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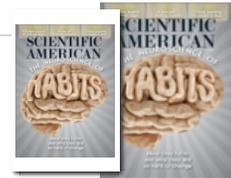
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Wild Green Yonder: Flying the Environmentally Friendly Skies on Alternative Fuels

From liquid coal to biofuels, military and commercial aviators are searching for domestically sourced, cost-effective and clean alternatives to petroleum-derived jet fuel

Jan 14, 2008 | By [David Biello](#)

In December the U.S. Air Force flew a C-17 transport plane across the country powered in part by a new propellant: natural gas transmuted into a synthetic liquid fuel. Heat and catalysts converted methane into *syngas* (carbon monoxide and hydrogen) which were then transformed into liquid hydrocarbons (otherwise known as oil and its derivatives): petroleum, gasoline and, in the case of aviation, kerosene.

"Hitler flew Messerschmitts on it," says William Anderson, assistant secretary of the U.S. Air Force for installations, environment and logistics, about such [Fischer-Tropsch synthetic fuel](#), which can be made from methane, coal, plant oils—even wood waste. "We believe that having a secure domestic source of fuel makes it easier for us to do that mission [to fly and fight]. It is less likely that there would be some disruption to the fuel source that we need to fly airplanes."

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Whether for [supersonic fighter jets](#) or commercial airliners, the aviation world has begun a quest for the fuel of the future, transitioning away from petroleum-derived



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JP-8 and Jet A varieties to Fischer-Tropsch synthetics or biofuels. Driven by security and environmental concerns as well as skyrocketing oil prices—United Airlines more than doubled its fuel surcharge per ticket to \$50 on January 12—the aviation industry continues to cut back on fuel burn as it searches for cleaner, cheaper alternatives.

"We are definitely interested in having an alternative source of energy available to us for both economic and environmental reasons, not to mention pure supply," says John Heimlich, chief economist at the Air Transport Association of America (ATA) in Washington, D.C., which represents airlines responsible for more than 90 percent of U.S. passenger and freight air traffic. "There are a host of fuels out there; some could be better, some could be worse. We need to find something at least as good, if not better."

Rock to Liquid

Jet aircraft today typically burn kerosene, an energy-dense hydrocarbon fuel that delivers as much as 48 megajoules per kilogram (20,700 British thermal units per pound), allowing for long-distance travel. Americans have taken advantage of this capacity, according to the U.S. Bureau of Transportation Statistics: Airlines reported ferrying more than 72 million passengers last July, a record high for a single month.

At the same time, the aviation industry has become far more fuel efficient in the face of soaring prices. (Airlines spent \$37 billion for fuel alone in 2007 through November and may follow United in imposing steeper fuel surcharges on customers in 2008.) According to the ATA, the industry has reduced the amount of fuel burned by 23 percent since 2000 by taking such steps as making aircraft lighter and introducing more efficient engines. "Today, Northwest Airlines is averaging roughly 50 passenger miles per gallon [21 kilometers per liter] of fuel," says Tim McGraw, Northwest's director of safety, health and environment, largely by replacing its aging fleet of airplanes with newer, more efficient jets.

The primary reason for such improvements has been the steady rise in fuel costs. For example, the Air Force has watched its energy spending double since 2003 even though it cut fuel consumption by more than 10,000 barrels a day during the same period. "Over 80 percent of the entire Air Force energy buy is in liquid aviation fuel," Anderson says. "That represents a little less than \$6 billion a year of taxpayer money that goes into feeding our fleet with fuel."

As a result, the Air Force—and other military branches as well as the Defense Advanced Research Project Agency (DARPA)—have begun to experiment with alternatives. "Alternative fuels offer the potential, if not to lower the price [of petroleum-derived fuels], at least to provide a hedge in the future against their future growth or, put differently, their volatility," says technologist Douglas Kirkpatrick, DARPA's program manager for alternative fuels efforts. "The key here is to go from one source to many."

He adds: "Anyone who runs a business knows that you don't want to have one supplier. Essentially, that's the position we're in."

In the short term, the Air Force hopes to make use of the [Fischer-Tropsch chemistry](#) that kept Nazi-era Germany and the apartheid-era Union of South Africa's airplanes

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flying in the absence of oil (and still supplies 40 percent of South Africa's transportation fuel needs) to ensure diversity of supply. In addition to flying the C-17 across the country—a plane powered by the same Pratt and Whitney F117-100 engine employed on commercial Boeing 757s—the Air Force in August certified its still flying 1950s-era B-52 bombers to burn synfuel.

"Why start with an old weapons system?" Anderson says. "It's a very simple engine compared to newer ones, less things can go wrong."

The natural gas-derived synfuel performed perfectly in both planes during ground tests, flights and even during cold starts in the dead of winter in Minot, N. Dak. The 50–50 blend of synfuel and JP-8 fulfilled all 40 of the Air Force's fuel performance criteria, including coming through in extremely high and low temperatures. "Pilots are telling us that they're feeling no difference at the controls between the fuels," Anderson notes.

Fischer-Tropsch synfuels promise to provide a potentially cleaner fuel supply as well. Burning the purer fuel—clearer than petroleum-derived kerosene—eliminates sulfur emissions that lead to acid rain and reduces (by 50 to 90 percent) the amount of tiny particles that usually remain after combustion, according to Richard Altman, executive director of the Commercial Aviation Alternative Fuels Initiative (CAAFI), an industry effort to develop new energy options.

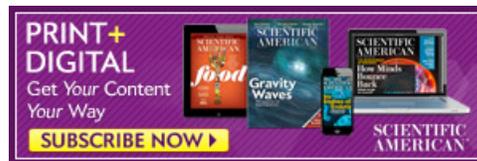
But synfuel will not lead to fewer emissions of carbon dioxide, the greenhouse gas primarily responsible for global climate change. Environmental group the Natural Resources Defense Council estimates that **turning coal to liquid fuel emits twice as much carbon dioxide** as producing petroleum fuels. "We will only buy fuel that is greener than our current alternatives," Anderson says. "Our current alternative is petroleum-based jet fuel."

The European Union plans to restrict carbon emissions from airplanes beginning in 2012; in the U.S., legislation is pending that would impose similar limits, and five states (California, Connecticut, Pennsylvania, New Jersey, New Mexico and New York) have petitioned the Environmental Protection Agency (EPA) to regulate such emissions in the interim. "We now know that the solution that will be most environmentally acceptable," CAAFI's Altman says, "will have significant biofuels."

Beyond Kerosene

The amount of emissions from aircraft compared with other vehicles is relatively small—roughly 3 percent of total worldwide greenhouse gas emissions from fossil fuel burning, according to the [U.N. Intergovernmental Panel on Climate Change \(IPCC\)](#)—nonetheless it has a major impact on the climate. By releasing carbon dioxide higher in the atmosphere, airplanes allow the molecule more time to trap heat, also contributing via [contrails](#) and other chemically active gases, the IPCC notes.

Some airlines have been effective in reducing greenhouse gas emissions. "At Northwest, our greenhouse gas emissions have gone down 25 percent since 2000 and about 5 percent less than 1990," says Ken Hylander, Northwest's senior vice president of safety and engineering. "If Northwest was a country, we would be Kyoto [Protocol on reducing greenhouse gas emissions] compliant."



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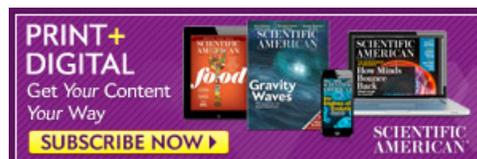


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But emissions from the aviation industry as a whole continue to climb. According to the EPA, from 1990 to 2005 greenhouse emissions from military aircraft slid by 50 percent but those from commercial carriers rose by 16 percent, largely due to growth in the number of carriers.

Efficiency alone—even in the form of aircraft with improved engines and designs such as the Boeing 787, expected to deliver a 20 percent improvement in fuel efficiency over existing big airplanes—is not the answer. "A low-CO₂ fuel will help us to address that remaining portion of the pie," says David Daggett, technology leader for energy and emissions at Boeing. "That's why we're interested in biofuels specifically."

One such biofuel—[ethanol](#)—is already being used to power a heavily employed commercial fleet: piston-engine propeller crop dusters. Max Shauck, chair of the Baylor Institute for Air Science (who flew an ethanol-powered prop plane at air shows in the 1980s), has converted at least 1,000 such aircraft in Brazil, a country that has weaned itself from foreign oil by [embracing ethanol domestically produced from sugarcane](#).

In addition to being easier on the engine, ethanol costs one quarter to one half as much as the aviation gas typically used in such propeller planes. Ethanol decreases the number of hours or distance such an aircraft can fly, however, due to its lower energy density, but "it develops more power and it's a greenhouse gas-neutral fuel," Shauck says. "There's plenty of ethanol produced in the world to power all the piston-engine aircraft."

The Federal Aviation Administration (FAA) is conducting tests but has yet to certify ethanol as a fuel for piston-engine planes in the U.S., says Lourdes Maurice, chief scientist and technical advisor to the FAA's Office of Environment and Energy. Regardless, ethanol's low energy density makes it unsuitable for jet-turbine engines. "Clearly we can't use ethanol," CAAFI's Altman says. "That's a blessing. We don't want to compete with food crops."

Diesellike fuel derived from plant oils might avoid that problem as well as supply similar greenhouse gas reduction (depending on how the plants are cultivated). Already, a [Czechoslovakian L-29 jet](#)—specially built in the 1960s by the Czech military to run on alternative fuels—flew for 37 minutes and reached an altitude of 17,000 feet (5,180 meters) powered entirely by reformulated canola oil. "Would you rather buy your oil from the Middle East," asks BioJet 1 copilot Doug Rodante, president of Green Fuels International (a company that promotes alternative fuels), "or the Midwest?"

But biodiesel solidifies into a gel at the cold temperatures found at high altitude, a fatal flaw for any aircraft fuel. The Czech jet has fuel heaters to get around this problem, and similar solutions could be engineered into other jet engines, argues physicist Rudi Wiedemann, president and CEO of Biodiesel Solutions, Inc., in Sparks, Nev., the flight's fuel provider.

Or the [biodiesel](#) itself can be further refined to ensure that it doesn't solidify until at least -40 degrees Celsius (-40 degrees Fahrenheit), the current standard for petroleum-derived jet fuel. UOP, a Honeywell Company, has developed such a "green

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diesel" by heating vegetable and animal oils to add hydrogen atoms to the long hydrocarbon chains, under the aegis of DARPA. In addition, its "ecofining" process adds kinks in the chains to prevent them from easily stacking—or gelling—at cold temperatures, producing a diesellike fuel with as much as twice the combustion quality of the petroleum-derived variety.

Boeing has tested two such "vegetable-based biofuels" with this antifreezing property in the General Electric jet engines used on many of its 747 aircraft, Daggett says. Virgin Atlantic airline announced that early this year it will conduct the first flight test of a biodiesel–petroleum diesel blend in one of the four engines of a 747 aircraft; Air New Zealand is planning a similar test flight on a Rolls Royce engine in one of its 747s later in the year.

The first UOP-derived ecofining facility, capable of producing 100 million gallons of diesel fuel for ground vehicles, is now being built in Livorno, Italy; a second facility is set to be constructed in Sines, Portugal. "Going to biofuels doesn't mean we have to make compromises. We are already making fuels that look exactly like the real thing, or better," says Jennifer Holmgren, UOP's director of renewable energy chemicals. "The real limitation is going to be feedstock."

There is not enough oil from plants such as soy and canola to supply even a fraction of the 60 million–plus gallons of jet fuel burned every day by U.S. aircraft, nearly one quarter of global use, even if all such sources were converted to fuel (which would significantly impact food supplies.) And Boeing has had a hard time finding biofuel suppliers who can produce testable quantities of their product. "Immediately that weeds out a lot of companies when you ask for 1,000 gallons," Daggett says.

As a result, both private companies like UOP, government agencies like DARPA and commercial organizations such as CAAFI have begun to consider a broader array of sources, including the oil from the seeds of Brazil's babassu palm tree or the conversion of the woody or [cellulosic](#) parts of plants. Chemical engineer Charles Wyman of the University of California, Riverside, argues for biorefineries turning seed oil, the stalks and other detritus of crop plants, and even wood pulp waste into an assortment of alternative fuels.

"You are growing wood or grasses in a renewable way in some sort of energy plantation to produce biomass," he says. "Convert some of that to ethanol, and the fraction you can't convert, use Fischer-Tropsch to make diesel fuel that could be tailored towards jet fuel."

Or [algae could be grown](#). The tiny plant can produce "60 percent of its weight as oil under stress," according to Wyman. Closed vats might produce pure strains of such high-oil species for feeding into large ponds to grow sufficient supplies, says systems engineer Ron Pate at Sandia National Laboratories in New Mexico, who has been analyzing the fuel potential of microscopic plants.

Such vast [algae farms](#) might also subsist on so-called "impaired" water, either salty ocean or polluted waters, Pate says. "Water coming out of sewage treatment plants has nutrients—nitrates, which encourage algae to grow," Boeing's Daggett notes. "You can harvest the algae and extract the oil, then release the water in a cleaner state than

what it would have been leaving the sewage plant."

But **biorefineries** would cost hundreds of millions of dollars and require significant upgrades in existing processes, whereas such algae schemes have yet to be tried. The U.S. Department of Energy (DOE) has provided the money for a few pilot biorefineries and DARPA has provided funding for initial efforts to begin exploring algae's feasibility, but it will be years before any such fuel is widely available. "Ten to 20 years is a reasonable time frame," Daggett says.

Fossil Blends

The Air Force, meanwhile, plans to certify its entire fleet of aircraft on Fischer-Tropsch process synthetic fuels derived from methane or coal by 2011 and plans to purchase enough such fuel to power at least 50 percent of the fleet in the continental U.S. by 2016. Tests began in November on the performance of the purer synfuel in the jet afterburner engines that are used for supersonic flight.

"That's about 400 million gallons [1.5 billion liters] of fuel," Anderson says, compared to 281,000 gallons [1.06 million liters] purchased this year and an estimated 500,000 gallons [1.9 million liters] next year. "It may only be marginally [environmentally] better in 2016. Carbon neutral? Probably not."

Although such synfuels may actually increase greenhouse gas emissions, depending on how they are **produced**, they will deliver some independence from the tyranny of petroleum. "The coal in the ground in the U.S. at current use will last 400 to 500 years. If you double, triple or quadruple the use of coal, it won't be 400, of course, it'll be 100 or 50 years," Anderson notes. "But it's 50 more years to get to the carbon-free economy."

Before then, the impact on Earth's climate can be limited by blending relatively small amounts of **biofuels** into such synfuels—an option DARPA, for one, rejects for logistical reasons—or capturing the carbon dioxide from synfuel production and using it to enhance the growth of the plants to be turned into fuel. "Put as little as 20 percent biofuel into nonrenewable fuels—coal-to-liquid and gas-to-liquid—you can be carbon neutral in a mix," CAAFI's Altman says.

Such a 20 percent mix would not require any modifications to existing aircraft engines or infrastructure, Green Flight International's Rodante says. "Jet fuel and biofuel mix is something that is easily done," he says "I don't believe 100 percent biofuel is the answer."

Oil prices at \$100 per barrel are already well above the \$40 per barrel level at which synfuel producing facilities break even, and even the \$70 per barrel level that might make carbon capture economically feasible. "The biggest challenge is production capacity—and staying the course," FAA's Maurice says. "If the price of crude were to drop, can we sustain the interest?"

Still, the combination of factors involved: energy security, diversity of supply and the environment may sustain commercial aviation's interest, though its overall goals are smaller—certifying synfuel blends next year, full synfuels by 2010 and biofuels in 2013. "There is an underlying demand for something better than \$90 per barrel oil,

that has better domestic supply and can help cope with increasing environmental pressure," ATA's Heimlich says. "I have yet to see that silver bullet magic fuel."

In the interim, many airlines are offering ways to [offset the greenhouse gas emissions](#) associated with air travel, such as U.S.-based Delta Air Line's program with The Conservation Fund to plant trees in return for \$5.50 that passengers are given the option of adding to the price of a domestic round-trip ticket or \$11 for international round-trip flights. Britain-based Virgin Atlantic has a similar agreement with myclimate (a Swiss offset provider), who uses added flyer fees, which vary depending on ticket price, to fund renewable energy projects in developing countries such as India. It remains unclear, however, how much such passenger-funded partnerships do to alleviate climate change and they are a poor substitute for a [carbon-neutral](#) alternative jet fuel.

"We should have stayed the course in the 1970s and then we wouldn't be having this discussion," the Air Force's Anderson says. "Whether it takes 30 or 50 years [to develop such a fuel], it's going to take longer if we start tomorrow than if we start today."

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"[Brazil] has weaned itself from foreign oil by embracing ethanol domestically produced from sugarcane."

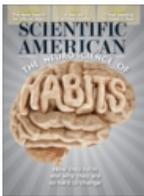
Sugar cane ethanol is a fraction of Brazil's oil independence (~12% of Brazil's energy needs), much more of the credit goes to Petrobras for becoming better at extracting and refining oil (~88%).

Brazil produces the oil equivalent of about 300,000 barrels per day of sugar cane ethanol, and its total oil consumption (according to the Energy Information Administration) is 2,500,000 barrels per day. Petrobras produces about 2,400,000 barrels per day of oil. In other words, 88% of Brazil's energy needs come from oil.

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