Boeing's products can be found here.](#)



In December 2022, Boeing and United Airlines announced the carrier is investing in its future fleet with an order for 100 787 airplanes, with the option to purchase 100 more. The deal is the largest 787 Dreamliner order in Boeing's history. United is also purchasing 100 737 MAX jets. (Boeing photo)

New orders mean more efficient fleets

774 big things: In 2022, our customers ordered 774 new commercial aircraft. New airplanes provide significant efficiency gains — each generation has reduced fuel use and emissions by 15%-25%.

Why it matters: Deploying the latest generation of airplanes is one of the most significant contributions to reducing carbon emissions available over the next decade.

Research matters: The emissions reductions available today in our latest generation of aircraft are a direct result of Boeing committing a significant amount of its research and development investment to sustainable technologies, such as:

- The Advanced Technology Winglet on the 737 MAX that reduces drag and increases lift.
- Lightweight carbon-fiber composite material on the 787 that is 30% lighter than aluminum.
- Folding wingtips on the 777X that offer unconstrained wingspan and contribute to 5% greater aerodynamic efficiency.

Go deeper: Read about [our orders and deliveries here.](#)

“With this investment in its future fleet, the 737 MAX and 787 will help United accelerate its fleet modernization and global growth strategy. The Boeing team is honored by United's trust in our family of airplanes to connect people and transport cargo around the world for decades to come.”

Stan Deal, president and CEO of Boeing Commercial Airplanes

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Showing up, sustainably

Boeing’s newest and largest members of its 737 MAX and 777X airplane families flew to the 2022 Farnborough International Airshow on sustainable aviation fuel blended with conventional jet fuel at a 30/70 ratio, using the same SAF blend for their daily flying displays. The 737 MAX family leverages advanced aerodynamic design and highly efficient engines to reduce fuel use and emissions 20%, and the noise footprint is 50% less than the airplanes they replaced. The 777-9 will deliver 10% better fuel use, emissions and operating costs.

Videos:

- 777-9: [Watch it fly.](#)
- 737-10: [See efficient flight.](#)



Arriving at EAA AirVenture in Oshkosh, Wisconsin, on a 30/70 blend of SAF, the 2022 Boeing ecoDemonstrator provided tours to more than 5,000 show visitors and served as a beautiful backdrop for attendees celebrating WomenVenture day. Boeing sponsored EAA WomenVenture as it celebrated its 15th year of programming designed to encourage and support women in aviation. (Boeing photo)

Video: [Watch AirVenture in Oshkosh.](#)

Operational Efficiency

Safe, sustainable skies are the priority. Boeing continues to invest to ensure our aircraft have the latest equipment and services to support advanced procedures, and we also work with airlines, government customers, air navigation service providers and airports on efficiency improvements. These include procedures such as continuous descent approaches and equipment upgrades such as GPS-based navigation for more direct routings. We develop services to leverage data for fuel and flight efficiency, help customers optimize flight planning and provide pilots with real-time weather and traffic information.

“Boeing has multiple digital solutions available today and even more that are in development to help customers improve their fuel and flight efficiency while reducing carbon emissions.”

Stephanie Pope, president and CEO
of Boeing Global Services

Managing air traffic efficiently

Boeing works with governments, airports, airlines and air navigation service providers around the world on exploring new approaches to air traffic management (ATM).

Why it matters: Optimized ATM is a critical component needed to reach the commercial aviation industry’s net-zero ambition — collaboration on how to manage airspace more efficiently can reduce emissions by about 10%, according to EUROCONTROL.

Around the globe: ATM solutions designed to address specific, local and regional needs help airports and airlines operate more safely, quietly and sustainably:

- **China:** Boeing is supporting China’s Air Traffic Management Bureau in exploring a new approach to ATM called “EoR” — Established on Required Navigation Performance (RNP). It’s a separation standard for landing aircraft established by the ICAO, which enables safe separation on parallel runways through simultaneous RNP-equipped arrivals, while reducing fuel burn, greenhouse gas emissions and noise.
- **Europe:** Boeing is participating in seven new Single European ATM Research (SESAR) 3 Joint Undertaking research projects, renewing a 20-year-plus commitment to aircraft operational efficiency and air traffic management in Europe and paving the way to a future sustainable sky. The seven projects address critical areas for change, including emissions reduction, automation enabled by artificial intelligence, resilient ATM service provision, as well as the swift uptake of solutions for the integration of drones (U-space), urban air mobility, multimodality and reduced emissions operations. The partnership is a European undertaking between private and public sector partners to accelerate the delivery of the Digital European Sky through



Executive operations support assistant in EUROCONTROL’s Maastricht Upper Area Control Centre, which enables air traffic controllers to provide safe and efficient air traffic services. (EUROCONTROL photo)

research and innovation. To do so, it is harnessing, developing and accelerating the implementation of the most cutting-edge technological solutions to manage conventional aircraft, drones, air taxis and vehicles flying at higher altitudes.

- **India:** Boeing completed the development of a 10-year road map for Communication, Navigation and Surveillance/Air Traffic Management (CNS/ATM) for Airports Authority of India (AAI). Backed by the U.S. Trade and Development Agency, Boeing and AAI conducted an analysis across operational, environmental, regulatory, technological, safety and financial factors. The resulting road map focuses on improving airspace utilization and maintaining safe and efficient aircraft operations — helping to modernize the Indian National Airspace System with domestic traffic expected to double by the end of this decade.

The bottom line: Boeing will continue developing local and global partnerships within the aviation ecosystem, enabling exchange of expertise and technology to help build a safer and more sustainable future of flight.

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Celebrating a decade of paperless flight decks

The big picture: In the summer of 2012, Boeing’s Jeppesen FliteDeck Pro launched — the very first electronic flight bag (EFB) application to test what, at the time, felt revolutionary: pilots flying with digital charts and maps, free of paper binders. A decade later, the digital solutions revolution in aerospace continues to enable airlines to make impressive strides in operational efficiency and their sustainability targets.



Kubota Garden. Seattle (Boeing photo)



Numbers represent data from 2012 through August 2022.

Renewable Energy

Renewable energy can help reduce carbon emissions inside our operations and from our products and services. For our products, renewable energy can help reduce the carbon intensity of an energy powering our products, such as Sustainable Aviation Fuel (SAF), green hydrogen and batteries. Boeing believes SAF is a necessary lever to decarbonize aviation. However, it will take a “SAF and” approach and not a “SAF or” approach to support the commercial aviation industry’s ambition for net zero by 2050. As part of the “SAF and” approach, Boeing continues to advance the viability of other renewable energy carriers and their safe use on aircraft.

For additional information on SAF, please reference the [SAF Fact Sheet](#).

Creating a decarbonized solution in the UAE

When Boeing was invited to analyze a study that looked at developing SAF in the United Arab Emirates (UAE), the decision to participate was easy and will support the growth of SAF production in the region.

The “**Power-to-Liquids Roadmap**” report examines the financial, economic and environmental benefits of decarbonizing the country’s aviation industry with an emerging SAF technology.

Boeing’s role: The report was developed by the UAE Ministry of Energy and Infrastructure in collaboration with the World Economic Forum’s Clean Skies for Tomorrow Initiative. Boeing participated by offering expertise at the launch event, analyzing the findings and being an active member of the UAE’s SAF task force, which is led by the Ministry of Energy and Infrastructure and provides strategic guidance on a range of fuel options, including Power-to-Liquids (PtL), a type of SAF.

What is PtL? SAF requires careful attention to detail. There are several pathways to creating PtL (Power-to-Liquid) including the process where renewable electricity, CO₂ and water are synthesized into a liquid hydrocarbon, including jet fuel.



The Emirates flight test utilized 18 tons of SAF in one engine of a 777-300ER blended from two producers, Neste and Virent. The flight flew over the Dubai coastline for just over an hour. (Emirates photo)

Here’s how it’s made:

- Electricity is applied to the water (H₂O). The hydrogen is collected and the oxygen is set aside.
- The hydrogen is mixed with the carbon dioxide in a reactor until it matures.
- The liquid is removed from the reactor, which results in PtL jet fuel.

Resources needed: This PtL relies on two things in the UAE: tapping into the UAE’s abundant sources of renewable energy (intense sunshine and sustained winds), as well as its ability to capture carbon dioxide from the air or from point sources such as industrial waste gases.

PtL is considered a significant technology for the UAE to decarbonize aviation. Other

countries are also studying PtL to mature the technology and assess how this pathway may help them decarbonize.

The upshot: The UAE report shows that it would be ambitious but feasible for the country to produce as much as 11 million tons of PtL SAF by 2050 — equivalent to approximately 70% of national jet fuel consumption.

It’s all about partnerships: “We collaborate with policymakers across six continents to support the SAF value chain, including its supply, use, certification and life cycle,” said Mohammed Al Ghailani, Boeing’s sustainability lead for the Middle East and Africa. “We were thrilled to support the UAE’s ongoing research into developing a renewable fuel that would be suitable to the region.”

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Feedstocks and forces – Boeing’s work to scale up SAF around the world

Why it matters: Today, SAF is made from waste-based agricultural products and used cooking oil and reduces emissions by up to 80% compared to conventional jet fuel. Most is currently blended with fossil fuel. Boeing is working to make SAF more accessible to help deliver on its commitment that commercial airplanes will be compatible to fly on 100% SAF by 2030. SAF development and production deliver economic growth, provide energy security for countries and create jobs across multiple industries.

SAF sources and building scale: Boeing is researching, developing and advocating for SAF across the globe, working with the most sustainable feedstocks that are available.

- **Australia and New Zealand:** Boeing is working on a SAF road map, in partnership with the Commonwealth Scientific and Industrial Research Organisation (CSIRO), to help analyze the availability of sustainable feedstocks in the Asia-Pacific region, primarily focusing on Australia and New Zealand.
- **Brazil** is the second-largest biofuel producer globally. Boeing’s focus includes feedstocks that can be sourced sustainably, such as sugar cane, eucalyptus and other residual biomass options.
- **China** is planning to scale up SAF adoption and Boeing has partnered with Peking University to develop fundamental research meant to guide the industry in identifying promising SAF feedstocks and pathways.
- **Ethiopia:** Boeing supports a SAF e-learning and academic program in partnership with Roundtable for Sustainable Biomaterials (RSB). Boeing conducted a feasibility study on Carinata (Ethiopian mustard) as a feedstock for SAF production.

- **Europe:** Boeing’s technology office in Madrid participates in research and development activities with the Horizon Europe program to develop new pathways and to join consortia focused on energy transition for both small and large airports.
- **India:** In collaboration with World Economic Forum’s Clean Skies for Tomorrow initiative, India produced a road map detailing how to scale production and use of SAF, including feedstock analysis, production capacity and technological maturity.
- **Japan:** In August 2022, Boeing announced its new center focusing on sustainability and supporting a newly expanded cooperation agreement with Japan’s Ministry of Economy, Trade and Industry. Read more on our partnerships in Japan on [Page 45](#).
- **Middle East:** Boeing also participated in the Sustainable Bioenergy Research Consortium’s (SBRC) Seawater Energy and Agriculture System (SEAS), which is an integrated system of aquaculture, halo-agriculture and mangrove silviculture to produce SAF and seafood. The first airplane flight fueled with jet fuel produced through SBRC’s SEAS happened in January 2019.
- **Mexico:** Boeing is the only multinational company working with the Biojet Consortium, established in 2016 and is comprised of 14 research centers and companies that are exploring alternative aviation fuel supply chain in Mexico.
- **South Africa:** Since 2014, Boeing has been working with RSB and World Wildlife Fund-South Africa to help small-hold farmers to grow crops that produce SAF. Boeing is partnering with Stellenbosch University to deliver SAF e-learning.

- **UK:** Boeing is focused on supporting the creation of a policy, capital and innovation ecosystem in the UK to enable the Government’s Jet Zero Strategy commitment of having five plants in construction by 2025. Boeing was proud to be the founding partner of the Energy Innovation Centre at the University of Sheffield, which has since been selected as the home of the UK SAF clearing house.
- **U.S.:** Boeing focuses on SAF procurement, research and development, and promoting SAF commercial scale-up in the U.S. and around the globe. Boeing also recently announced the purchase of 5.6 million gallons of SAF for its commercial operations in 2023.



Dr. Alejandro Rios Galvan, director of the Sustainable Bioenergy Research Consortium at Khalifa University in Abu Dhabi, and Boeing’s SAF feedstock expert Onofre Andrade meet as partners at a solar energy plant in Masdar City — where low-carbon energy will be used to produce green hydrogen. (Boeing photo)