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Commercial Aviation and the Environment



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Air Travel and Sustainability

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Aviation's focus on environment is good for business and the planet

Commercial aviation is poised for tremendous growth, as technology and economic growth are making air travel more accessible to people around the world.

To meet this increasing demand, Boeing is designing and building more advanced products. Airlines are investing in more fuel-efficient airplanes, opening routes and improving service. And when aviation expands, it generates trade, tourism and further economic growth.

Boeing also understands that commercial aviation needs to grow sustainably. At Boeing, 75 percent of research and development funding supports greater environmental performance in our products, services and operations.

This investment helps meet aviation's environmental goals and its business needs. Simply put, using less fuel reduces greenhouse gas emissions and helps customer profitability at a time when jet fuel can account for more than 40 percent of an airline's operating budget.

Aviation has long been focused on efficiency, a trend that will continue. Airplanes today – which are 70 percent more efficient than Jet Age models – are far more efficient than most cars, trucks and many trains.

The 787 Dreamliner uses 20 percent less fuel than the airplane it replaces. Flying on the new 737 MAX will be comparable even to driving an electric car (see graphic).

Boeing continues to look for opportunities to improve sustainability through an airplane's life cycle, from design and production to flight operations and end-of-service recycling. That includes:

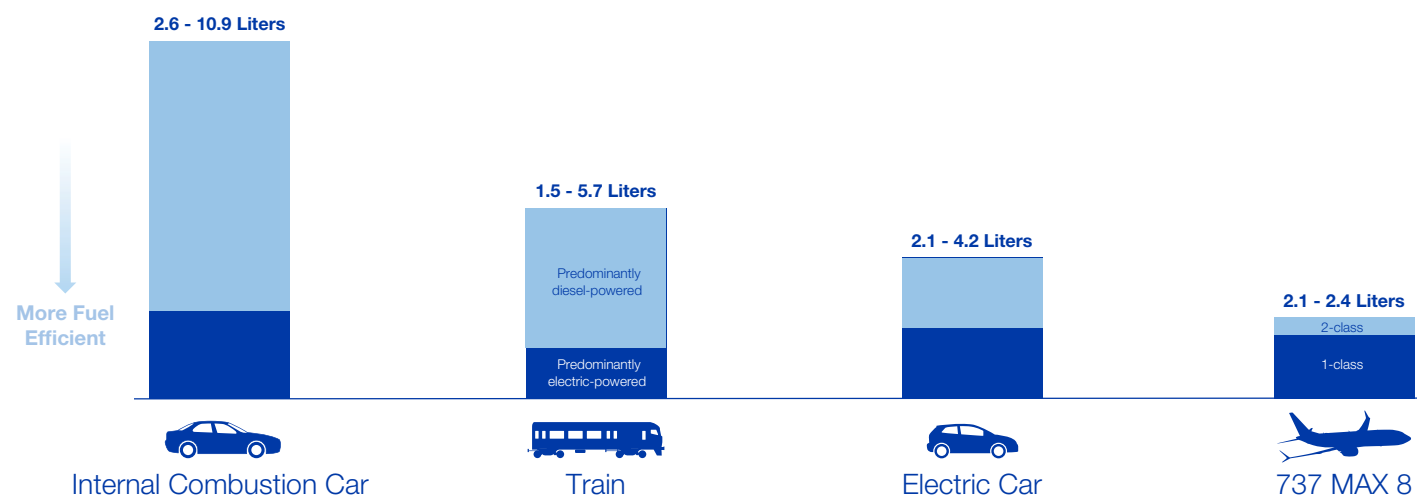
- » Bringing to market the world's most fuel-efficient airplane family – 737 MAX, 747-8, 787 and 777X – and services that improve gate-to-gate efficiency.
- » A Design for Environment philosophy that sets ambitious targets and embeds tools into the design process to improve Boeing airplanes' environmental performance.

- » Working with many stakeholders to advance our industry's environmental progress, including commercialization of sustainable aviation biofuel.
- » Investing in programs, such as the ecoDemonstrator, that accelerate testing and use of new technologies.
- » Aggressive goals to improve our facilities' environmental performance.

Today's airplanes are far more efficient than most cars and trucks - and this trend will continue.

Looking ahead, Boeing is committed to further our industry's environmental stewardship through continued innovation and global engagement. Our customers, industry, employees and communities deserve nothing less.

Air travel is fuel efficient



Equivalent liters of fuel per 100 passenger kilometers.

More Efficient Airplanes

Market leadership with the world's most fuel-efficient products

Boeing is providing the world's most efficient airplanes to serve our customers and help meet our industry's environmental goals.

When airplanes use less fuel, airlines reduce their costs and greenhouse-gas emissions. When airplanes are quieter, it reduces noise in local communities.

Looking to the future, Boeing is investing billions of dollars to design and build a new generation of products made with lighter materials, improved aerodynamics, more efficient engines and technologies that increase our customers' operational efficiency.

When airplanes use less fuel, airlines reduce their costs and greenhouse-gas emissions.

The 747-8 Intercontinental and Freighter are prime examples,

improving fuel efficiency – and reducing emissions – by 16 percent compared to the airplanes they replace. Today's Queen of the Skies features advanced engines, a new wing and advanced materials for better performance with a smaller environmental footprint.

The single-aisle 737 MAX will be the most fuel-efficient airplane in its class. With deliveries starting in 2017, this airplane's improved aerodynamics and engine efficiency will give the airplane an 8 percent per seat operating cost advantage over its competition.

The 737 MAX will be 14 percent

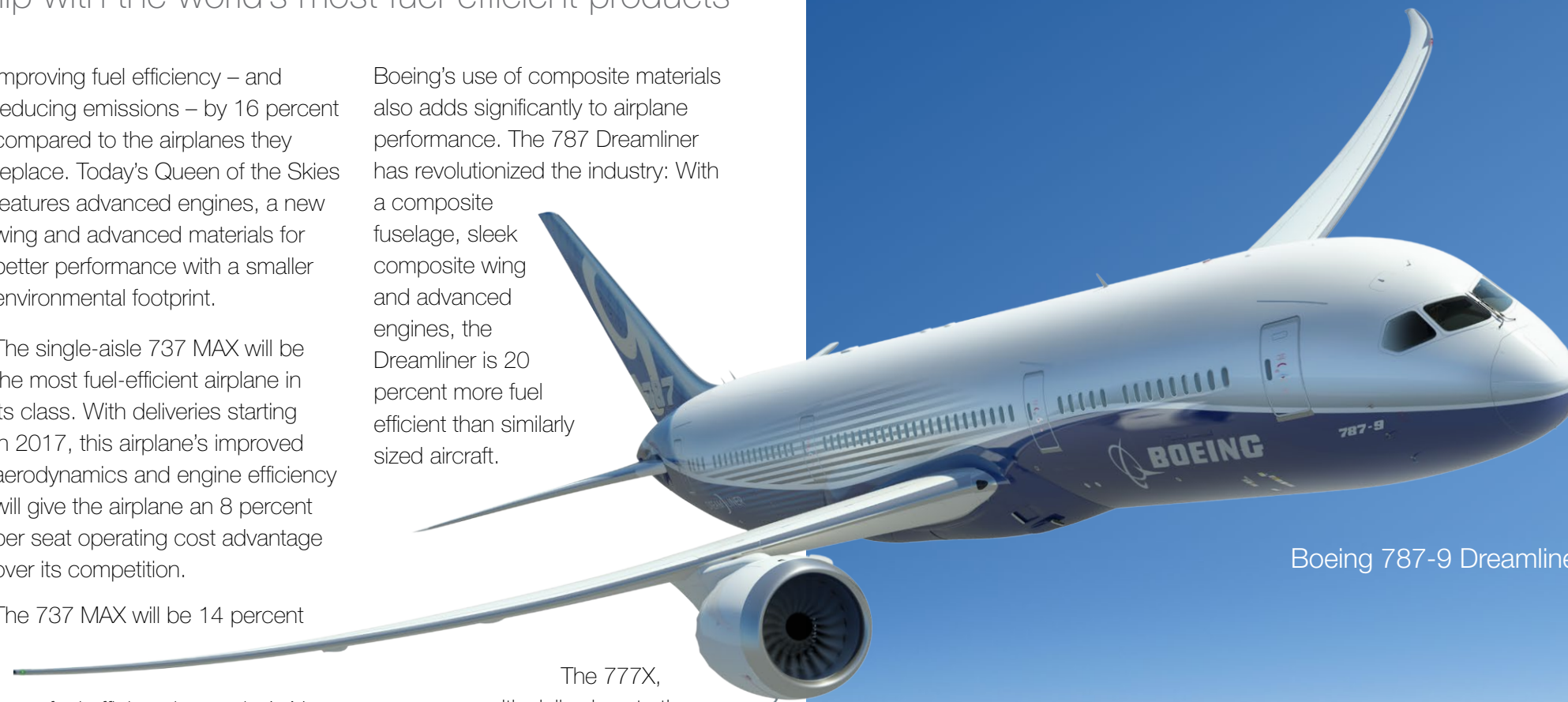
more fuel efficient than today's Next-Generation 737, with a 40 percent smaller community noise footprint.

Design updates, including Boeing's Advanced Technology winglet with natural laminar flow technology, are unique to Boeing and significantly enhance the aerodynamic efficiency of the 737.

Boeing's use of composite materials also adds significantly to airplane performance. The 787 Dreamliner has revolutionized the industry: With a composite fuselage, sleek composite wing and advanced engines, the Dreamliner is 20 percent more fuel efficient than similarly sized aircraft.

The 777X, with deliveries starting in 2020, will be the largest, most efficient twin-engine airplane in the world.

New engines and a composite wing design will ensure the 777X remains the most fuel-efficient commercial airplane in its category: 12 percent more efficient than its competitor.



Boeing 787-9 Dreamliner

Factory Efficiency

To meet a record-setting pace of airplane deliveries, Boeing and its employees continually look for ways to make factory production more efficient with Lean+ techniques. These processes drive quality into production, reduce cost and time and deliver significant environmental benefits, from reducing waste to saving energy. Here are some examples:

- » The efficient 737 line improved processes to ramp up from 31.5 airplanes per month in 2010 to 42 airplanes per month in 2014. At a Lean+ workshop, teams identified 15 major improvements in the 737 assembly.
- » To reach 47 airplanes a month in 2017, when the 737 MAX enters service, the 737 program is taking a Lean+ approach to reconfiguring existing floor space to add a third production line to Boeing's Renton, Wash., factory.
- » The 777 program produces 8.3 airplanes per month, up from 5 per month in 2010. Employees often contribute new ideas to eliminate rework and waste, improving safety, quality and flow time of 777 final assembly.
- » One team asked the company to develop a tool called a "paddle fitting jig" to help drill cleaner, straighter holes in hard-to-reach areas. The result: Angle-free, perfectly matched holes, faster production and savings of thousands of dollars per airplane.

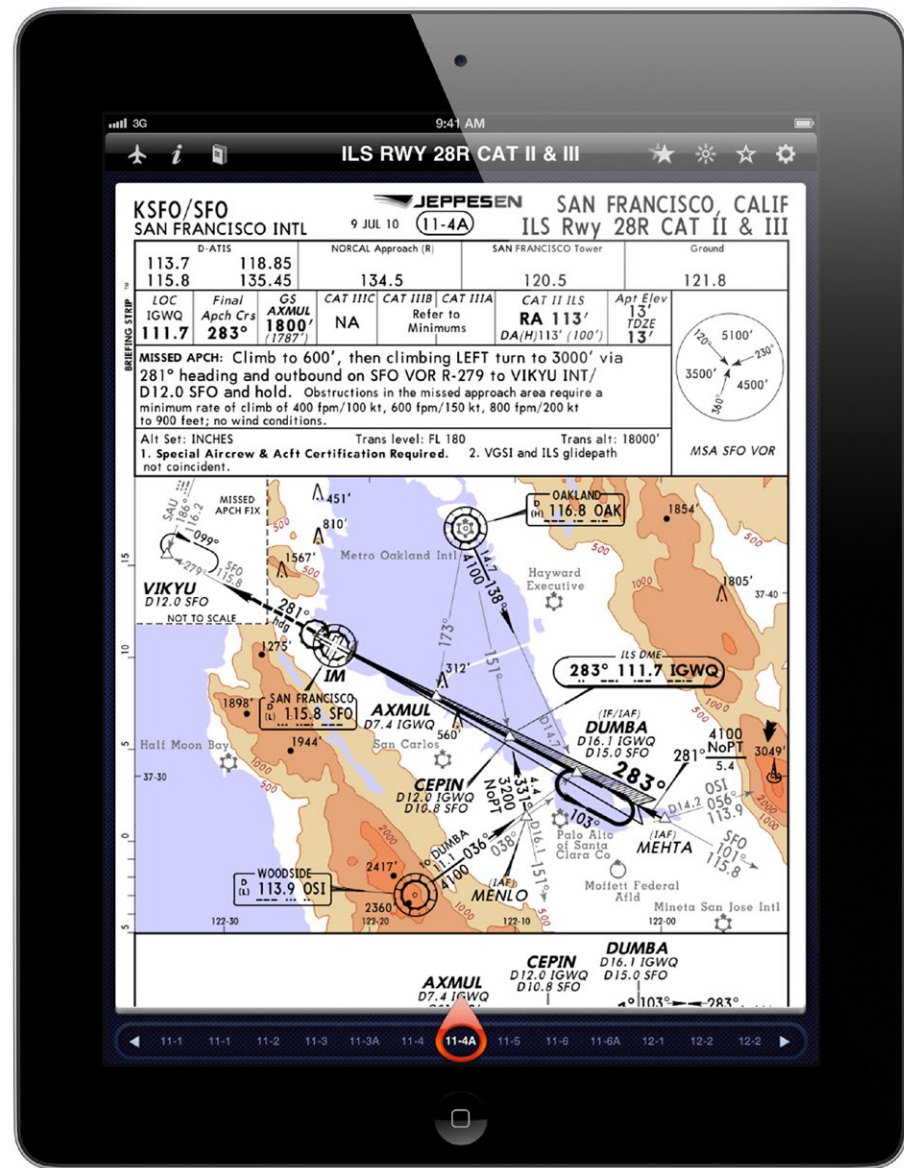
Reducing fuel consumption in today's fleet

To improve efficiency and reduce emissions for in-service airplanes, Boeing develops Performance Improvement Packages (PIP) that measurably reduce fuel consumption.

The PIP program was launched in 2008 when the price of oil reached \$150 a barrel, a serious threat to profitability in the airline business. Today, operators realize tremendous savings by multiplying Boeing's performance improvements across their existing fleets.

Examples include:

- » The 747-8 PIP increased efficiency by 1.8 percent with updates to the airplane's GENx-2B engines. These improvements mean that operators will use 30 fewer trucks of jet fuel per airplane per year.
- » The Next-Generation 737 PIP combined aerodynamic and engine performance improvements to reduce fuel consumption by up to 2 percent. This can save more than \$120,000 annually in fuel costs per airplane.



The Boeing Edge portfolio includes new digital products and data services for pilots on the flight deck.

Efficient Operations

Leveraging new technologies for gate-to-gate efficiency

To save fuel and time and reduce greenhouse-gas emissions from gate to gate, Boeing has developed valuable technologies that make flight operations more efficient and help address environmental regulations. Boeing is offering these technologies as part of the Boeing Edge, the company's portfolio of services that provide customers with a competitive advantage.

The results are tangible for airlines and the aviation industry. Trimming all flights by one minute would save airlines \$1.5 billion per year in fuel costs and reduce carbon dioxide emissions by 4.8 million tons (4.35 metric tons) annually, according to the International Air Transport Association.

The Boeing Edge portfolio includes new digital products and data services for pilots on the flight deck. With easy-to-read images and real-time data, these digital solutions reduce pilot workload, reduce fuel consumption and emissions, increase situational awareness and lower costs for operators.

One example is a mobile application developed by Jeppesen, a Boeing subsidiary, that replaces a pilot's paper charts, reducing weight by as much as 50 pounds per pilot. Others are the Boeing Fuel Dashboard and Boeing Emissions Reporter, which monitor fuel consumption, identify fuel savings opportunities and track and report carbon emissions.

Digital subscription services such as Wind Updates and Direct Routes allow pilots to make adjustments en route based on current weather and air traffic conditions.

Using Boeing-developed algorithms, these services support more efficient trajectory prediction during preflight and continuous optimization in flight by providing tailored information for flight crews and airplane flight management systems.

Boeing also works with customers to improve efficiency during landings. Boeing's Required Navigational Performance reduces noise and fuel use and improves accessibility to airports in challenging terrain.

Boeing continues to advocate for accelerating modernization of the global air traffic management system, which could boost efficiency for all airplanes flying by as much as 12 percent.

Boeing Edge digital solutions save fuel and time and reduce greenhouse-gas emissions and costs.

In countries and regions around the world, Boeing partners with governments, airlines, the International Civil Aviation Organization and other stakeholders to continuously improve system-wide efficiency, with a goal to reach 95 percent efficiency by 2025 and 98 percent efficiency by 2050.



Sustainable Aviation Biofuel

Significant progress toward a new fuel for aviation

Sustainability is key

Boeing biofuel projects meet broad goals for sustainability: Reducing net greenhouse-gas emissions, supporting socioeconomic development and avoiding adverse effects to local food security, fresh water and land use.

Regional biofuel efforts supported by Boeing utilize principles established by the globally recognized Roundtable on Sustainable Biomaterials (RSB) to evaluate sustainability based on several criteria. Advanced biofuel feedstocks are non-food crops that typically require less land and proportionately less fertilizer and water. They also are exponentially more efficient and more sustainable sources of energy than first-generation feedstocks.

Our current projects include:

- » In the U.A.E., Boeing partners with Etihad Airways to support research at Masdar Institute of Science and Technology on halophytes, desert plants that can be irrigated with seawater.
- » In Southern Africa and Southeast Asia, we work with airlines and RSB to expand ways for farmers with small plots of land to tap into demand for sustainable feedstocks.
- » In China, Boeing and the Commercial Aircraft Corp. of China (COMAC) collaborate to efficiently produce biofuel from waste cooking oil, also known as “gutter oil.”

Boeing is proud of its leadership role in working with partners around the world to develop sustainable aviation biofuel. Renewable jet fuel is essential to achieve commercial aviation’s environmental goals and reduce its reliance on petroleum.

When produced sustainably, aviation biofuel reduces carbon emissions by 50 to 80 percent compared with petroleum Jet A through its life cycle.

Since aviation biofuel was approved for commercial use in 2011, airlines have flown more than 1,500 flights with a blend of biofuel and fossil

fuel. Our industry’s challenge is to increase the global supply and bring down the price of biofuel to meet strong demand from airlines.

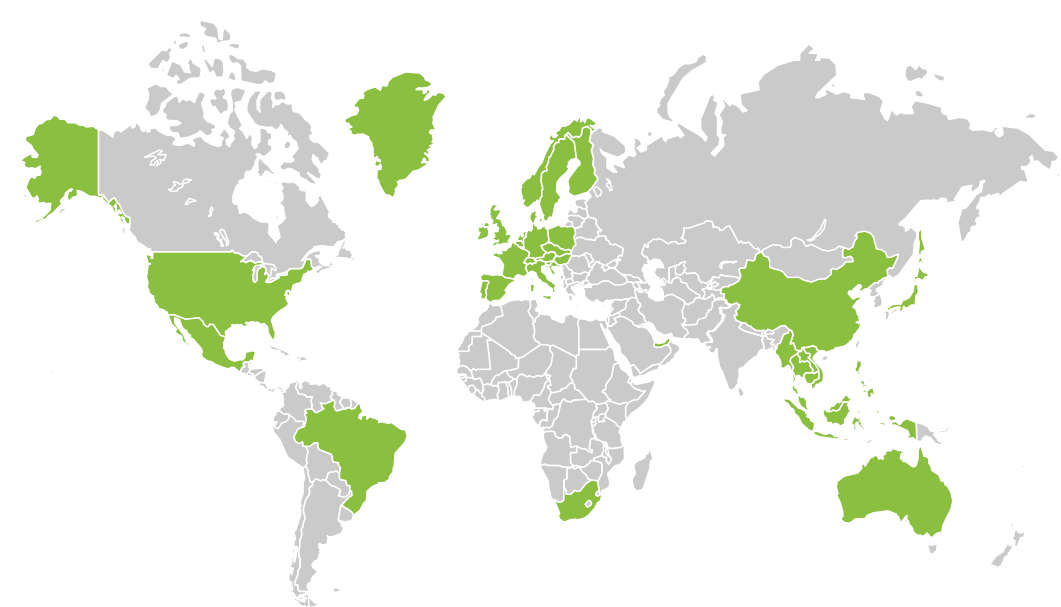
Boeing is committed to meet this challenge by collaborating with airlines, engine companies, governments, researchers and others to advance sustainable aviation biofuel supply chains around the world. Our company’s aggressive goal is that before 2016, the supply of sustainable aviation biofuel will address 1 percent – about 600 million gallons – of global jet fuel demand, leading to increased market acceptance and investment.

Boeing is focused on “drop in” biofuels that perform as well as or better than petroleum and can be blended directly with Jet A without changing airplanes, engines or the fueling infrastructure. Our projects also meet stringent standards for sustainability to ensure they support environmental and community goals (see sidebar).

Currently Boeing supports biofuel projects around the globe, including in Australia, Brazil, China, Europe, Japan, the Middle East, Southeast Asia, Southern Africa and the United States. These explore a wide variety of feedstocks, from used cooking oil and agricultural waste to algae, halophytes, camelina and jatropha, among others.

We also actively pursue approvals for new types of aviation biofuel. In a breakthrough that could rapidly expand supply for our industry, Boeing discovered that “green diesel,” a truck fuel made from oils and fats, is chemically similar to currently approved aviation biofuel.

With global production capacity of 800 million gallons, green diesel is price competitive with petroleum jet fuel, including government incentives. Boeing is now working with the U.S. Federal Aviation Administration and other key stakeholders to approve this fuel for use in commercial aviation.



Boeing collaborates with stakeholders around the world to develop sustainable aviation biofuel.

Sustainable aviation biofuel reduces CO₂ emissions by 50 to 80 percent compared to Jet A through its life cycle.



The Boeing ecoDemonstrator 787 Flight Test Airplane

Boeing ecoDemonstrator

Accelerating the testing and use of new technologies

The Boeing ecoDemonstrator Program is a great example of the company's investment to speed development of technologies that will make our aircraft cleaner, quieter and more fuel efficient.

Using ecoDemonstrator flight test airplanes – including a 737, 787 Dreamliner and 757 – Boeing works with key stakeholders to improve sustainability across an airplane's life cycle, from design and manufacturing to in-service operation and retirement. The ecoDemonstrator Program is testing a different suite of environmentally progressive technologies each year for the next several years (see graphic).

The program focuses on items that decrease fuel use, reduce noise, lower global and local emissions, improve in-flight operations and decrease the use of energy and other resources.

In this effort, Boeing partners with selected suppliers, airlines and government agencies, including

NASA and the U.S. Federal Aviation Administration's Continuous Lower Energy, Emissions and Noise (CLEEN) program. Our shared goal is to test, refine and complete technologies ranging from alternative energy sources to advanced components that directly improve fuel efficiency.

ecoDemonstrator speeds development of technologies that make our aircraft cleaner, quieter and more fuel efficient.

The ecoDemonstrator's inaugural flight in 2012 tested a range of innovations on an American Airlines Next-Generation 737-800. They included assessments of natural laminar flow, a technology that will be incorporated into the 737 MAX Advanced Technology Winglet

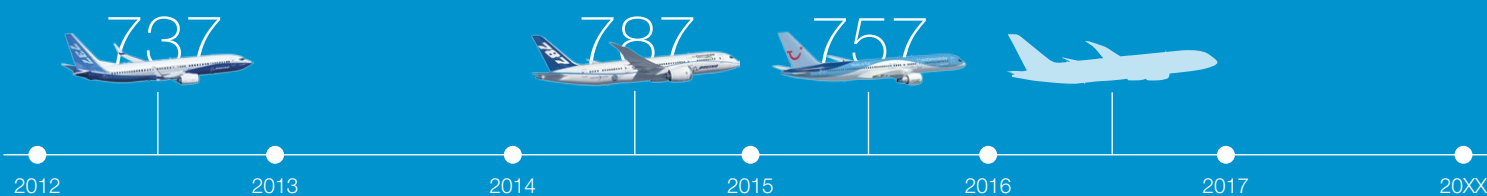
design to make this fuel-saving feature even more efficient.

The 2012 ecoDemonstrator also tested a regenerative hydrogen fuel cell to provide cabin power and advanced flight trajectory and in-flight planning software to enable more direct and efficient routes.

In 2014, a Boeing 787 will test a ceramic matrix composite nozzle on the engine that allows for higher combustion temperatures, leading to better fuel efficiency. The program will also sample greenhouse gases in the atmosphere during flight for later analysis.

Boeing's 757 ecoDemonstrator flight test airplane, which will take to the skies in 2015, has already completed initial testing of lightweight interior sidewall panels to reduce noise. The airplane will also assess an active flow control on the vertical tail aimed at reducing weight, a system to reduce environmental noise and wireless technologies that can reduce weight, fuel and power consumption on Boeing aircraft.

Improving sustainability through an airplane's life cycle



The Boeing ecoDemonstrator Program is testing a different suite of environmentally progressive technologies each year for the next several years.

Aircraft Recycling

Increasing opportunities to reduce waste after airplanes are retired

With airlines purchasing more fuel-efficient airplanes to reduce costs, Boeing has estimated that the industry will retire more than 8,000 aircraft from the current global fleet over the next decade. Ensuring that retired aircraft can be recycled and disassembled responsibly is a key element in Boeing's life cycle approach to environmental design.

We work with partners to expand the reuse of parts and materials in airplanes being retired today. We also work with industry and research institutions to develop technologies that will more efficiently recycle advanced carbon composites in a new generation of airplanes.

In 2006, Boeing was a founding partner of the Aircraft Fleet Recycling Association (AFRA). AFRA, the leading global organization focused on promoting environmental best practices for aircraft disassembly,

offers best-practice guides and accreditation for safe, sustainable aircraft dismantling and parts reuse.

Airplane carpet, which is replaced 20 to 30 times over an airplane's lifetime, is another focus area. To reduce waste sent to landfills and make it cheaper and easier for customers to replace soiled carpet, Boeing is testing nylon modular carpet tiles. They are easy to replace when needed and can be recycled into new carpet tiles.

Boeing wants to expand reuse of parts and materials in airplanes retired today and decades from now.

Boeing is also exploring methods to recycle composites in airplanes leaving service decades from now. This is important as we increase the use of composites in airplanes such as the 787, which is 50 percent composites by weight, and the 777X.

Recycled fiber is already used to make parts for cars and electronics and sports equipment. Our long-term goal is significant "closed loop" recycling of carbon fiber into aerospace industry parts.

Boeing cooperates with University of Nottingham in the United Kingdom, BMW, ORACLE TEAM USA and other partners to refine recycling processes. Boeing also looks for future opportunities to recycle composite scrap from 787 production. The Boeing ecoDemonstrator Program will test a wing access door made from recycled carbon fiber.

Boeing's long-term goal is significant "closed loop" recycling of carbon fiber into aerospace industry parts.

Boeing is accelerating improvements in environmental performance of the company's operations, even as our commercial production rates continue to grow. We are committed to zero growth in greenhouse-gas emissions, water use and solid waste to landfill through 2017, based on our history of performance.

Boeing is increasingly using sustainable energy sources and incorporating energy conservation into our operations.

- » Boeing relies on carbon-free hydroelectric and renewable energy sources for nearly half of total electricity consumption.
- » Carbon-free hydroelectric energy supplies more than 80 percent of the power for Boeing's Everett and Seattle facilities.
- » The 787 final assembly building in North Charleston, South Carolina, is powered by 100 percent renewable energy, sourced from 10 acres (4.05 hectares) of solar panels on the roof and coupled with renewable energy credits purchased from the local utility.
- » Since 2011, Boeing has earned the ENERGY STAR Partner of the Year award from the U.S. Environmental Protection Agency.

Improvements in Boeing's environmental performance are the result of innovative projects at facilities across the globe.

Boeing Commercial Airplanes delivery centers in Everett, Wash., and South Carolina have received Leadership in Energy and Environmental Design (LEED) Gold certification from the U.S. Green Building Council. In Salt Lake City, Utah, Boeing's LEED Silver-certified

Boeing is increasingly using sustainable energy sources and incorporating energy conservation into our operations.

paint facility for the 787-9 horizontal stabilizer is heated partially with solar energy collected by solar tubes on the building's roof. LEED standards include lower energy and water use, natural lighting and use of recyclable and locally sourced materials.

Employee involvement is crucial to achieving Boeing's environmental commitments. Among many examples, a team on the 787

program switched to rechargeable batteries in headlamps for their work sealing wing fuel tanks. The team now uses 400 rechargeable batteries a year – compared to 50,000 disposable batteries - reducing waste by 16,000 pounds (900 kilograms) annually.

Cleaner Operations

Sustainable energy sources, efficient buildings, employee involvement



The 787 final assembly building in South Carolina is powered by 100 percent renewable energy sources.