Sustainable Aviation Biofuel Development

The Boeing Company builds some of the most advanced and environmentally progressive airplanes in the world, helping to make commercial aviation one of the most efficient modes of transportation. As part of its commitment to technological excellence and continually lessening aviation’s environmental impacts, Boeing is working closely with industry, academia, government and environmental organizations to accelerate the availability of low-carbon sustainable fuel sources.

- Goals and requirements for sustainable biofuel development are as follows:
  - Ideally, aviation biofuel must provide an environmental advantage over conventional petroleum fuels and be a drop-in replacement.
  - Production should be sustainable for years to come and provided social and economic benefit to the region where the crops are grown.
  - Potential plant sources must not compete with food or water resources or lead to land-use change.
  - It must meet aviation’s unique technical and safety requirements.

- When evaluating the technical requirements for commercial jet fuel they must meet the following criteria:
  - Have high energy content per unit weight and volume
  - Perform well in the harsh environment where commercial jets operate
  - Meet the demanding requirements for aircraft turbine engines
  - Meet all of the safety requirements for aviation

Where Boeing is focusing its efforts

Boeing and its industry colleagues are working to accelerate the availability of sustainable aviation biofuel because it presents a significant opportunity to effectively power the world’s commercial aircraft fleet in an environmentally responsible manner. In addition to offering greater socio-economic benefits, the bottom-line implications are increasingly promising. Thanks to new technologies, production costs per gallon are improving—bringing economic viability more clearly into view. As feedstock availability increases, production and end-product costs will decrease. And because the feedstocks are grown regionally, these new fuels have the potential to deliver entirely new supply chain models.

In a world where carbon has a high cost, a sustainable aviation fuel that moves the industry toward carbon-neutrality will be economically advantageous. Achieving this vision requires continued collaboration between governments, industry and financiers.
What’s the difference between first- and advanced generation biofuel?
First-generation biofuel is made from the sugars, starches, oils or fats of conventional agricultural products using conventional technologies. Corn and soybeans are examples of feedstocks used to produce first-generation biofuel. Advanced generation biofuel is derived from non-food crops utilizing new biomass-to-fuel-conversion technologies. Examples of feedstocks for advanced generation biofuel development include:

**Algae:** Simple, photosynthetic plants lacking leaves and roots
**Halophytes:** Salt water grasses and other saline habitat species
**Jatropha:** A widely distributed tropical plant featuring a high-oil-yield
**Switchgrass:** A hardy, drought-resistant grass
**Camelina:** An energy crop grown in rotation with dry wheat

What makes advanced generation biofuel more ideal?
First-generation biofuel feedstocks are inefficient and non-sustainable sources of energy. They typically require large landmasses and are food crops predominately grown for human consumption. Using these feedstocks to produce aviation biofuel creates a scenario where two different applications—food source and fuel source—compete against one another, effectively driving up food prices (especially in developing countries). This food-versus-fuel issue is primarily related to agricultural ethanol, and it is of lesser significance for agricultural related biodiesel. Since commercial passenger jets cannot use ethanol, the food displacement issue is primarily a concern for first-generation ground transport applications.

Conversely, advanced generation biofuel feedstocks are exponentially more efficient and sustainable sources of energy than their first-generation counterparts. They typically require far smaller landmasses and proportionately less fertilizer and water resources, and are non-food crops. This is why Boeing is focusing its low-carbon fuels development efforts on aviation biofuel derived from these next-generation fuel sources.

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November 2011
Boeing Environmental Communications, 206-766-2949
From algae-based aviation fuel to ground-based applications of solar technologies that power spacecraft, innovative Boeing designs are creating a cleaner future.
Creating a Better Future

Through our skilled and innovative workforce, we are making tremendous strides to improve the environmental performance of Boeing, of our products and of the global aerospace industry.

Environmental considerations drive our people and our business.

Our customers want more airplanes that can be operated and maintained using less fuel and fewer hazardous chemicals. Our investors want the increased productivity that comes from saving energy, conserving water and eliminating waste. Our neighbors want to ensure that we are protecting the environment. And the innovative people of Boeing, as we have always done in the past, are stepping up to this challenge.

For the past 95 years, Boeing has focused some of the best and brightest talent from around the world to develop that which rested only in the imagination of previous generations. As we look forward to our 100th anniversary as a company, we realize that pollution and climate change are serious challenges that require aggressive action. We also believe that, through our skilled and innovative workforce, we are making tremendous strides to improve the environmental performance of our company, our products and the global aerospace industry.

We are building the next generation of efficient aerospace products. We are pioneering the research into cleaner fuels. We are improving the efficiency of the global air traffic management system to reduce the global carbon footprint of air travel. And we are investing in bold, new technologies to create a brighter future.

At the same time, inside our own facilities, we are conserving energy, water and natural resources; this both improves our productivity and decreases Boeing’s environmental footprint. Since 2002, on a revenue-adjusted basis, Boeing has reduced carbon dioxide emissions by 28 percent, energy consumption by 30 percent, hazardous-waste generation by 44 percent and water intake by 41 percent.

Our newest facility in South Carolina demonstrates Boeing’s commitment to continuous environmental improvement. This site will send zero waste to landfills and be powered entirely with energy from renewable sources — including solar panels on the roof of the 787 Dreamliner final assembly building there.
### Summary of Environmental Performance (2007-2010)

<table>
<thead>
<tr>
<th></th>
<th>2007</th>
<th>2008*</th>
<th>2009</th>
<th>2010</th>
<th>% Improvement Absolute ('07-'10)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Revenue</strong> (U.S. dollars in millions)</td>
<td>$66,387</td>
<td>$60,909</td>
<td>$68,281</td>
<td>$64,306</td>
<td></td>
</tr>
<tr>
<td><strong>U.S. employment</strong> (year end)</td>
<td>159,313</td>
<td>162,191</td>
<td>157,073</td>
<td>160,537</td>
<td></td>
</tr>
<tr>
<td><strong>Energy consumption</strong> (in millions of MMBTUs or trillions of British Thermal Units)</td>
<td>12.95</td>
<td>12.68</td>
<td>12.64</td>
<td>12.24</td>
<td>5%</td>
</tr>
<tr>
<td><strong>CO₂ emissions</strong> (in millions of metric tons)</td>
<td>1.33</td>
<td>1.30</td>
<td>1.29</td>
<td>1.25</td>
<td>6%</td>
</tr>
<tr>
<td><strong>Water intake</strong> (in billions of U.S. gallons)</td>
<td>1.83</td>
<td>1.81</td>
<td>1.71</td>
<td>1.63</td>
<td>11%</td>
</tr>
<tr>
<td><strong>Hazardous waste</strong> (in thousands of U.S. tons generated)</td>
<td>8.99</td>
<td>7.71</td>
<td>8.15</td>
<td>6.94</td>
<td>23%</td>
</tr>
<tr>
<td><strong>Solid waste diverted from landfills</strong> (as a percentage of total non-hazardous solid waste generated)</td>
<td>58%</td>
<td>64%</td>
<td>68%</td>
<td>73%</td>
<td>26%</td>
</tr>
<tr>
<td><strong>Environmental fines</strong> (U.S. dollars in millions)</td>
<td>$0.472</td>
<td>$0.024</td>
<td>$0.028</td>
<td>$0.647</td>
<td></td>
</tr>
</tbody>
</table>

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At Boeing, we have challenged ourselves to make our products, services and operations ever more environmentally progressive. Boeing employees around the globe are embracing this challenge and making incredible strides to benefit our customers, our investors, our communities and our world. As we accelerate these environmental improvements, we continue to pursue new game-changing possibilities.

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Jim McNerney  
Chairman, President and Chief Executive Officer  
The Boeing Company

Mary Armstrong  
Vice President  
Boeing Environment, Health and Safety

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* 2008 data reflects reduced production as a result of a labor strike.

** Water intake data for 2007–2009 has been adjusted to reflect additional intake from a previously unrecorded water meter in Auburn, Wash., as well as a billing error in Everett, Wash.

*** Hazardous waste data for 2007–2009 has been restated to reflect the addition of Portland – PDX, a facility in Oregon used by Boeing to paint twin-aisle airplanes.

**** Majority of 2007 and 2010 fines relate to settlements for storm water permit violations at Santa Susana, Calif.
Pioneering Environmental Technologies

Boeing believes that climate change is a serious environmental challenge that requires credible action. Recognizing this, we are committed to reducing emissions of greenhouse gases from our facilities and products.

Reducing Our Footprint

At our operations in the United States, Boeing has set the following revenue-adjusted targets for the period between 2007 and 2012:

- 25% reduction in greenhouse gas emissions
- 25% reduction in energy consumption
- 25% reduction in water intake
- 25% reduction in hazardous-waste generation

In addition, we committed to increasing the amount of solid waste diverted from landfills to 75 percent, measured on an absolute basis, for the period between 2007 and 2012. Waste is diverted from landfills through a combination of recycling, composting and energy recovery programs.

Since establishing these targets, Boeing has announced increases in production rates for all commercial airplane models and added major new manufacturing operations. Although these changes put pressure on our ability to meet revenue-adjusted targets, Boeing continues to believe that we will be able to achieve an absolute reduction in our environmental footprint at the same time we increase our manufacturing production.

Improving Product Performance

Boeing is introducing enhancements to boost fuel efficiency and reduce CO$_2$ emissions of our entire product line of commercial airplanes. Starting in 2012, Boeing will begin flying an ecoDemonstrator 737 to accelerate the development of technologies in the areas of fuel efficiency, emissions and noise reduction.

Sustainable Biofuels

Boeing is focusing on sustainable aviation biofuels produced from renewable resources that do not compete with food crops for land or water. Since 2008, flight tests conducted by airlines and military operators with a variety of Boeing aircraft show that biofuels perform as well as or better than kerosene-based jet fuel.

We are bringing together agricultural interests, academic researchers, refiners and aerospace companies around the globe to establish local infrastructure needed to develop a sustainable and economically viable biofuels industry.
Efficient Air Transportation Systems
A modern global air traffic control system will rely on satellite-based navigation that takes advantage of the sophistication of airplane flight management systems. Boeing is leading an industry team to develop the Next-Generation Air Transportation System. Modernizing the global air traffic system is scheduled to be completed around 2025.

These improvements allow planes to fly more direct, use airspace more efficiently, minimize delays and employ more precise navigation capabilities. This can improve fuel efficiency by up to 12 percent with a corresponding reduction in CO\textsubscript{2} emissions.

Alternative Energy Solutions
Using the technology that powers satellites, Boeing subsidiary Spectrolab produces solar cells that can convert more than 40 percent of sunlight into electricity for use on Earth. Boeing also is demonstrating advanced aerospace and computing technology to help government customers and public utilities make electrical grids more secure and efficient, bring down energy costs and reduce waste.

In addition, we are researching innovative uses of fuel cells — which convert hydrogen into energy and water with zero emissions — for applications in aerospace and beyond. Boeing fuel cells lit up the red carpet at the 2010 Academy Awards in Hollywood, Calif.
Measuring Our Progress
Since 2002, Boeing has reduced carbon dioxide emissions and energy consumption by nearly one-third and cut water intake and hazardous-waste generation by more than 40 percent, as measured on a revenue-adjusted basis.

Data reported reflects environmental performance at the following core metric sites, which represents the vast majority of Boeing’s operating locations in the United States:

- **Alabama:** Huntsville
- **Arizona:** Mesa
- **California:** Anaheim; El Segundo; Huntington Beach; and Boeing Defense, Space & Security operations in Long Beach
- **Kansas:** Wichita (Boeing Defense, Space & Security operations only)
- **Missouri:** St. Charles and St. Louis
- **Oregon:** Portland
- **Pennsylvania:** Philadelphia
- **Texas:** Houston and San Antonio
- **Washington:** Auburn, Developmental Center, Everett, Frederickson, Kent Space Center, North Boeing Field/Plant 2 and Renton

### Solid Waste Diverted From Landfills

#### Solid Waste Diverted From Landfills at U.S. Sites – Absolute

![Graph showing recycling rate (% of nonhazardous solid waste) over years from 2007 to 2010.]

- Includes data from core metric sites as well as Bellevue, Wash.; Boeing Commercial Airplanes operations in Long Beach, Calif.; and Seal Beach, Calif.
- Calculated by dividing the amount of operational nonhazardous solid waste recycled by the total amount of operational nonhazardous solid waste generated.

### Carbon Dioxide Emissions

#### CO₂ Emissions at U.S. Sites – Absolute

- Includes data from core metric sites as well as Bellevue, Wash.; Corporate Headquarters, Chicago, Ill.; Boeing Commercial Airplanes operations in Long Beach, Calif.; and West Hills, Calif.
- Metric ton = approximately 1.1 U.S. ton (or approximately 2,200 pounds).
- CO₂ emissions are calculated based on consumption of electricity, natural gas and fuel oil. (Our facility in Philadelphia is the only major U.S. site that uses fuel oil for heating.) Consumption of other fuels is not represented.
- Emissions from purchased electricity is calculated using regional eGRID 2007 electricity CO₂ factors. Emissions from natural gas and fuel oil are calculated using the emission factors provided in the U.S. EPA greenhouse gas mandatory reporting rule.
- 2008 data reflects reduced production as a result of a labor strike.
- Data in the chart is normalized for divestitures by excluding Boeing Commercial Airplanes operations in Wichita (now Spirit AeroSystem) from 2002 to 2005. Boeing Defense, Space & Security’s Wichita operations are included in this data.

#### CO₂ Emissions at U.S. Sites – Revenue Adjusted

- Includes data from core metric sites as well as Bellevue, Wash.; Corporate Headquarters, Chicago, Ill.; Boeing Commercial Airplanes operations in Long Beach, Calif.; and Seal Beach, Calif.
- Calculated by dividing the amount of operational nonhazardous solid waste recycled by the total amount of operational nonhazardous solid waste generated.
Water Intake

**Water Intake at U.S. Sites – Absolute**

- Includes data from core metric sites as well as Bellevue, Wash.; Corporate Headquarters, Chicago, Ill.; Boeing Commercial Airplanes operations in Long Beach, Calif.; Seal Beach, Calif.; and West Hills, Calif.
- 1 U.S. gallon = approximately 3.79 liters.
- Data in the chart is normalized for divestitures by excluding Boeing Commercial Airplanes operations in Wichita (now Spirit AeroSystems) from 2002 to 2005. Boeing Defense, Space & Security’s Wichita operations are included in this data.
- 2008 data reflects reduced production as a result of a labor strike.
- Data for 2007-2009 has been adjusted to reflect additional intake from a previously unrecorded water meter in Auburn, Wash., as well as a billing error in Everett, Wash.

**Water Intake at U.S. Sites – Revenue Adjusted**

- Improved by 28% since 2002
- Improved by 41% since 2002

Hazardous Waste

**Hazardous Waste at U.S. Sites – Absolute**

- Includes data from core metric sites as well as El Paso, Texas; Heath, Ohio; Macon, Ga.; Palmdale, Calif.; Portland – PDX, Ore.; Salt Lake City, Utah; and Sylmar, Calif.
- 1 U.S. ton = approximately 0.91 metric tons.
- Hazardous waste data for 2007-2009 has been restated to reflect the addition of Portland – PDX, a facility in Oregon used by Boeing to paint twin-aisle airplanes.
- 2007 and 2008 data has been restated because a site misclassified operational hazardous waste as nonoperational hazardous waste.
- 2008 data reflects reduced production as a result of a labor strike.
- Operational hazardous waste does not include wastes derived from remediation and construction activities.
- Total normalized for divestitures by excluding Boeing Commercial Airplanes Wichita (now Spirit AeroSystem) from 2002 to 2005. Boeing Defense, Space & Security’s Wichita operations are included in this data.

**Hazardous Waste at U.S. Sites – Revenue Adjusted**

- Improved by 32% since 2002
- Improved by 44% since 2002
For more information about The Boeing Company, visit www.boeing.com and the sites below:

**2011 Environment Report**
Complete version of Boeing’s 2011 Environment Report is available at:
www.boeing.com/environment

**2010 Boeing Annual Report**
Read about the operational and financial performance of The Boeing Company in 2010.
www.boeing.com/companyoffices/financial

**Corporate Citizenship Report**
Every day, Boeing people are applying the same expertise and inventive spirit that go into developing our innovative products and services to help strengthen communities.
Boeing Commercial Airplanes and the Environment

Boeing is the world's leading aerospace company, with a strong tradition of innovation. With customers in more than 90 countries, Boeing recognizes that pollution and climate change are serious environmental challenges requiring immediate action. As a technology leader, our greatest contribution is to pioneer environmentally progressive products and services and relentlessly lessen our own environmental impacts.

Commercial Airplanes Plan and Commitments

Boeing is committed to improving aviation's environmental profile by:

- Delivering progressive new products and services with improved fuel efficiency and environmental performance.
  - The 787 Dreamliner will be 20 percent more fuel and CO₂ efficient than the airplanes it replaces, while the 747-8 will be 16 percent more fuel and CO₂ efficient.
- Pioneering the availability of sustainable aviation biofuels that emit 50-80% less carbon than fossil-based jet fuel on a life cycle basis, have greater energy density, lower NOx emissions and lower particulate matter.
- Driving new efficiencies into the existing fleet in support of aviation’s industry goal of achieving carbon-neutral growth from 2020.
- Maintaining the ISO14001 environmental certification standard at all major manufacturing operations.

Boeing’s Record

- **Innovative Leadership**: Through advancements in technology and innovation Boeing has helped improve the fuel-efficiency of commercial jetliners by 70 percent and reduce noise emissions by 90 percent since their introduction.
- **Efficient Transportation**: Current generation Boeing airplanes are as fuel and CO₂ efficient as the average train and more efficient than the average car*.
  *as measured by liters per 100 passenger kilometers. E.G. 787 uses 2.3 - 3.6 liters depending on density; train uses 2.0 - 3.8 liters; average car 6.4 liters; SUV (Range Rover) 10.7 liters.
- **Air Traffic Modernization**: We are advocates for next-generation Air Traffic Management technologies, which can eliminate billions of tons of aviation emissions and enable more precise routing of aircraft, and enable efficient take-off and arrival procedures.
- **Sustainable Aviation Fuels**: Boeing co-founded the Sustainable Aviation Fuel Users Group consisting of leading airlines, environmental groups and fuel technology leaders helping to accelerate the development and availability of sustainable new aviation fuels.