Aviation and the Environment

Jan Närlinge
President
Boeing Northern Europe

Denmark
17-18 November 2008
How can we most effectively minimize aviation's impact on the environment – specifically CO2 emissions?

Aviation is a prerequisite for today's civilization

- Trade, growth and prosperity
- Balancing of wealth – access to markets
- Peace & stability
- Democracy & cooperation
“Climate change and pollution are serious global concerns. Boeing has a clear strategy to protect our eco-system by pioneering environmentally progressive products and services and relentlessly improving our own environmental footprint.”

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

In Service
- Emissions
- Noise

Manufacturing
- Manufacturing waste
- Energy use
- Emissions

End of Service
- Resale
- Materials recovery
- Recycle
How can we most effectively minimize aviation's impact on the environment – specifically CO₂ emissions?

The principles that guide Boeing’s actions

- Technology unlocks the future
- CO₂ and fuel are the priority
- System efficiency is essential
- A global approach involves and benefits everyone
Our plan and commitments

Relentlessly pursue manufacturing and life cycle improvements

Improve performance of worldwide fleet operations

Deliver progressive new products and services

Pioneer new technology

100%

Develop ISO 14001 certification plan for 100% of Boeing manufacturing sites.

Maximize Lean and recycling.

25%

Focus on 25% efficiency improvements in worldwide fleet fuel use and CO₂ emissions by 2020.

15%

Improve CO₂ emissions and fuel efficiency by at least 15%

75%

Devote more than 75% of R&D toward benefiting environmental performance
Our plan and commitments

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Key frameworks that drive our manufacturing and life cycle improvements

An internationally recognized ISO 14001 standard to implement or improve environmental management systems

Lean

A set of progressive manufacturing principles and Lean practices to reduce environmental impact

A commitment to recycling during all phases of the airplane life cycle
ISO 14001 certification at all manufacturing sites

ISO 14001 certification schedule:

- 2004 – Exmouth, Australia
- 2006 – Everett, Washington
- 2007 – Portland, Oregon
- End of 2008 - All major BCA and IDS manufacturing sites

ISO 14001 is the internationally recognized standard
Lean+ Is a Natural Ally of the Environment

**Lean**: a systematic prevention of waste and sustained continuous improvements in our design and manufacturing processes.

Since 1999, Lean has enabled Boeing to achieve these reductions in 737 Airplane Program –

- 37% energy use
- 27% water
- 23% hazardous waste
- 24% acreage
- 41% factory size
- 52% power consumption
AFRA Goal:
Certified members will recycle more than 90 percent of each aircraft by 2012.

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

The first comprehensive airplane recycling program
AFRA recycles

Metals recycling

- More than 150 planes per year
- Boeing Current Market Outlook projects 7,200 planes will be scrapped between now and 2024
- Current scrapping rate:
  - 50% are 737/A320 size
  - 30% are 757/767/A330 size
  - 20% are 747/A340 size
- More than 1,800 tons aircraft specialty alloys per year (into high-grade manufacturing applications)
- More than 30,000 tons aircraft aluminum per year (mostly for automotive uses)
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Focus on 25% efficiency improvements in worldwide fleet fuel use and CO₂ emissions by 2020.
Improving the environmental performance of world wide fleet operations

Opportunities to reduce Fuel burn, Emissions and Noise

- **Airplane Improvements**: Airplane modifications for increased operational efficiency and environmental performance
- **Operational Efficiency**: Work with airlines to offer and implement integrated operational solutions; on the ground and in the air
- **Airspace Efficiency**: Collaborate with all stakeholders to optimize worldwide airspace navigation and efficiency
Airplane performance improvements are part of ongoing programs

737 Improvements
- Engine improvements lowering emissions
- Automated throttle control reduces takeoff noise footprint
- Increased precision navigation for operational efficiency
- Blended winglets for 3-5% aerodynamic efficiency
- Lighter weight carbon brakes
- Flight deck noise reduction

777 Improvements
- Wing modified to reduce drag
- Wing systems revision reduces drag
- New raked wingtip for improved aerodynamic efficiency
- Wing control surface tailoring reduces drag
- Engine inlet treatment for noise reduction
- Maneuver load alleviation for lower empty weight
Wing aerodynamics technology improves airplane efficiency

Efficient airplanes are also quieter

Good

Improvement in aerodynamic efficiency, %

Entry into service

737-200ADV

737-700

737-700 with winglets

Optional winglet

737-700 wing

737-300 wing

737-300
Current production airliners surpass future EU automotive emission objective

As specified, the future EU automotive standard is not defined on a per-occupant basis, so interpret 130 g / km applied to a four-passenger vehicle, having a load factor of 25% - the driver.

*130 g CO2/km for the average new car fleet by means of improvements in vehicle motor technology (http://eur-lex.europa.eu/LexUriServ/site/en/com/2007/com2007_0019en01.pdf)

Operational efficiency
Environmental performance improvements

Operational Performance
- Fuel efficiency consulting
- Maintenance Repair and Overhaul technology and procedures
- Flight planning optimization
- Airplane Health Management
- Required Navigational Performance (RNP)
- Electronic Flight Bag (EFB)

Materials Optimization
- Environmentally-certified parts
- Optimized parts distribution
- Waste-reduction and management

Customer Support and Training
- Maintenance manuals for fuel conservation
- Fuel conservation training
- Performance engineer training
Air space modernization will provide significant near-term benefits

Current situation:
Most air traffic systems are serving increased demand with outmoded technologies.
System congestion and delays waste fuel and increase emissions.

Vision for the future:
A next-generation air traffic system will enable more direct/efficient routing, and taxi routes and eliminate wasteful hold-times in the air.

“ATM enhancements could improve fuel efficiency and CO₂ emissions by up to 12%”
— IPCC

“Cutting flight times by a minute per flight on a global basis would save 4.8 million tons of CO₂ every year.”
— IATA
Technology and operational opportunities: advanced arrivals

**Continuous Decent Arrivals (CDA)**
- Idle descent on approach vs. traditional step down method
- Significant noise and fuel burn reduction

**3D Arrivals**
- Integrates RNAV/RNP procedures with advanced ATM automation tools
- Utilizes existing flight management systems
- Provides vectoring options for approaches

**Tailored Arrivals (TA)**
- Most beneficial flight path available (ideally idle descent)
- Integrates all known air traffic, airspace, meteorological, obstacle clearance and environmental constraints
### ATFM WEEKLY BRIEFING

**Week 20/2008**
**Ending Sunday 18 May 2008**


#### THIS WEEK RESUME

<table>
<thead>
<tr>
<th></th>
<th>DAILY AVERAGES</th>
<th>LAST YEAR VARIATION</th>
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</thead>
<tbody>
<tr>
<td>Traffic Demand</td>
<td>29,056</td>
<td>3.5 %</td>
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<tr>
<td>Regulated Flights</td>
<td>6,439</td>
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<tr>
<td>Delayed Traffic</td>
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<tr>
<td>Total ATFM Delay</td>
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<td><strong>29.0 %</strong></td>
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<tr>
<td>Avg Delay Per Flight</td>
<td>2.18 min</td>
<td>24.6 %</td>
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<tr>
<td>Avg Delay Per Delayed Flight</td>
<td>18.27 min</td>
<td>7.3 %</td>
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<tr>
<td>Total En Route Delay</td>
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<td>58.8 %</td>
</tr>
<tr>
<td>Avg En Route Delay Per Flight</td>
<td>1.42 min</td>
<td>53.4 %</td>
</tr>
</tbody>
</table>

**ATFM: >1050 hr delay/day - almost 132 work days**
Our plan and commitments

- Relentlessly pursue manufacturing and life cycle improvements
- Improve performance of worldwide fleet operations
- Deliver progressive new products and services
- Pioneer new technology

100% 25% 15% 75%

Improve CO₂ emissions and fuel efficiency by at least 15%
Building on a strong track record

Early Jet Airplanes

90% Reduction in Noise Footprint

70% Fuel Improvement and Reduced CO₂

Noise footprint based on 85 dBA.

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The 787 Dreamliner

Enhanced Flight Deck
Breakthrough passenger cabin
Advanced Wing Design
Innovative Systems Technologies
Composite Primary Structure
Large cargo capacity
Advanced Engines and Nacelles
Overhead crew rests

Cleaner, quieter and more efficient

20%* Reduction in fuel and CO₂
28% Below 2008 industry limits for NOₓ
60%* Smaller noise footprint

*Relative to the 767
The 747-8

Cleaner, quieter and more efficient

16%* Reduction in fuel and CO₂
28% Below 2008 industry limits for NOₓ
30%* Smaller noise footprint

*Relative to the 747-400
One of the most efficient modes of transportation in the world

7.0 Liters
SUV

1.5 – 4.3 Liters
Predominantly electric-powered
Train

3.1 – 4.3 Liters
Predominantly diesel-powered
Petrol Sedan
Car

2.3 – 3.6 Liters
3-class, low density
3-class, high density
787

- Computed per 100 passenger kilometers, assuming average modal load factors (1.6 passengers for SUV and cars, 38.7% for German diesel train, 70% for low density 787, 90% for high density 787 and 47.6% for electric trains). Load factor not available for U.S. train and based on total system wide energy consumption and passengers carried in 2000.
- CO₂ generated by each transportation mode converted to equivalent liters of diesel for comparative purposes.
- Electric trains are assumed to have typical electricity generation factors, reflecting a mix of fossil fuels, nuclear and hydroelectric sources.
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Devote more than 75% of R&D toward benefiting environmental performance
Actively pursuing technology research for fuel, CO2 and noise efficiency

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

Researching renewable energy source
- Example: The Boeing hydrogen Fuel Cell Demonstrator
- Result: Replaces conventional power plants reducing fuel use, noise and emissions
There are two significant aviation industry challenges

- Fuel price and availability
- Need to reduce life cycle greenhouse gas emissions

Source: 2008 average annual oil price forecasts as of Sept 2008 (Global Insight, EIA) and June 2008 (Moody’s, IATA)
Pursuing alternative fuels initiatives

The industry is pursuing different alternative fuels initiatives to address these challenges.
Types of alternative fuels

**Synthetic**
Gas, coal or other hydrocarbon resource

**Other**
Ethanol, methane, liquid hydrogen

**Biofuels**
Oil-based feedstock such as soy beans, algae, jatropha
Focus on Sustainability

Are all biofuels equal? What are the best and worst sources?
CO$_2$ mixes throughout the atmosphere, where it remains for approximately 100 years.

Regardless of where it is absorbed from the atmosphere, the entire world benefits from the reduction.
Plant-based feedstocks naturally remove CO2 from the atmosphere.

Petroleum releases CO₂ that has been locked underground.

Plant feedstocks re-absorb CO₂ emissions as they grow.

Petroleum-based fuel

Plant-based fuel
Biofuel feedstocks must come from sustainable practices

Global CO₂ emissions that cause global warming

- Petroleum: 31%
- Natural Gas: 15%
- Coal: 26%
- Deforestation: 25%
- Other: 3%


Slash and burn deforestation
Aviation: small – but still a contributor

Emissions by sector, 2000-2030
Mt CO₂/year

- Air
- Other transport
- Power
- Industrial
- Buildings
- Forestry
- Agriculture & waste

Source: McKinsey & Co. /WBCSD Mobility 2030 model; IPCC
Boeing is focusing on sustainable biofuels

Sustainable biofuels address industry challenges:

- **Oil price:** New technology enabling affordable fuel supply and new business models

- **Environmental impact:** Sustainable biofuels reduce life cycle emissions + more upside
Sustainability considers: environmental, economic and social impacts

- **Lower CO₂ lifecycle**
  - Petroleum-based fuel vs. Plant-based fuel
    - No CO₂ removed
    - CO₂ removed

- **Does not compete with food or promote deforestation**

- **Promotes local and regional solutions and economies**
Viable and sustainable feedstock alternatives

Viability is based on timing, technology and local resources
Jatropha is a sustainable and high-yield feedstock

- Does not compete with food production
- Reclaims marginal soils
- Is drought tolerant and has low water use (high water efficiency)
- Has low nutrient requirements
- Is an energy crop
- Grows seeds with high oil contents
- Provides high quality oil
Boeing is focusing on high-productivity sustainable biofuels

Near-term viable biofuels

<table>
<thead>
<tr>
<th>Plant</th>
<th>Oil Yield (gallons per year/acre)</th>
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<tbody>
<tr>
<td>Soybean</td>
<td>0</td>
</tr>
<tr>
<td>Salicornia</td>
<td>500</td>
</tr>
<tr>
<td>Jatropha</td>
<td>1,000</td>
</tr>
<tr>
<td>Euphorbia</td>
<td>1,500</td>
</tr>
<tr>
<td>Algae</td>
<td>2,000</td>
</tr>
</tbody>
</table>
Economically Viable

Economically viable biofuels will deliver sustainable aviation fuel
Sustainable biofuel is economically viable

Source: Energy Information Administration. Oil prices adjusted for inflation.
Commercialization
The business case for sustainable aviation biofuel
Sustainable biofuel supply chain overview

Commercial viability threshold requirements:

- Sustainability principles established
- Sustainability practices and auditing
- Technology/agronomy in place
- Fuel processing technology in place
- Viable feedstock and processing developers in place

Feedstock project
Biofuel processing project
Biofuel delivery infrastructure
Airline use
Technical and Fuel Requirements

Sustainable biofuels must provide near-term replacement solution
Sustainable biofuels are a drop-in solution

- Sustainable biofuels have equal energy content
- Sustainable biofuels perform as well or better than today’s Jet-A fuel
- Sustainable biofuels work in existing aviation structure
- Sustainable, scaleable and affordable processing methods exist

There are no apparent showstoppers
Sustainable biofuels work in existing aviation infrastructure

- Meets fuel performance requirements
- Requires NO change to airplanes or engines
- Requires NO change to infrastructure
- Can be mixed or alternated with Jet-A fuel
Certification
Boeing is driving an accelerated timeline
Certification should focus on fuel performance – not on processing methods.

Current specification

Amendment to current specification to include high-performing sustainable biofuels (synthetic paraffinic kerosenes)

Amended specification

Specification now includes high performing biofuels
Boeing and Biofuels
How and why is Boeing getting involved in biofuels?
Boeing is partnering to enable sustainable biofuel flight tests

Sustainable biofuel flight tests:

- Demonstrate technical feasibility
- Identify sustainable biofuel sources
- Promote the development of viable commercial markets
First flight test with sustainable biofuels for commercial aviation

February 2008
Summary of major initiatives

- Accelerated certification timeline
- Flight test program in progress
- Commercialization underway via User Group
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Boeing is actively pursuing solutions

Current Solutions
- Airplane programs

Near Term Solutions
- Air Traffic Management

Mid Term Solutions
- Sustainable biofuels

2008 2011 2015
Air New Zealand and Boeing Announce December Date for Sustainable Biofuels Test Flight
Partnership with Rolls-Royce and UOP highlights the path to fuel certification

SEATTLE, Nov. 11, 2008 -- Air New Zealand and Boeing [NYSE: BA] today announced Dec. 3 as the date for the airline's sustainable biofuels flight from Auckland using a 747-400 jetliner. Conducted in partnership with Rolls-Royce and UOP, a Honeywell company, one of the airplane's four Rolls-Royce RB211 engines will be powered in part using advanced generation biofuels derived from jatropha. Air New Zealand now becomes the first airline to use a commercially viable biofuel sourced using sustainability best practices.

Boeing, Air New Zealand and UOP have worked diligently with growers and project developer Terasol Energy to identify sustainable jatropha in adequate quantities to conduct thorough preflight testing. Using proprietary UOP fuel processing technology, the jatropha crude oil was successfully converted to biojet fuel, marking the world's first large-scale production run of a commercially viable and sustainable biofuel for aviation use.