Environmental Cool Down

A new model computes CO_2 emissions with accuracy and consistency to support sustainable travel and tourism.

By Peter Berdy | *Ascend* Contributor

Carbon dioxide is the mean, evil molecule of our time. Belching out from vehicle exhausts, smokestacks and power plants, it is the biggest contributor to global warming. Yet CO_2 is not a pollutant. It is a natural component of the atmosphere, needed by plants to carry out photosynthesis. The problem is volume: there is a lot more of it in the industrial age, and it makes our planet temperature rise just enough to cause big problems.

For aviation, carbon dioxide is the most important greenhouse gas, or GHG, accounting for about 99 percent of aviation GHG emissions according to the United Nations Framework Convention on Climate Change reported in April 2005. In fact, everything related to emissions is usually translated into CO_2 equivalent, making it the benchmark for emissions, and placing a focus on carbon dioxide.

Aviation emissions come from the combustion of jet fuel. When burned in a jet engine, fuel is converted into heat, CO_2, water vapor and some particulates.

Corporations and individuals concerned about measuring their impact on the environment have come to *Sabre Holdings*® as a leader in the travel industry to better understand the detail of their emissions for air travel, whether that travel is for business reasons or personal ones.

In an effort to respond to its customers' needs, *Sabre Holdings* identifies emissions at two instances: at the time a booking is made and after travel has occurred. This is not a small task — there are hundreds of millions of bookings made through different distribution channels within the *Sabre*® global distribution system.

As the world's largest distributor of travel information, *Sabre Holdings* calculates and reports carbon dioxide emissions for air travel with dedication and diligence. Until the day comes when all airlines report their own emissions, *Sabre Holdings* will provide this information to all of its customers with the following principles: provide complete, reliable, accurate and consistent data and be transparent to the way it measures and reports carbon dioxide emissions.

Options For Modeling CO_2 Emissions

When closely examined, there were three options to develop the capability to estimate aviation emissions. *Sabre Holdings*' choices were to use emissions reported by airlines, use a third-party supplier of a "carbon calculator" or develop its own emissions estimates with a model.

Upon investigation, there was a lack of consistency of CO_2 reporting by airlines, and many don't even report at all. There is no requirement for airlines to report their emissions. Fuel consumption, the basis for determining carbon dioxide emissions, is not made available by airplane manufacturers. (Engine manufacturers report fuel consumption for the different components of landing and take off during certification. However, they do not report fuel consumption during cruise.) Currently, several airlines provide estimates of CO_2 emissions on their Web sites. Some of those use calculators developed by third parties, a few provide emissions based on their own data, others provide an indication of emissions (such as for a short or long trips) without specifying an individual's travel, and many have not taken steps to show emissions at all. In other words, the industry lacks a consistent approach to reporting CO_2 emissions.

The International Civil Aviation Organization released a model aimed at addressing these concerns about the same time the International Air Transport Association released guidelines on emissions modeling. IATA's document, "Aviation Carbon Offset Programmes Guidelines And Toolkit," which was issued in May, describes an approach for setting up an offset program that could be used for airlines as part of their drive to reduce CO_2 emissions.

During the course of these worldwide efforts, there have been several models developed for estimating aviation emission inventories for global aviation, such as SAGE (from U.S. Federal Aviation Administration), CORINAIR (European Union), and AERO2k. Elements of these models and their output were of interest for potential use in modeling.

Both IATA and ICAO use CORINAIR Emissions Inventory Guidebook to estimate fuel consumption, which in turn, is multiplied by a factor to convert fuel burned into CO_2. However, CORINAIR is outdated, and models about 50 of the more than 250 commercial airplanes. The use of analogies is required to estimate fuel consumption for newer aircraft types.

According to IATA, "The CORINAIR database does not contain fuel burn data for all existing aircraft types and so-called 'equivalent' types may have to be used as a substitute to approximate the estimated fuel burn for scheduled aircraft types."

In an example from ICAO, "To model a B737, CORINAIR contains two choices of older models, the B737-100 and B737-400. City pair routes that operate mainly newer, more fuel-efficient B737 models (B737-600/700/800/900), CORINAIR would overestimate the fuel burn and CO_2 production." As a result of this problem, *Sabre Holdings*' emissions model uses other sources including FAA-SAGE, which covers most aircraft types and does not rely on CORINAIR to model fuel consumption for all types.

When examining third-party vendors, *Sabre Holdings* found the vendors' carbon calculators often had incomplete data or elements for computing carbon dioxide emissions correctly and made too many assumptions about aviation. There were overall concerns about their capability to model emissions on the scale of millions of bookings that are made through the *Sabre GDS*.

After evaluating its own capability to model emissions, *Sabre Holdings* chose to build its own model for estimating carbon dioxide emissions based on its ready access to extensive aviation databases, emissions models and their output; enormous computer resources; a deep knowledge of the airline industry; and a commitment to get the job done correctly. The task included an emissions model that could be applied with consistency and accuracy that will estimate CO_2 emissions for an individual traveler on a specific flight as well as ensure the model can address enormous volumes of travel bookings.

Getting The Job Done

The project began with a thorough review of research that has already been done on aviation emissions, which included a large volume of excellent research data and resources, mostly from material sponsored and developed through efforts by the United Nations and supporting institutions. Research has been conducted by scientists around the world who contribute to U.N. efforts.

In addition, aviation regulatory agencies, such as the International Civil Aviation Organization, Eurocontrol, NASA and the U.S. Federal Aviation Administration, have been involved in modeling emissions. For example, the Committee on Aviation Environmental Protection of the ICAO has formed several working groups to address aviation environmental emissions.

Available Resources

After finishing the background review, the next step was to examine which resources and data were readily available to develop *Sabre Holdings*' emissions model. After digging deeper, a repository of data and tools to use for constructing the model was developed.

The toolkit behind *Sabre Holdings*' emissions model include:

- Intergovernmental Panel on Climate Change: Reference manuals, containing guidelines on methodology for aviation;
- ICAO: An extensive engine emissions exhaust databank covering almost every jet engine in use today;
- Eurocontrol: Base of Aircraft Data, or BADA, that contains performance tables on air speed, rate of climb and descent, and fuel flow at various flight levels for specific airplane types (is also used as inputs for other models);
- E.U. Environment Agency: CORINAIR, a model to estimate pollutants for specific equipment types for emissions modeling;
- U.S. FAA: Output from SAGE, the System for Assessing Aviation's Global Emissions, and EDMS model, the Emissions and Dispersion Modeling System, which have data that can be used for determining emissions formulas for various equipment types;
- U.S. Department of Transportation: Output from its Form 41 database for cargo ton miles and passenger ton miles by aircraft type;
- U.S. Environmental Protection Agency: Conversion factors useful for converting units;

Existing models required some assumptions because of a lack of specific scientific data or to keep the complexity of emissions modeling within manageable limits. Typical assumptions made by existing models included:

- Standard atmospheric conditions and no consideration of winds,
- Flights with a standard payload and no fuel tankering,
- No consideration of delays and holdings,
- Simplified routing and trajectory modeling,
- No aircraft and engine deterioration, which takes place as aircraft age.

Assumptions made for *Sabre Holdings'* model followed those general assumptions. In addition, to evaluate the effect of CO_2 related to passenger travel, cargo from the equation for passenger emissions was removed because airlines have two types of payload — passenger related (including passenger weight and weight of bags) and cargo. The idea behind removing cargo is that each payload category is responsible for its share of emissions.

The following information was required to develop *Sabre Holdings'* emissions model:

- Details about all scheduled flights worldwide, including origin-destination, airline and equipment type,
- Airline specific, including average seats per airplane type,
- Detailed data on emissions for all aircraft in scheduled service,
- Estimates of unit fuel consumption by aircraft type.

All these items were located or developed and then placed in the toolkit. There were hundreds of numbers to analyze with statistical analysis and correlation just to develop the core elements for the model.

Once the model was complete and ready for testing, the emissions output was tested against several sources, including airline Web sites for specific flight segments, output from ICAO, E.U. and FAA models. In addition, fuel consumption data for specific aircraft available from selected *Sabre Holdings* airline clients was benchmarked.

The model has the capability to estimate emissions for any commercial flight by estimating fuel consumption for specific airplane type, and then it converts fuel consumption into carbon dioxide. Finally, it divides the carbon dioxide for the flight by the number of seats to estimate CO_2 emissions for an individual passenger's journey.

Knowing that the CO_2 for a seat on a flight can be measured, test emissions for a short- and long-distance trip can be examined looking at the emission for two different aircraft — an older and new aircraft — on these routes to compare the differences in their emissions.

When examining a 500-mile flight operated with a DC-9 and comparing CO_2 emissions per seat to a next-generation Boeing 737, the DC-9 produces about 100 kilograms of CO_2 per seat, twice the amount produced by the Boeing 737.

Similarly, when looking at a 5,000-mile trip operated with a DC-10 compared to an Airbus A330, the CO_2 per seat for the DC-10 is about 750 kilograms versus 500 for the A330.

Solving CO_2 Issues

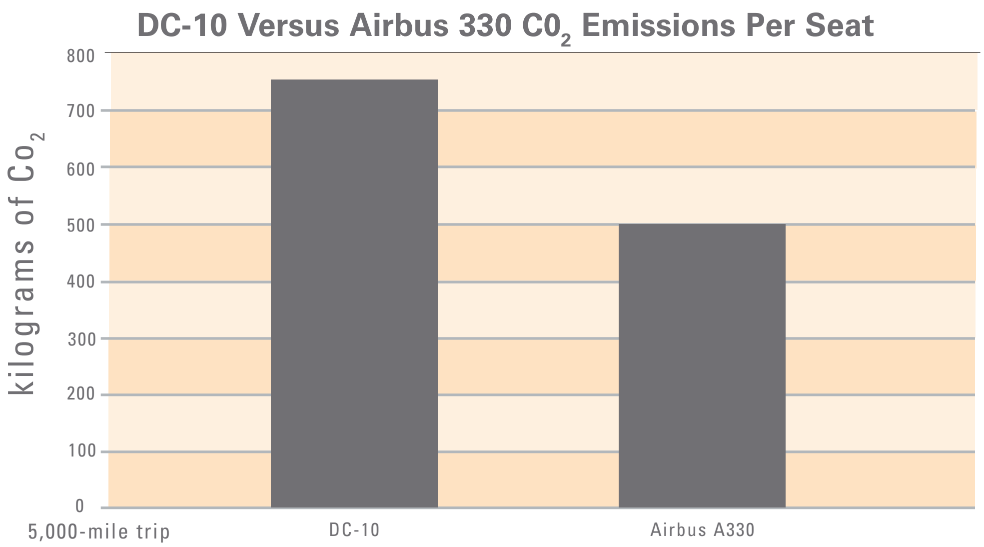
Addressing the problem of reducing carbon dioxide emissions from aviation falls on the shoulders of specific groups, including government agencies that set targets to reduce emissions and devise mechanisms to enforce and pay for the reductions; manufacturers that are working on designing more efficient airplanes and engines; and the airlines and supporting infrastructure (air traffic control and airports) involved in modifying operating procedures to reduce fuel consumption.

For individual consumers, information about carbon dioxide emissions can be useful to understand the order of magnitude of their own emissions when they travel, and also for comparison for emissions with other modes of transportation. However, most travel is conducted by air due to large distances where other types of transportation can be considerably more time consuming, and comparisons may not be relevant.

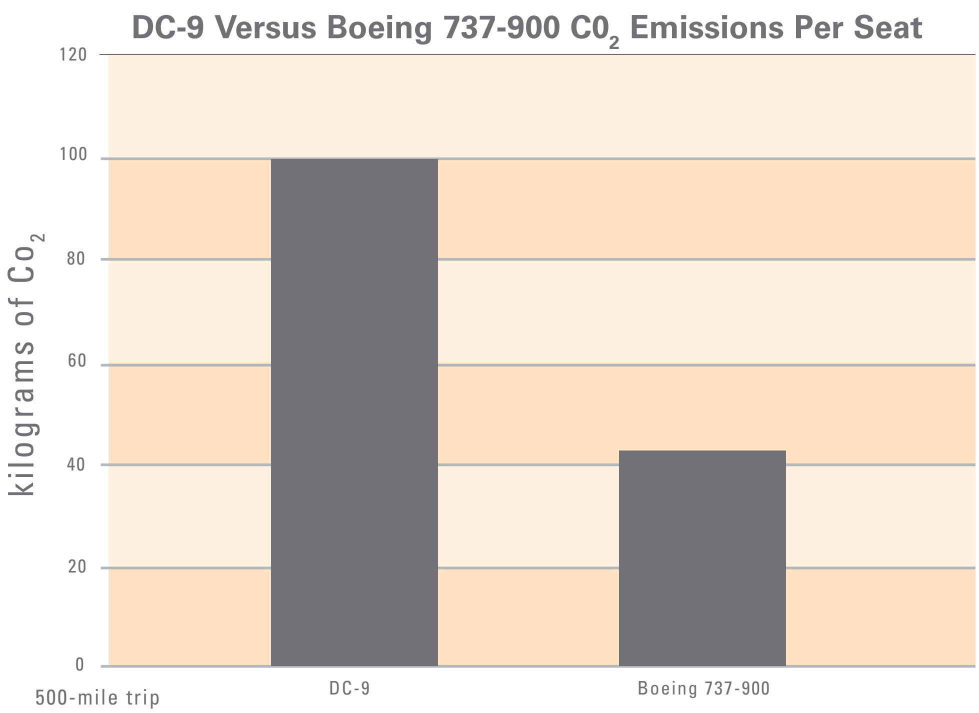
Since the volume of CO_2 emissions can be identified, one way to understand the potential effects are to look at commodity markets where CO_2 is traded and monetize emissions to get an idea of what the cost of emissions might be. In other words, take the estimated volume of CO_2 emissions of a trip and multiply it by the going rate for a ton of CO_2.

The emphasis on global warming is to reduce CO_2 emissions overall. However, this is already taking place in commercial aviation. There have been ongoing reductions in emissions due to more advanced engines and airplane design. Economics is driving change as well — the high price of jet fuel is forcing airlines to ground older planes that consume more fuel.

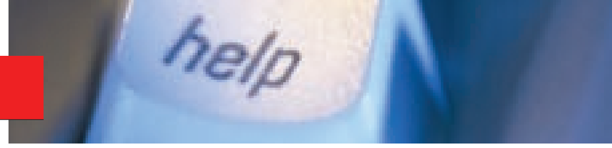
There is also work in progress to make improvements in air traffic control and air traffic management as well as airlines and aircraft manufacturers changing their operational procedures:



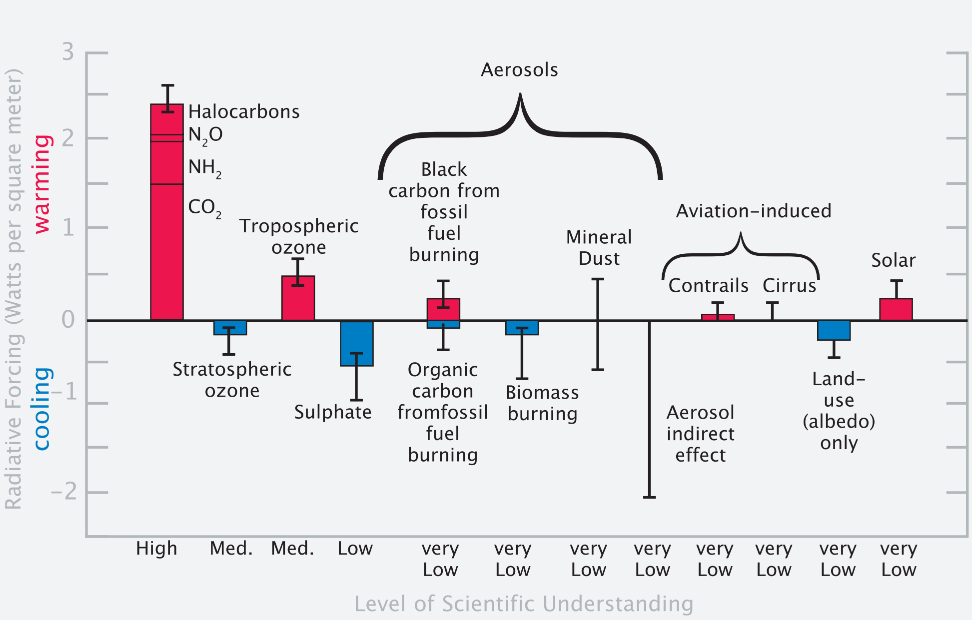
The CO_2 emissions per seat for the DC-10 on a 5,000-mile flight is 750 kilograms compared to only 500 kilograms of CO_2 emissions per seat for the Airbus A330.



When comparing CO_2 emissions on a 500-mile trip, a Boeing 737-900 produces about 50 kilograms per seat versus the DC-9, which produces twice as much at about 100 kilograms per seat.



Radiative Forcing



The current level of scientific understanding for key individual radiative forcing elements indicates that while the effects produced by CO_2 and certain elements appear to be well known, the scientific understanding of the impact of many other elements on global warming ranges from medium to very low.

An index called radiative forcing index, or RFI, is used for comparing the effect of different agents causing climate change, notably CO_2. It is used to compare two different time periods. Radiative forcing can be used to look at the effects of all historic aviation emissions and for long-term projections. However, it does not examine the influence of a single flight.

One misconception is that aviation CO_2 is more damaging because it is emitted at high altitudes. According to the Intergovernmental Panel on Climate Change, CO_2 has a long atmospheric residence time (about 100 years); therefore, it becomes well mixed throughout the atmosphere. The effects of emissions from aircraft at altitude are indistinguishable from the same quantity of CO_2 emitted by any other source, according to the IPCC Summary for Policymakers on Aviation and the Global Atmosphere, 1999 section 2.

Many scientists now consider that radiative forcing (or a simple multiplier) is not the correct metric to model the effects of aviation. As Professor Keith Shine from the Department of Meteorology at the University of Reading wrote on carbon offset schemes in a letter to the Guardian early last year: "The issue of RFI is a really fractious one, and most of those that have researched it have concluded that it is a horrible misapplication of science and misusing something that was presented in an IPCC report in 1999 (Towards Greener Skies: The Surprising Truth About Flying And The Environment — easyJet, 2007).

"Carbon dioxide has an atmospheric lifetime of more than 60 years and becomes well mixed during this period regardless of where the emission occurred," said Robert Sausen, head of the department of atmospheric dynamics at the Institute of Atmospheric Physics of the German Aerospace Center. "Hence, CO_2 emissions from aviation have the same effect as emissions from other sources" (ICAO Environmental Report, 2007, page 123).

Sabre Holdings' emissions model measures CO_2 but does not consider radiative forcing.

- For air navigation service providers, this includes efficient use of airspace, developing shortest feasible routes, reducing inefficiency in current flight patterns, taking advantage of prevailing climate conditions, changing the way flights are routed and examining separation, developing continuous descent approaches, and improving terminal management.
- For airlines, this includes careful fleet planning, using aircraft best suited for particular routes, optimizing aircraft speed; limiting use of the auxiliary power units; reducing weight; and optimizing altitude selection, speed and flap settings.
- For manufacturers, this means working on technology improvements for airframe and engine design as well as possible use of alternate fuels.

Sabre Holdings has built a model to estimate CO_2 emissions for air travel to provide this information with consistency and accuracy.

The model reports CO_2 emissions only, since carbon dioxide is the most important greenhouse gas. It will not monetize the emissions estimates or apply factors such as radiative forcing due to variability and uncertainty.

The aviation industry has a history of reducing emissions with more efficient aircraft, engines and improved operating procedures. It has taken responsibility for continuing to reduce emissions out of economic necessity, and it will continue to do so in the future. Further steps to reduce aviation emissions are already underway, including better air traffic management as well as engine and airframe manufacturers that are making improvements to reduce fuel consumption with technology and airlines that are working to optimize how they operate.

Sabre Holdings continues to support the efforts aviation has made to improve its impact on the environment, and it will continue to work with its customers to promote tools that will assist them to promote sustainable travel and tourism.

Peter Berdy is a consultant for Sabre Airline Solutions® *and developer of* Sabre Holdings' *emissions model. He can be contacted at peter.berdy@sabre.com.*

Why Does Co2 Weigh So Much?

CO_2 emissions from air travel are related to fuel consumption. A gallon of jet fuel weighs about 6.7 pounds. So how can jet fuel produce 21 pounds of the greenhouse gas, carbon dioxide, when it is burned in an airplane's engines?

Jet fuel is mostly chains of carbon and hydrogen atoms. A carbon atom has an atomic weight of 12, and each oxygen atom has a weight of 16, giving each single molecule of CO_2 an atomic weight of 44 (12 from carbon and 32 from oxygen). To calculate the amount of CO_2 produced from a gallon of jet fuel, the weight of the carbon in the gasoline is multiplied by 44 divided by 12 or 3.7. Since gasoline is about 90 percent carbon and 10 percent hydrogen by weight, the carbon in a gallon of jet fuel weighs about 6 pounds (90 percent of 6.7 pounds). Multiply the weight of the carbon (6 pounds) by 3.7, which equals 21 pounds of CO_2.

The number used by ICAO and IATA to convert jet fuel into CO_2 is 3.157.

Sources: http://www.fueleconomy.gov/Feg/co2.shtml and Aviation Carbon Offset Programmes IATA Guidelines And Toolkit, May 2008.