Innovative Solutions

Aerospace Technology and the Environment

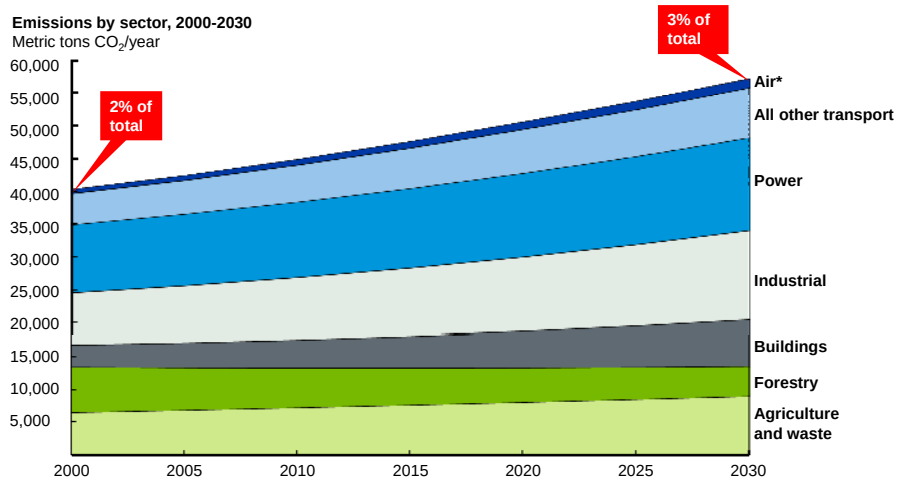
Dr. Matthew W. Ganz
Vice President/General Manager
Boeing Research & Technology

The Challenge

"Just as employees mastered "impossible" challenges like supersonic flight, stealth, space exploration and super-efficient composite airplanes, now we must focus our spirit of innovation and our resources on reducing greenhouse-gas emissions in our products and operations."

W. J. McNerney
Chairman, President and CEO
The Boeing Company

Aviation: 2% of Global CO_2 Emissions

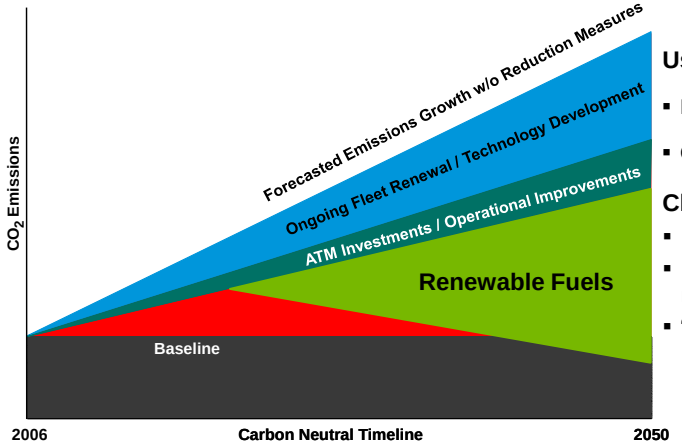


* Note: Aviation has warming impacts beyond CO_2 emissions, and the relative size and implications are still being debated

** Growth rate projections vary by source; for aviation, the range of emissions growth projections is 2.8% - 4.0%

Source: WBCSD Mobility 2030 model; IPCC

The Commercial Aviation Challenge
Carbon-Neutral Growth



Using less fuel

- Efficient airplanes
- Operational efficiency

Changing the fuel

- Lower lifecycle CO_2
- No infrastructure modifications
- "Sustainable Biofuels"

Presented to ICAO GIACC/3 February 2009 by Paul Steele on behalf of ACI, CANSO, IATA and ICCAIA

Sustainable Biofuels Enable Continued Growth

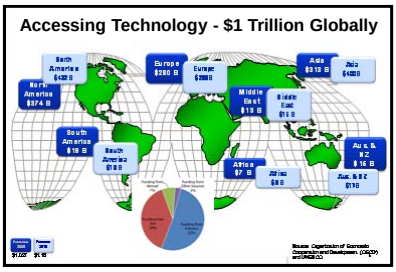
Technology Innovation

Innovation Throughout Our Product's Lifecycle

Leveraging the world's knowledge for technology innovation

Reducing Environmental Footprint of Global Supply Chain

- Leverage & integrate global technology sources
  - External Technical Affiliations
  - Collaborations
  - Universities
  - Global Research Centers
- Research and track the world's scientific and industrial communities to jointly improve the environment
  - Air Traffic Management
  - Bio Fuels
  - Propulsion Technology
  - Environmental Friendly Manufacturing



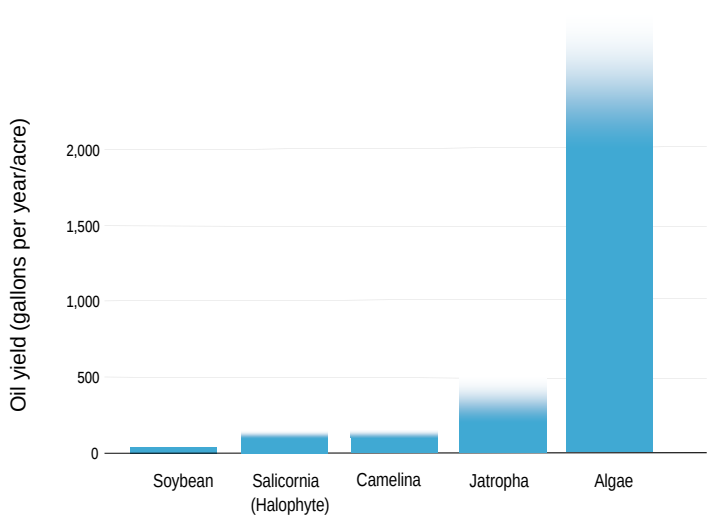
Partnering to proved energy solutions

Innovation Towards More Sustainable Fuels

Traditional Fuels: Fossil	1st Generation Biofuels	2nd Generation Biofuels
		
Opportunities		
• Significant supplies • Proven technology	• Steady supply • Public policy support	• Lower lifecycle CO_2 • Avoids "food for fuel" • Regional solutions
Challenges		
• Capital costs • Energy, water intensive • CCS tech. not mature	• Competes with food • Airplane compatibility	• Supply chain not mature • Costs near-term

We are focusing our efforts on sustainable biofuels

Boeing Is Focusing on High-Productivity Sustainable Biofuels



Near-term viable biofuels

Global Biofuel Development Activities

US/China Energy Cooperation Program, a public private partnership now includes Chinese partners with U.S. Companies including Boeing, United Technology, Honeywell, DuPont, Corning, Cummings and AECOM to complete and industry study, industry road mapping strategy and associated flight demonstration.

UAE's Sustainable Bio Energy Research Center, Boeing, the Masdar Institute, Etihad Airways and Honeywell's establish the Sustainable Bioenergy Research Project (SBRP), an innovative saltwater agricultural system to support the continued development of sustainable biofuel sources for aviation fuel.

Sustainable Aviation Fuel Users Group, a sustainable biofuels initiative, in partnership with airlines around the world — including European companies Air France, Cargolux, KLM, SAS and Virgin Atlantic Airways — with support and advice from the world's leading environmental organizations, the World Wildlife Fund (WWF) and Natural Resources Defense Council (NRDC).

Hydrogen as an Aviation Fuel

Manned Fuel Cell Aircraft

- Two Seat Aircraft
- Electronic motor
- Proton exchange membrane (PEM) fuel cell/Lithium-Ion hybrid system
- Zero carbon dioxide emission, very low noise
- Flown in Madrid, Spain

High Altitude Long Endurance Aircraft (HALE)

- Two Hydrogen internal combustion engines
  - Three-stage turbochargers
  - Two 8 ft diameter LH2 fuel tanks
- 4+ Days Endurance

Infrastructure, Volume, and Safety Remain Significant Challenges

Life Cycle Environmental Footprint Reduction

- **Minimizing manufacturing waste**
- **Conserving energy and water**
- **Reducing emissions**

Innovative Environmental Solutions

Boeing's 2012 Environmental Targets

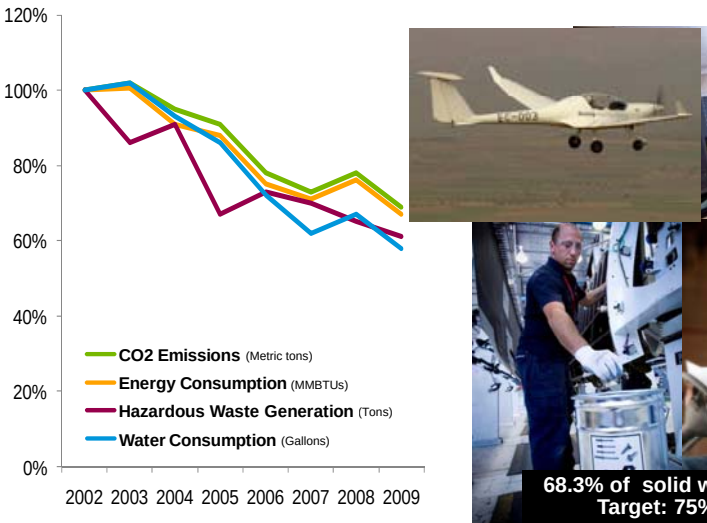
- **Energy consumption***
- **Greenhouse gas emissions***
- **Water consumption***
- **Hazardous waste***
- **Solid waste recycling**

25%
Improvement
Over 5 Years

*Revenue-adjusted basis

Outperformed Our 2009 Plan

Making Steady Progress
Smaller Environmental Footprint*



*Major U.S. facilities on revenue-adjusted basis

Life Cycle Environmental Footprint Reduction

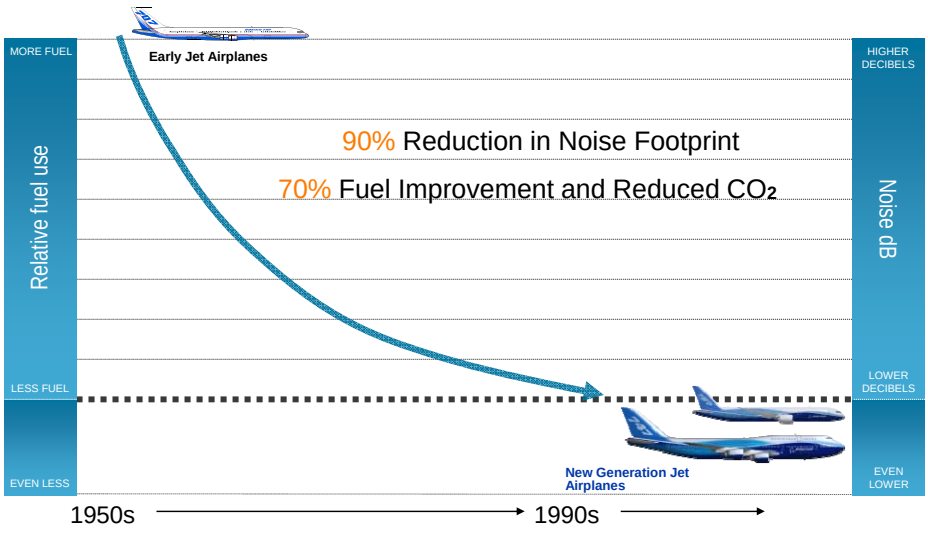
- Reducing emissions
- Minimizing noise
- Reducing fuel consumption

Design for Environment

New Technologies	Concept Development	Joint Definition	Detail Definition	In-production Improvements	Fleet Improvements

Providing the World's Emerging Technologies and
Embedding Environmental Considerations Early in Design Process

Track Record of Significant Progress



Noise footprint based on 85 dBa.

Improving New Airplanes In Service
Fuel Efficiency

787
- **20% more fuel efficient than airplanes it will replace**

747-8
- **16% more fuel efficient than airplanes it will replace**

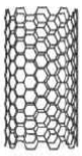
767/NewGen Tanker
- **5.5% more fuel efficient with addition of winglets**

777-200, -200ER and -300
- **1% more fuel efficient**

Next-Generation 737
- **2% more fuel efficient**

Each Gallon of Fuel Not Burned = 21 Pounds CO_2 Not Emitted

Developing Technologies to Reduce Fuel Consumption, Emissions and Noise



Researching next generation materials

Example: Next generation composites

Result: Reduces weight, which reduces fuel use and emissions

Designing aerodynamic improvements

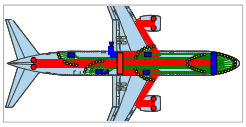
Example: Advanced wing design, raked wing tip

Result: Reduces drag which reduces fuel use and emissions

Researching improved propulsion systems

Example: Integrating new, more efficient engines

Result: Reduces fuel consumption and emissions and lowers noise



Researching less energy-intensive electric systems

Example: Reducing pneumatic systems

Result: Improving electrical efficiency improves fuel efficiency

Modernizing Air Traffic Management to Reduce Fuel Consumption and Emissions

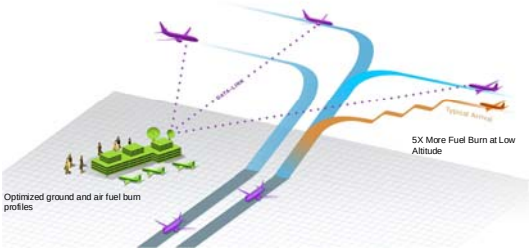
Boeing demonstrated improvements in U.S. Europe and Australia

- Optimizing flight paths
- Relieving system congestion
- Integrating ATM/airborne tech

PHOTO: AIR TRAFFIC CONTROL OF NETHERLANDS (LVNL)

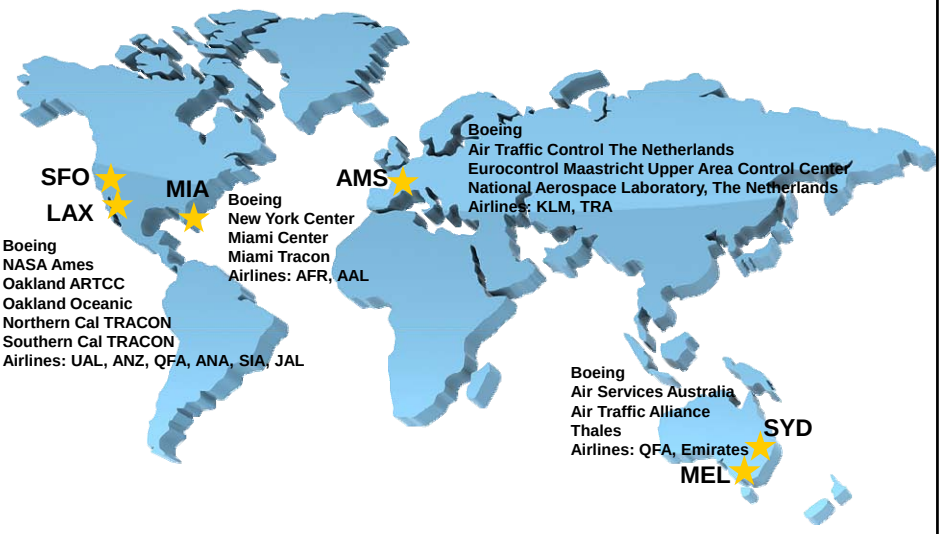
Collaborating to research and develop Next-Gen air traffic system

- **Airbus**
- **Cessna**
- **Honeywell**
- **Lockheed-Martin**



Up to 20% Fuel Savings from Optimized System

Boeing Tailored Arrivals Operational Trials



Life Cycle Environmental Footprint Reduction

Boeing Is Leading Industry Recycling

First Comprehensive Airplane Recycling Program

- **AFRA goal:**
  Certified members will recycle more than 90 percent of each end-of-service aircraft by 2012
- **Carbon-fiber recycling piloted at four Boeing sites in 2010**

AFRA member organizations have:

- Recycled more than 6,000 commercial aircraft
- Recycled more than 1,000 military aircraft
- Re-marketed approximately 2,000 airplanes

Carbon Fiber Composites Recycling
Today

Supply chain
- Materials Supply

Manufacturing
- Fly-away
- Excess scrap

Product

End-of-service

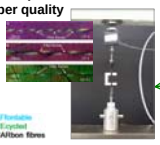
~35% to landfill

Waste
(disposal $)

Fiber reclamation technologies

Recyclate use for aerospace proof-of-concept applications

Testing to improve fiber quality



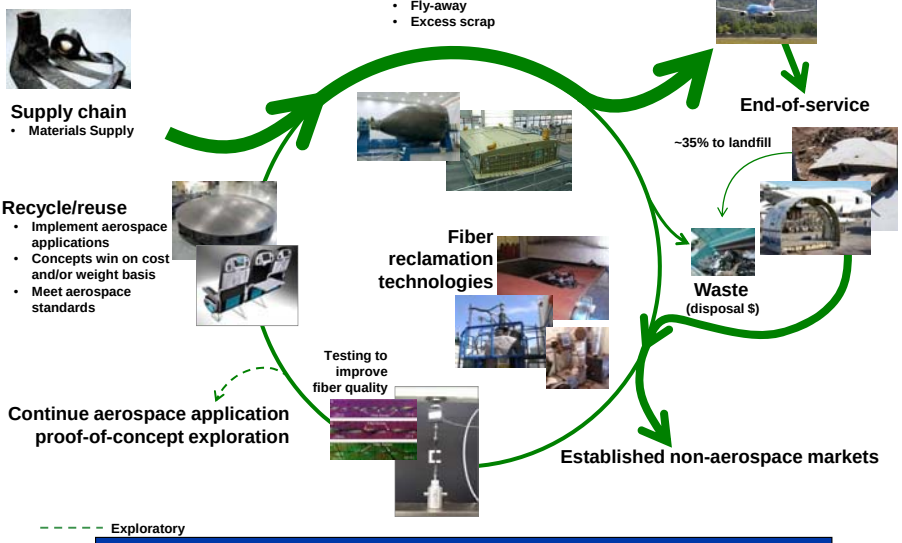
Develop recycled fiber market
- Initially lower tech manufacturing
- Demand will expand to higher-tech manufacturing
- Continually develop/improve material forms

Exploratory

Recycle more than 90% of each aircraft by 2016

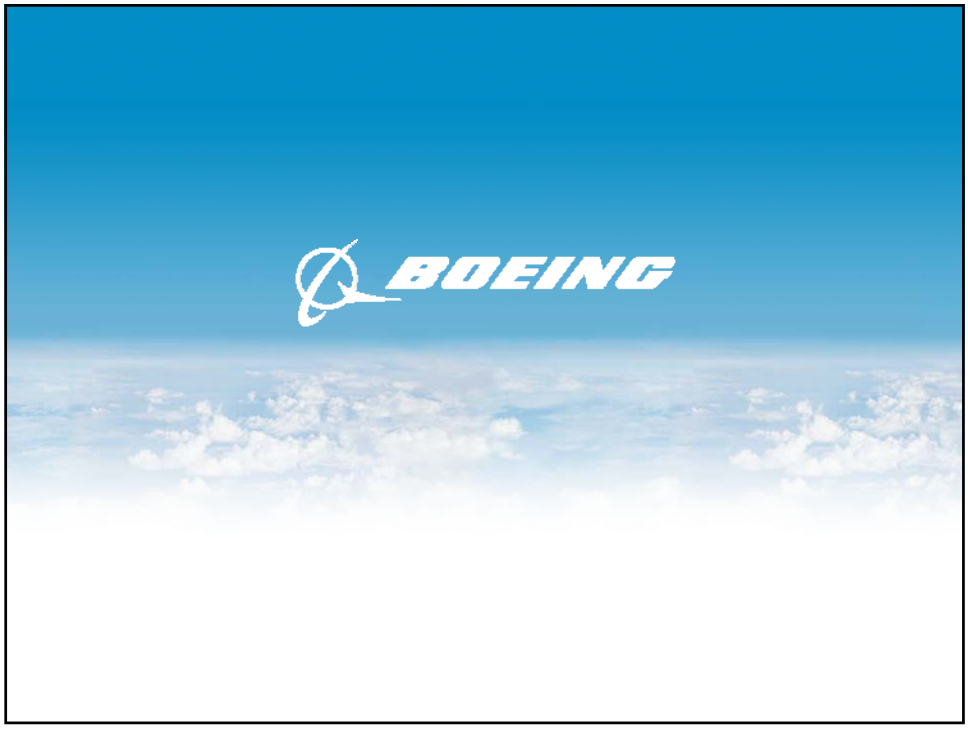
Carbon Fiber Composites Recycling
Tomorrow – Moving toward sustainability

AFRA Aircraft Fleet Recycling Association Accredited by AFRA



Recycle more than 90% of each aircraft by 2016

Technology Innovation Across the Lifecycle


BOEING