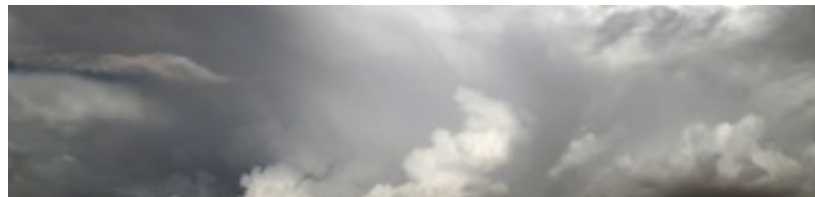
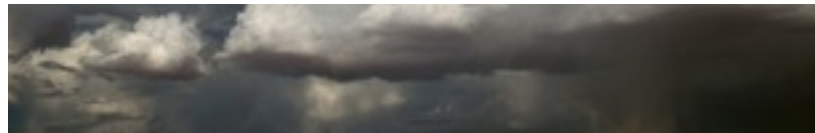




# AIR TRAVEL CARBON AND ENERGY EFFICIENCY



Case studies • Best practices • Industry trends • Airline rankings



BRIGHTER  
PLANET



Matthew Kling and Ian Hough  
Copyright 2011 Brighter Planet, all rights reserved.

### **Contact**

Brighter Planet  
Vermont and San Francisco  
<http://brighterplanet.com>  
[staff@brighterplanet.com](mailto:staff@brighterplanet.com)  
802-458-0441

### **About Brighter Planet**

Brighter Planet is a leading innovator of advanced carbon calculation and mitigation tools that enable businesses and their clients to operate more efficiently, reduce their footprints and create a cleaner environment. Brighter Planet serves hundreds of thousands of customers daily, has performed millions of cloud-based carbon calculations, and has helped clients avert hundreds of millions of pounds of carbon dioxide emissions. The company has received the Social Innovation Award from the Financial Times and was named Best Small Business of 2010 by Treehugger.

# Executive summary

Brighter Planet, using an advanced flight carbon and energy model, analyzed more than a decade of commercial airline databases to reveal new details of disparities between the most and least environmentally friendly airlines for travellers. This report presents our findings, including detailed airline efficiency rankings, an examination of the five key drivers of energy efficiency, and an analysis of the huge economic and environmental benefits of the past decade's fuel efficiency improvements.

Our analysis of data covering more than 9 billion passenger departures and 12 trillion passenger-miles flown shows that carbon efficiency per passenger per mile varies tenfold across the industry. Our overarching conclusion is that a simplistic, traditional approach to air travel carbon accounting has obscured major sustainability opportunities by overlooking carbon efficiency. By using a more sophisticated accounting, companies can significantly reduce the carbon footprints of their travelling employees without necessarily cutting flights or increasing costs.

At a time when businesses increasingly are under pressure by governments, shareholders, and the general public to reduce the carbon footprints of their travelers, this research redefines how corporations and travel managers should understand and manage the impact of air travel.

## Key findings:

- **Airline efficiency varies dramatically due to aircraft, routes, and payloads.** Continental, JetBlue, and Frontier earned the highest efficiency ratings among the 20 largest airlines in the U.S. market, with last-place American Eagle emitting more than twice as much carbon per passenger per mile. Internationally, Ryanair, Singapore Airlines, and Delta claimed top rankings for efficiency among the 20 largest airlines, with SAS rated the worst.
- **Carbon efficiency per passenger per mile varies tenfold across the industry.** This finding runs counter to standard carbon accounting practices that treat flight efficiency as relatively uniform and lead to major inaccuracies and lost opportunities.
- **Focusing on efficiency provides new opportunities for cutting carbon footprints.** An analysis of more than 300,000 employee flights at two of the largest American corporations revealed that these companies could cut their travellers' carbon footprints by as much as 40% simply by choosing more efficient flights serving the same routes, without necessarily increasing ticket prices.
- **Five key drivers account for the wide disparity in flight efficiency.** Aircraft fuel economy, passenger load factor, seat density, freight share and distance are critical factors for accurate flight carbon measurement and management.
- **Market trends in the aviation industry are driving evolutions in flight efficiency.** Air travel efficiency has increased 20% since 2000, an improvement that in the US has saved airlines and travelers more than \$33 billion on fuel and prevented the release of 670 billion pounds of CO<sub>2</sub>e.

# Table of Contents

<b>Introduction</b>	<b>5</b>
Uncovering sustainability potential	5
Aviation emissions	6
Efficiency variation	6
Modeling air travel impacts	7
Corporate case studies	8
<b>Efficiency drivers</b>	<b>9</b>
Aircraft model	10
Seating density	11
Load factor	12
Freight share	13
Distance	14
<b>Overall efficiency</b>	<b>15</b>
Flight case studies	16
Airline rankings	17
Industry trends	19
Latent opportunity	21
Best practices	22
<b>Appendices</b>	<b>23</b>
Methodology notes	23
CM1 overview	24
References	24

# Introduction

## Uncovering sustainability potential

Corporate travel sustainability management is taking off. Nearly four in ten Global 500 companies publicly reported carbon emissions from employee travel last year, a figure growing at about 10% annually.<sup>1</sup> Flights account for the lion's share of many companies' travel expenditures and travel carbon footprints and are the leading category for travel sustainability management.

As more and more organizations move to measure, report, and manage air travel emissions, CSR and travel managers can find themselves on a steep learning curve. While there are industry reporting standards that define acceptable approaches to flight carbon calculation, they provide enormous latitude in the level of detail permitted, meaning that an acceptable emissions figure for a single flight can fall anywhere within a wide range.

Under most standards, a company can calculate employee travel emissions by grouping all flights into three or four distance categories, summing the miles flown within each category, and multiplying each sum by an emissions factor. Alternatively, the company could perform a detailed analysis of the airline, aircraft, route, and passenger characteristics for every segment of each flight. The latter approach is far more accurate, although most organizations not surprisingly choose the former for its ease and simplicity.

But while the simpler approach may suffice for basic sustainability reporting in an early phase of adoption, it barely scratches the surface of what's possible through mature sustainability management. The simple approach assumes flights are uniform in their impact per mile flown, but that's far from the case. Our modeling based on aviation industry datasets shows that carbon impact per passenger per mile varies by a factor of more than ten across the industry. This variation exists not just within the industry as a whole, but among equally-priced itinerary choices between the same two airports.

**“Major carbon variation exists among equally-priced itinerary choices for a single city pair.”**

Oversimplifying flight carbon analysis introduces major inaccuracy that could mean reported figures are off by a very wide margin. It obscures key footprint trends that vary independently from flight volumes. And it prevents major sustainability gains possible through managing travel programs for carbon efficiency, because it incorrectly implies that the only way to cut carbon is to reduce air travel. Broadening the focus from annual carbon totals to also measure carbon efficiency per mile can uncover major opportunities.

---

<sup>1</sup> Carbon Disclosure Project

## Aviation emissions

The commercial aviation industry is a large and diverse market. Worldwide, a fleet of 27,000 planes representing hundreds of aircraft models and some 1,600 airlines shuttles more than 4.5 billion passengers over 1.5 trillion passenger-miles annually between 3,700 airports.<sup>2</sup>

Commercial air travel consumes about 75 billion gallons of jet fuel each year, costing airlines over \$140 billion and adding 3 trillion pounds of CO<sub>2</sub>e to the atmosphere.<sup>3</sup> Flights represent 2%, 3%, and 3% of global, European, and US greenhouse gas emissions, respectively, and a far greater portion for many businesses.<sup>4</sup> With air travel, fuel prices, global temperatures, and economic uncertainty all on the rise, issues surrounding passenger air travel efficiency have never been more important.

This is not news. Much research has been directed toward understanding the economic and environmental effects of air travel. Reports by the Intergovernmental Panel on Climate Change (IPCC), World Resources Institute (WRI), US Environmental Protection Agency (EPA), UK Department for Environment, Food, and Rural Affairs (DEFRA), European Environment Agency (EEA), and other authorities have done much to advance our understanding of flight carbon and energy impacts. But most efforts have treated the aviation industry as a discrete unit or assumed relative uniformity in air travel energy efficiency.

## Efficiency variation

This is one of the first studies to fully address the wide variability in flight efficiency. The dearth of such information has been partly responsible for the lack of nuanced approaches to corporate travel sustainability management discussed above, and for the resulting missed opportunities in business intelligence and effective green management.

**“An efficiency focus reveals opportunities to reduce impact in ways other than cutting flights.”**

The status quo is understandable—ultimately we care about air travel’s total impact, so from the perspective of a government regulator, a climate scientist, or a nascent sustainability program this is the most important figure to track. But from a business intelligence perspective, a singular focus on carbon quantity eclipses what can be an equally enlightening metric—carbon efficiency, measured in emissions per passenger per mile.

Looking at emissions per passenger per mile normalizes for size, allowing us to compare the characteristics of disparate routes, planes, airlines, and corporate travel programs, and expose the underlying components of efficiency. Just as importantly, an efficiency focus uncovers opportunities to reduce impacts in ways other than simply cutting flights.

---

<sup>2</sup> IATA Economic & Social Benefits of Air Transport; Airports Council International World Airport Traffic Report

<sup>3</sup> ICAO Environmental Report 2010; IATA Industry Facts June 2011

<sup>4</sup> ICAO Environmental Report 2010; EEA GHG Inventory; US EPA GHG Inventory

The range in flight efficiency is striking, varying by a factor of more than ten across the industry. A flight in the 10th percentile for efficiency uses more than 2.5 times as much fuel per passenger per mile as a flight in the 90th percentile. The spread in an individual's air travel efficiency is greater still, because seat class choice can increase a passenger's emissions by a factor of almost four.<sup>5</sup>

Given this variation, treating flights as uniform should be no more than a last resort or a crude ballparking measure. To effectively measure and manage flight efficiency, travel and sustainability managers should understand and account for the key factors that cause this enormous variation.

## Modeling air travel impacts

This paper uses detailed modeling to explore the causes and consequences of the dramatic variation in flight efficiency. In the following sections we identify the variables that determine flight efficiency, analyze their relative importance, rank airlines by their

average efficiency, and investigate how efficiency is evolving over time. This insight, coupled with proper intelligence on one's own travel, will help individuals and business travel managers actively consider sustainability alongside cost and convenience when managing and reporting air travel emissions.

The analysis that underlies this paper was performed using the Brighter Planet flight carbon and energy model hosted on the web-based CM1 platform. This model has been certified by the leading validator Det Norske Veritas as complying with the major international carbon calculation standards. It goes far beyond the minimum requirements of those standards, accounting for a flight's aircraft, seating density, load factor, freight share, and distance. Our findings are based on the modeled emissions of 130 million nonstop flights from 2000 through 2010. The data for these flights is sourced from commercial flight censuses by the US Bureau of Transportation Statistics and the International Civil Aviation Organization.<sup>6</sup>

### Snapshot: Analysis

- Based on modeled emissions of 9.7 billion passengers on 130 million flights from 2000 to 2010
- Performed using Brighter Planet CM1 cloud-based carbon models
- Methodology certified by Det Norske Veritas for compliance with Greenhouse Gas Protocol, ISO 14064-1, and Climate Registry GRP standards.



### Snapshot: Data sources

- US Bureau of Transportation Statistics (BTS)
- International Civil Aviation Organization (ICAO)
- European Environment Agency (EEA)
- International Air Transport Association (IATA)
- US Federal Aviation Administration (FAA)
- OpenFlights.org
- Employee flight data from two G500 companies



<sup>5</sup> We do not include the effect of seat class choice in the analysis for this paper, as we only look at variation between rather than within flights. Brighter Planet does account for seat class in flight calculations elsewhere.

<sup>6</sup> See appendix for more details on data sources and flight modeling methodology.

## Case study:

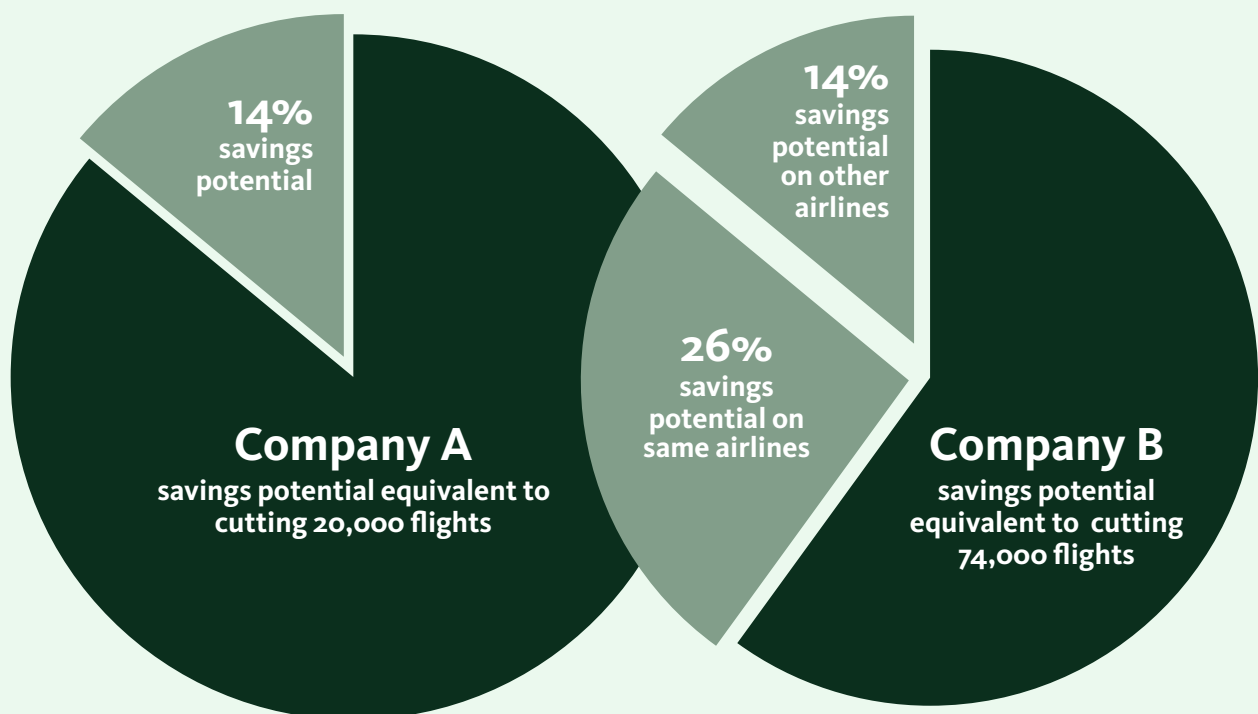
# Opportunity analysis at two G500 companies

Brighter Planet worked with two Global 500 companies to analyze the potential for reducing the environmental impact of their employee air travel. They provided Brighter Planet with data on their 50 or 100 most-traveled routes, representing over 300,000 employee flights, and we used our CM1 web service to calculate emissions for each flight and alternate itineraries serving the same routes.

We found significant savings opportunities—the companies could reduce carbon emissions across the routes we analyzed by up to 40% if they switched from the least efficient to most efficient flights. What's more, we found no significant relationship between ticket price and carbon efficiency, indicating these sustainability gains wouldn't necessarily come at a higher cost.

Most routes offered potential savings—62% of Company A's travel and 97% of Company B's travel was on a route served by a low-carbon alternative flight. Company A could reduce emissions on those routes by 25% if they switched from the highest- to lowest-carbon flights, amounting to a 14% reduction in overall emissions. Company B had the potential to reduce overall emissions by 40%.

Company B also wanted to explore savings opportunities on alternate flights offered by their preferred airlines. We found that 83% of their travel was on routes served by a low-carbon alternative on the same airline. Switching from the most to least efficient flights would reduce emissions across those routes by 35%, amounting to a 26% reduction in total emissions without changing airlines.



**Air travel carbon savings potential at two multi-billion-dollar companies without reducing travel volume, by choosing low-carbon flight alternatives**



# Efficiency drivers

## Five key variables determine a flight's carbon efficiency per passenger per mile: aircraft model, seating density, load factor, freight share, and distance.

Carbon emissions are directly tied to fuel consumption, which for nonstop flights is a function of aircraft model and distance. To calculate emissions per passenger per mile based on a flight's total footprint, freight share is used to deduct non-passenger cargo emissions, and remaining emissions are then divided by the number of passengers on board and the distance flown. The number of passengers is determined by aircraft model, seating density, and load factor (the percentage of seats filled).

Brighter Planet's flight carbon and energy model uses these five factors to calculate emissions from passenger air travel. Since most passengers know only their flight's origin, destination, and airline, we maintain a database of nonstop routes taken from the US BTS T-100 and ICAO TFS that allows the model to look up the flight's aircraft, seating density, load factor, and freight share.

This database currently covers US domestic flights since 2000 and international flights worldwide since 2007. It contains 4.5 million nonstop routes covering 130 million aircraft departures, 9.7 billion passenger enplanements, and 12.8 trillion passenger-miles of travel. The model also calculates the flight distance between origin and destination, using a multiplier to account for real-world routing and circling while waiting for clearance to land.

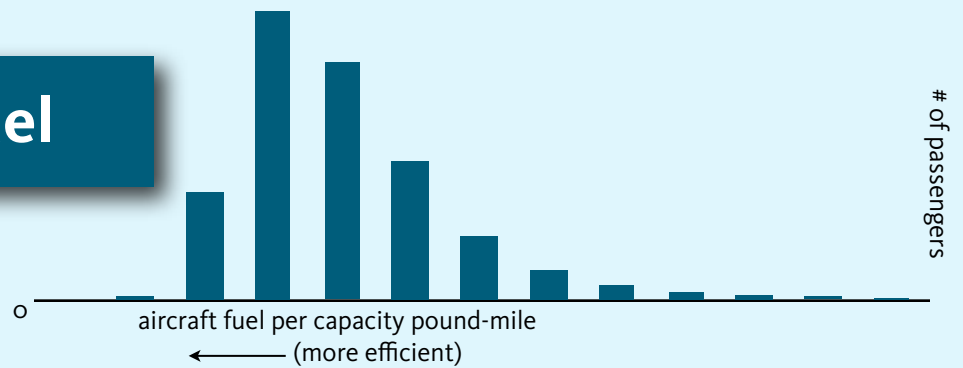
***“ We turned CM1 on itself to analyze efficiency for each of the 4.5 million nonstop routes in our database. ”***

To examine how carbon efficiency and the factors that affect it vary over time and throughout the aviation industry, we turned CM1 on itself and calculated the emissions per passenger per mile, fuel per capacity pound-mile, seating density, and distance for all 4.5 million nonstop routes in our database. When analyzing the results, we weighted each route by the number of passengers carried to show the characteristics of an average passenger's trip.

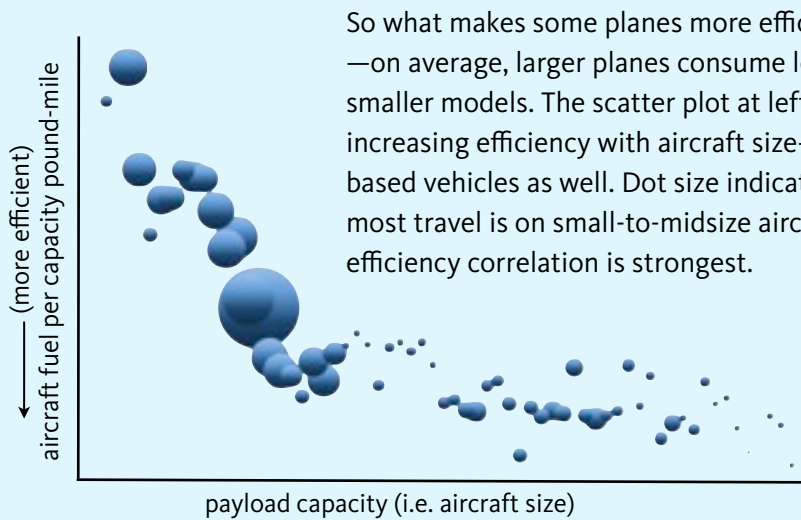
The following pages cover findings for each of the five key efficiency variables, and how they come together to drive overall efficiency variation across the industry and its evolution since 2000.

## Efficiency driver:

# Aircraft model



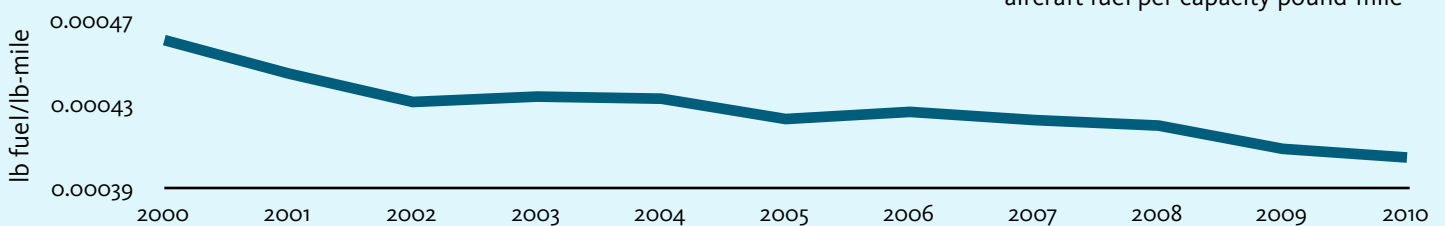
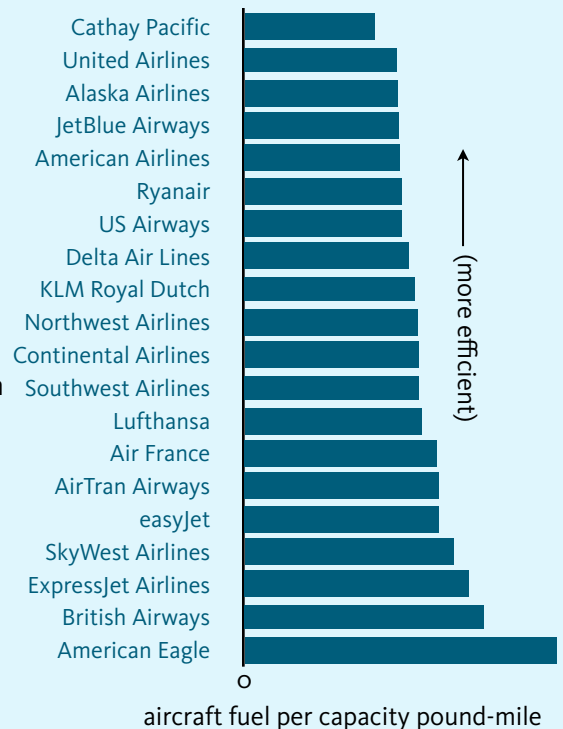
Like cars, planes vary in fuel efficiency. Engine technology, aerodynamics, size, and other factors affect the fuel required to haul a pound of cargo one mile. This variation is significant—an aircraft in the 90th percentile for efficiency uses less than half the fuel per capacity pound-mile as one in the 10th percentile (an aircraft's capacity pound-miles is the total quantity of weight it could carry multiplied by the flight distance).



So what makes some planes more efficient than others? Aircraft size is one factor—on average, larger planes consume less fuel per capacity pound-mile than smaller models. The scatter plot at left shows the loose but clear relationship of increasing efficiency with aircraft size—a familiar relationship for land- and water-based vehicles as well. Dot size indicates total passenger volumes, indicating that most travel is on small-to-midsize aircraft, the range through which size-efficiency correlation is strongest.

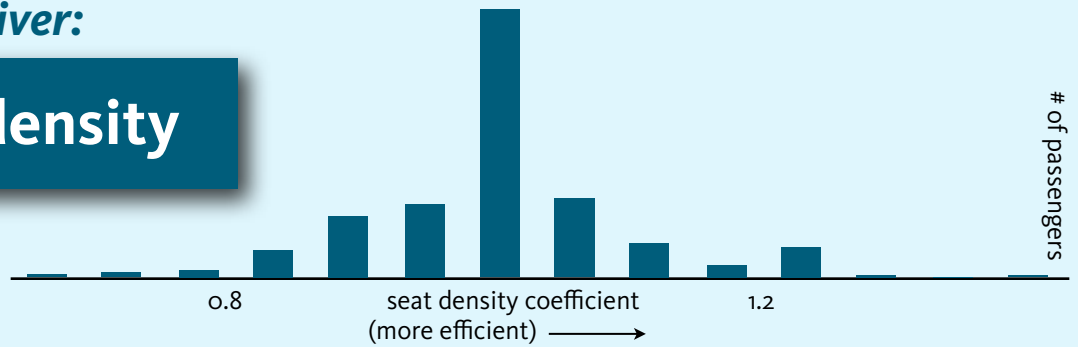
Based on their fleet makeup, airlines vary dramatically in their average aircraft fuel economy. Among the 20 largest airlines, Cathay Pacific and United transport their average passenger on the most efficient planes, while American Eagle and ExpressJet operate the least efficient fleets.

The average passenger in 2010 flew on a plane 12% more efficient than in 2000. This trend will likely continue as aircraft manufacturers compete more fiercely on fuel economy in response to rising oil prices.



## Efficiency driver:

# Seating density



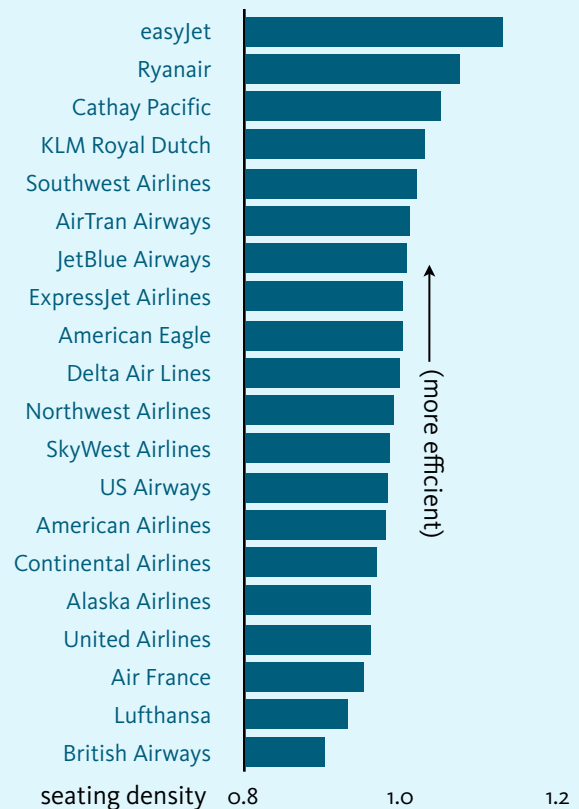
Not all 747-800's are created equal. When an airline takes delivery of a new or refurbished aircraft, the cabin is customized according to the desired size and mix of seats. One airline might choose to outfit their new Airbus A320 with a spacious first class, an economy plus class with extra legroom, and a standard economy class, while another might outfit the same Airbus 320 with the maximum possible number of high-density coach seats. The more passengers a given aircraft model can accommodate, the less fuel used per passenger.

To compare seating density efficiencies across aircraft of different sizes, we calculated a “seat density coefficient” that indicates how the density of seats on a particular plane compares to the industry-wide average for that model of aircraft. If JetBlue fits 156 seats on its Airbus A319 while the average Airbus A319 accommodates only 120 seats, then the JetBlue plane’s coefficient would be  $156/120$ , or 1.3.

Seating density varies significantly across the aviation industry. Among the 20 largest airlines, the average passenger on easyJet and Ryanair see the most efficient cabin configurations, while British Airways and Lufthansa fit the fewest seats onto a given plane.

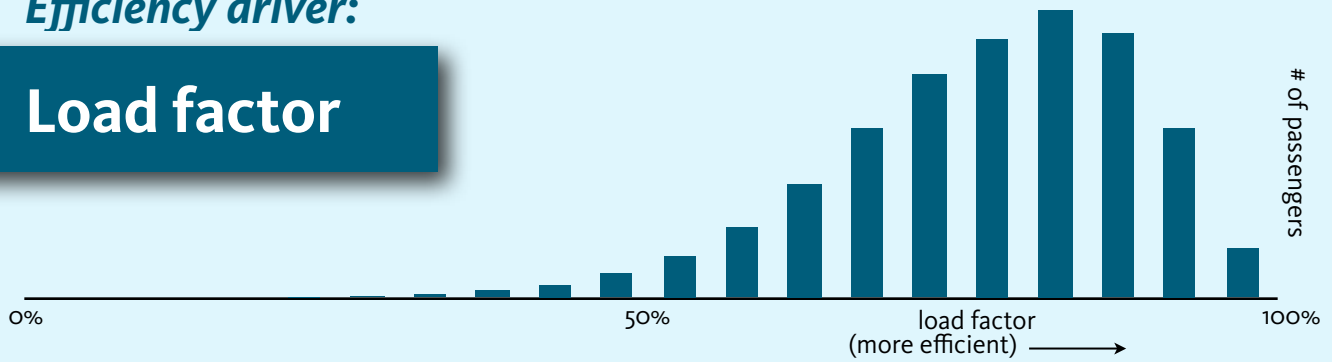
Seat density is closely tied to seat class—a large first or business class section dramatically lowers an aircraft’s seat density. This paper only looks at variation between flights, so we distinguish between aircraft that contain a larger or smaller first class section, but don’t address the effect on an individual’s footprint of choosing a first

class seat versus economy. But travelers looking to limit their flight footprint should clearly remember that economy seats have a much smaller impact than business or first class seats. The Brighter Planet CM1 flight carbon and energy model does take this into account.



## Efficiency driver:

# Load factor



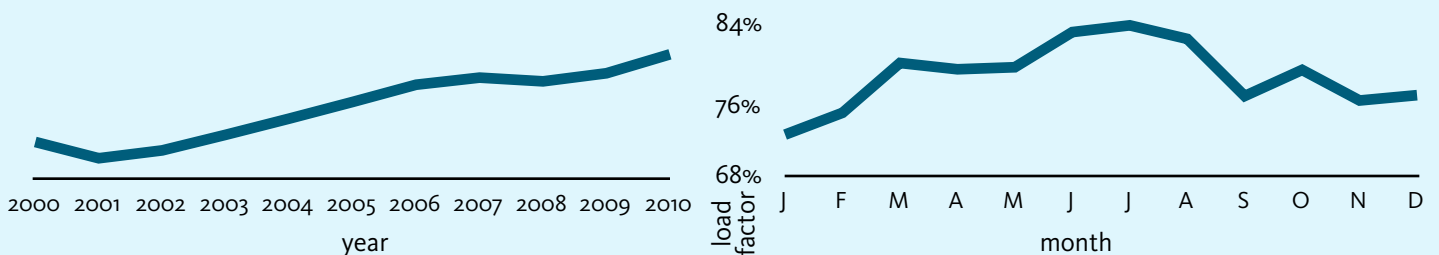
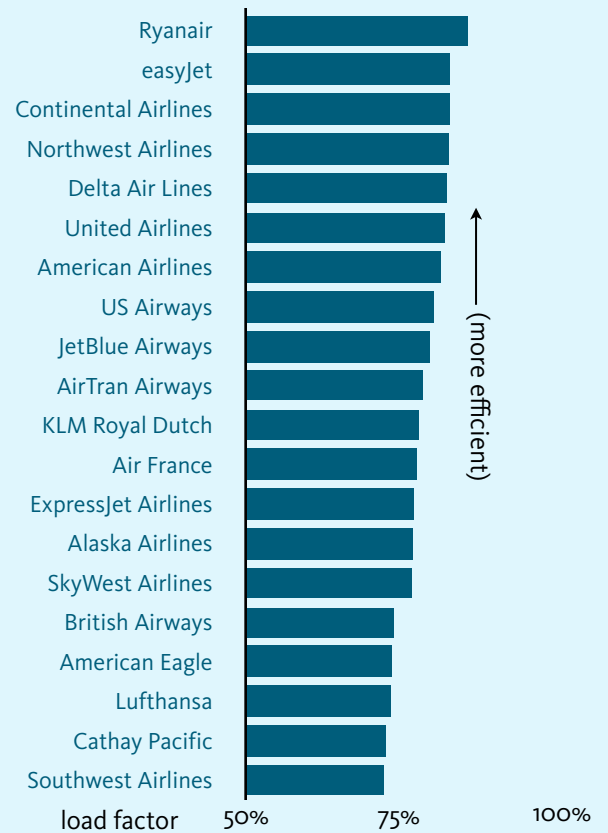
Passenger load factor—the portion of available seats filled on a given flight—has a major influence on each passenger’s footprint, because total emissions are divided among the passengers on board. Fewer occupied seats means a larger share assigned to each person.

The average passenger travels on a flight that’s 80% full, while the average flight is 74% full. But load factor varies significantly across the aviation industry—a flight in the 90th percentile for load factor is more than 1.5 times as full as one in the 10th percentile.

An airline’s average load factor is a major driver of overall competitiveness on efficiency per passenger per mile. Among the 20 largest airlines globally, Ryanair and easyJet have the highest load factors, or fewest empty seats, while Southwest and Cathay Pacific have the lowest load factors.

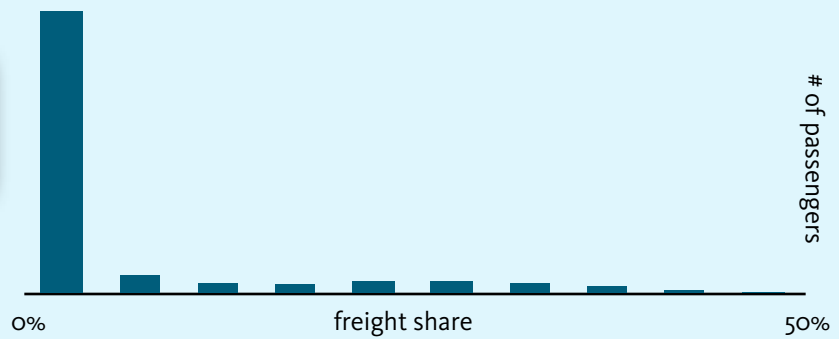
Seat occupancy rates have risen steadily over the past decade, increasing from an average of 70% in 2001 to 81% in 2010—an improvement of more than 1% per year. No other efficiency driver has seen this rate of progress. While room remains for this trend to continue, load factor gains eventually will come up against limits.

Unlike most of the other efficiency drivers, load factor varies seasonally. Average load factor follows a predictable annual cycle independent of longer trends, reaching peak efficiency in summer months and seeing the largest number of empty seats in winter.



## Efficiency driver:

# Freight share

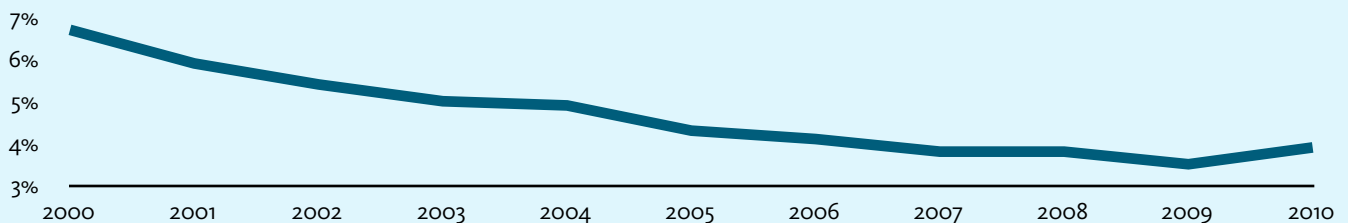
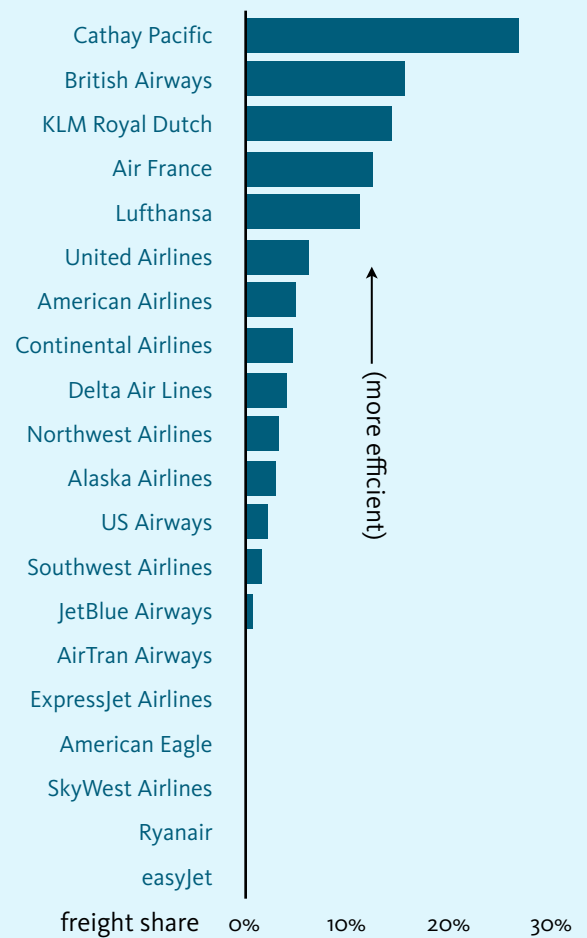


A full 78% of commercial passenger flights carry extra cargo beyond passengers and their baggage—typically mail or other commercial freight—and this weight claims a share of the flight’s footprint, reducing the share for which passengers are responsible.

Flight emissions are allocated between passengers and freight according to weight. A flight’s “freight share” is the portion of its total payload comprised of freight, with the remainder consisting of passengers and baggage.

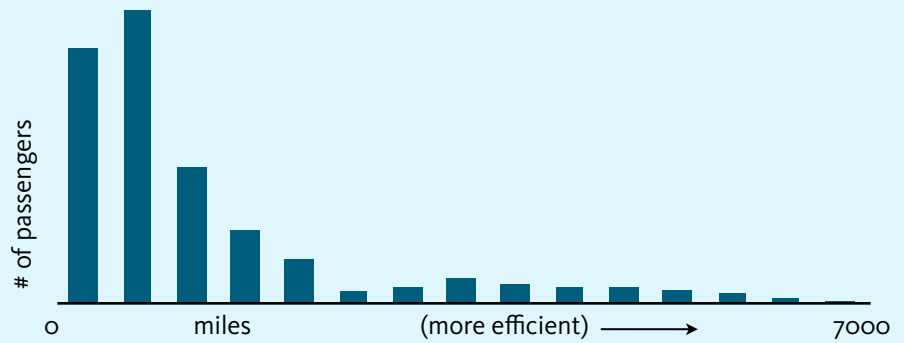
While the vast majority of flights carry extra freight, they typically carry only a small amount. The average freight share is less than 5% of total payload, which translates to a minimal impact on traveler footprints. But for the small portion of passenger flights that do carry significant amounts of commercial cargo, it can have an important effect on passenger emissions.

Freight share is getting smaller by the year. Between 2000 and 2010, average freight carried was cut nearly in half. This trend corresponds with an increase in passenger load factor, suggesting the possibility that freight is being supplanted by passengers with little net effect on efficiency. But correlation analysis shows the two trends are almost entirely independent (the weighted correlation coefficient is just -0.05), with freight share decreases happening in different segments of the market from load factor increases. Freight share is generally higher on international flights, so the declining trend in freight share may be accompanied by an increase in emissions per passenger per mile on these flights.

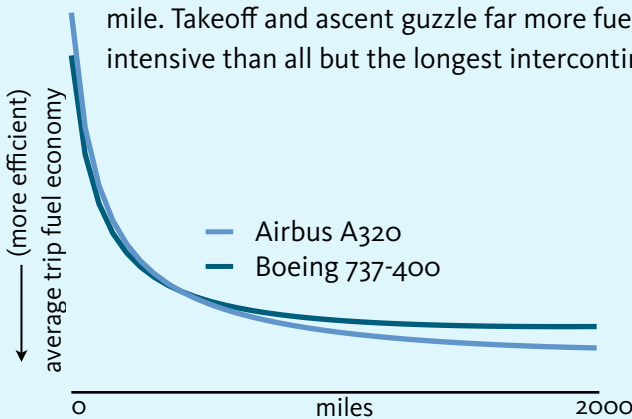


## Efficiency driver:

# Distance



Commercial passenger routes cover the full spectrum of distances from short hops to antipodal hauls. It almost goes without saying that distance traveled is the single most important determinant of a passenger's total flight footprint, and nearly every flight carbon calculator takes it into account. But what's less intuitive, and less often accounted for, is that distance also affects *efficiency*—fuel used per mile. Takeoff and ascent guzzle far more fuel than cruising at altitude, making short flights more fuel-intensive than all but the longest intercontinental flights, where fuel weight reduces efficiency.

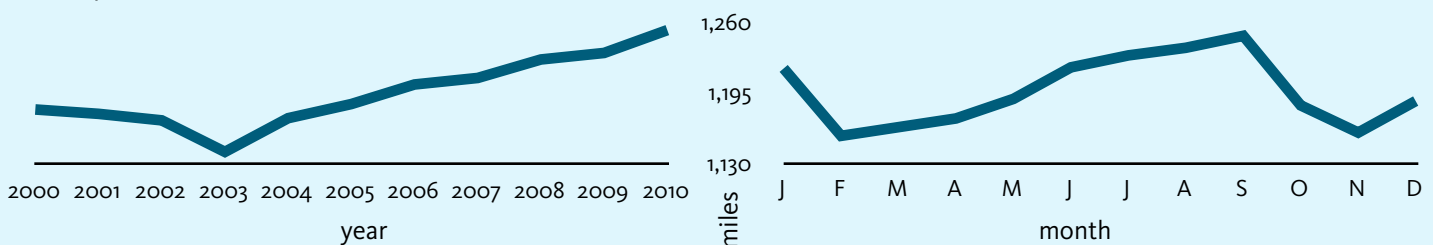
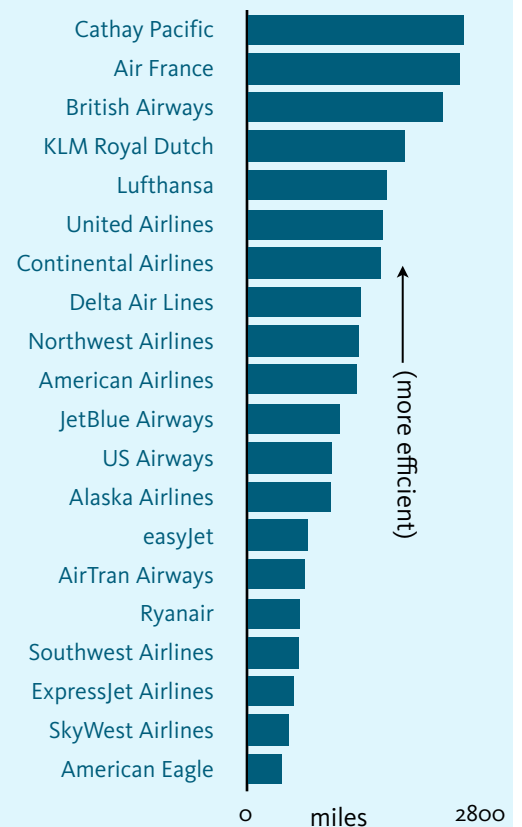


This analysis only looks at nonstop flights, but adding stopovers between origin and final destination has a double effect on emissions—a stop is certain to increase the total distance flown, and it breaks a single flight into two shorter flights, decreasing the efficiency of each.

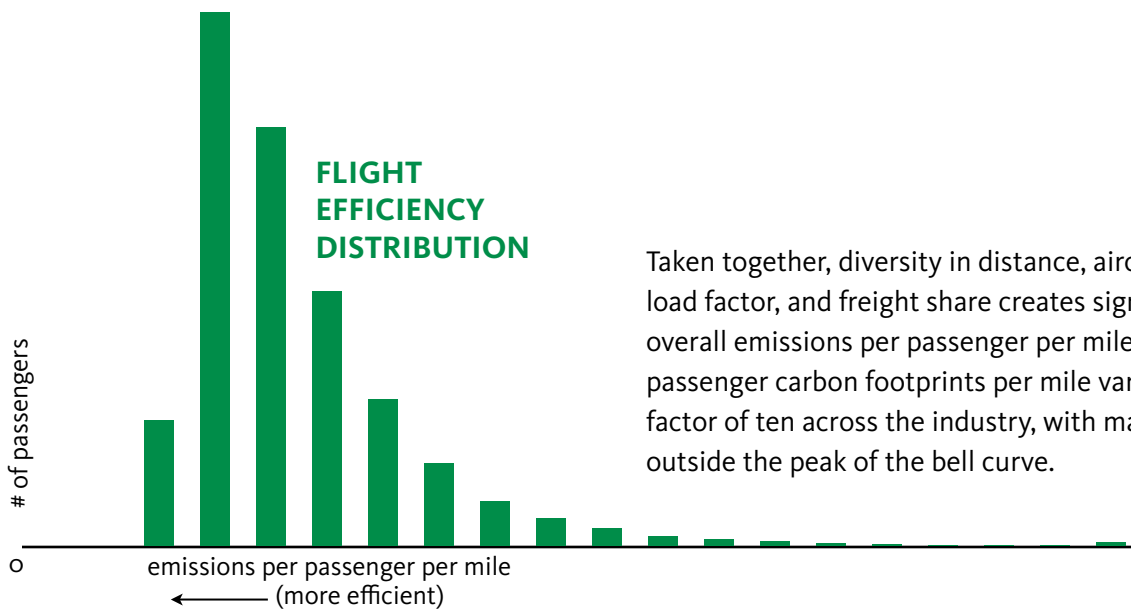
An aircraft's fuel use can be modeled as a complex mathematical equation that accounts for the changes in efficiency over the different flight stages. As the above chart shows, efficiency on a long trip can be many times higher than on a short flight.

Most passengers travel less than two thousand miles, but it's a long-tailed distribution, with significant numbers of flights at much longer distances. Organizations whose employees typically fly long distances without stopovers—and airlines that disproportionately cover longer routes—end up more fuel-efficient than their counterparts.

Average flight length has increased steadily since 2003, due perhaps in part to airlines shifting away from inefficient shorter routes to keep pace with rising fuel costs. Regardless of the cause, a continuation of this trend would mean increased efficiency across the industry in coming years. Average flight distance also fluctuates seasonally, with peaks in summer and winter.



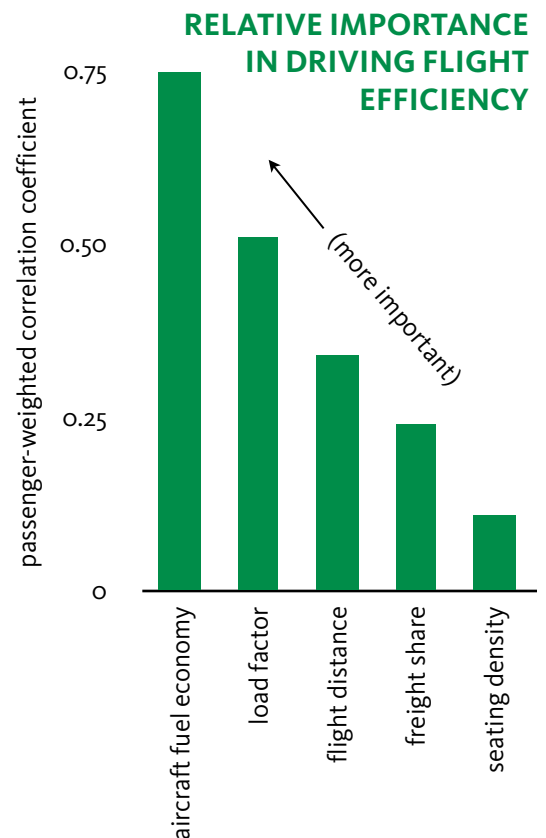
# Overall efficiency



Taken together, diversity in distance, aircraft, seating density, load factor, and freight share creates significant variation in overall emissions per passenger per mile.<sup>7</sup> To reiterate, passenger carbon footprints per mile vary by more than a factor of ten across the industry, with many flights falling outside the peak of the bell curve.

Although each of the five factors can theoretically have a large effect on efficiency, their real world importance is in fact hardly uniform. The data show that some factors are much bigger drivers of efficiency variation than others, with the correlation coefficient (measuring the strength of the relationship between each variable and final flight efficiency) varying significantly among the five factors. Aircraft fuel economy shows the strongest correlation with emissions per passenger per mile, while seat density coefficient is the weakest predictor of a flight's overall efficiency.

Selecting flights with high load factors and efficient aircraft models is a better strategy for minimizing emissions than choosing itineraries based on seating density and freight share—although accounting for all factors is the only way to ensure robust reporting and management. Distance is typically a given when selecting a flight, but it's worth noting that nonstop flights are more efficient because relative to indirect flights they increase efficiency while decreasing total distance.



<sup>7</sup> Factoring in seat class, which is not accounted for here, would make this spread greater still.

## Case study:

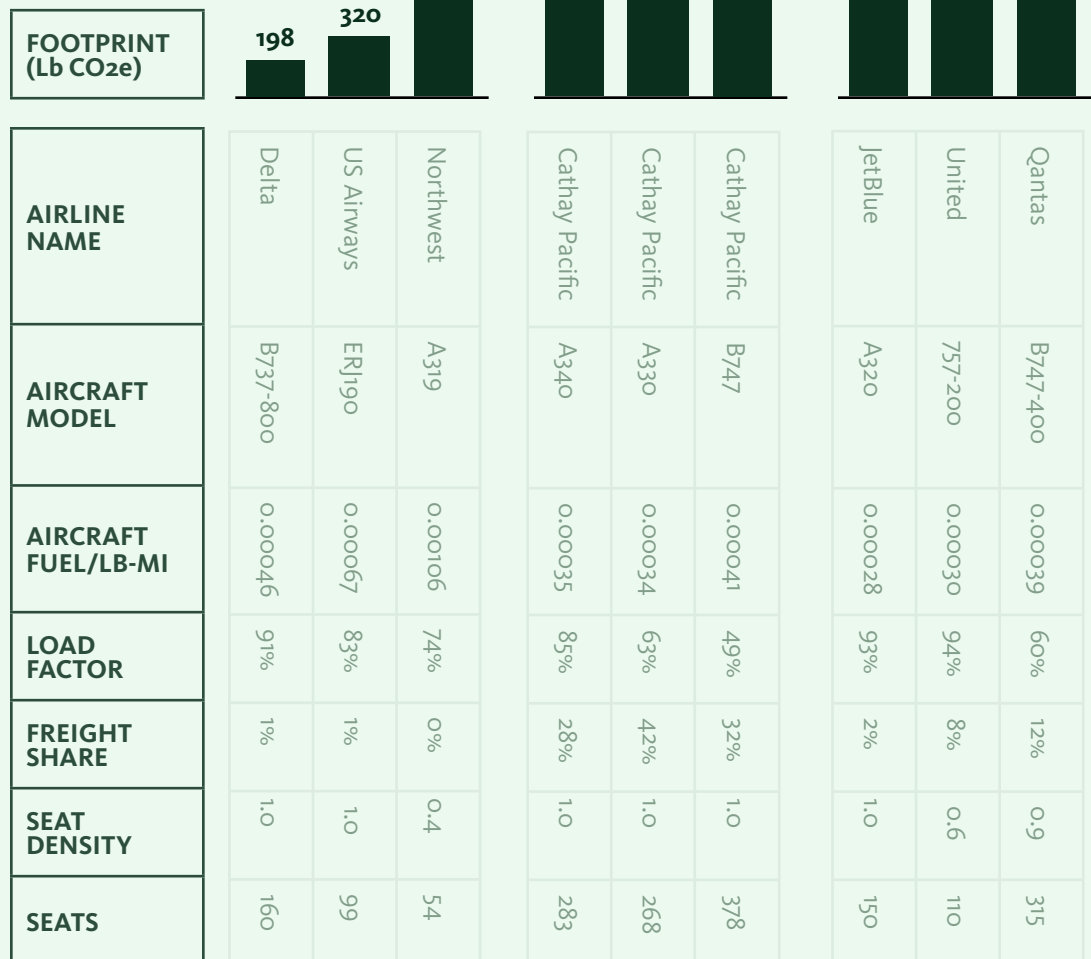
# Flight footprint comparison

The following real-world flights show the footprint variation for three sample city pairs. In each case, the least efficient flight emits at least twice as much as the most efficient. For example, the flight from N.Y. to L.A. on Qantas has almost three times the impact as the JetBlue flight. That's because the Qantas plane is larger and less efficient, burning 40% more fuel per capacity pound-mile, and it is half empty, only carrying 44 more passengers than the JetBlue flight. The second example shows the variation that often exists even within a single airline.

## 2640 miles NEW YORK to LOS ANGELES

## 1320 miles MUMBAI to DUBAI

## 243 miles CHARLOTTE to ATLANTA





# Airline efficiency rankings

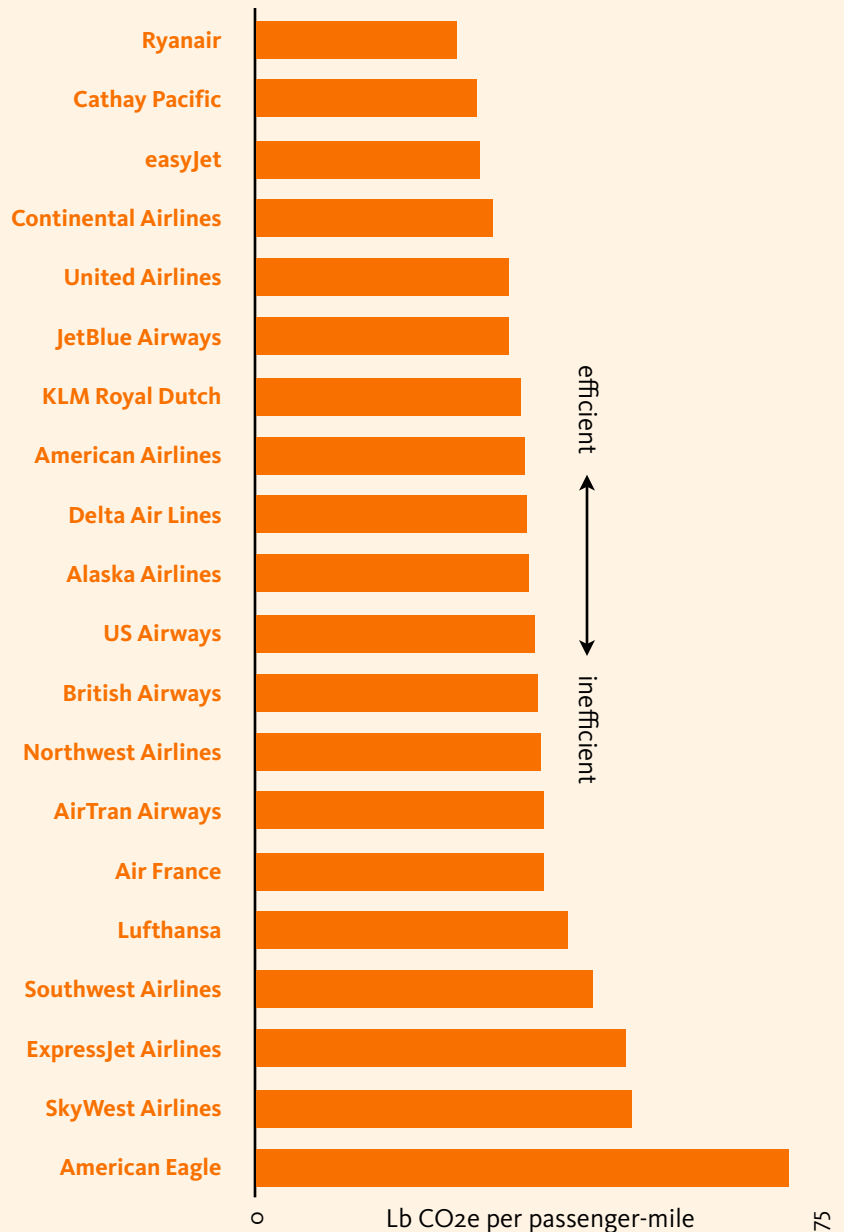
Some airlines are much more successful at optimizing efficiency than others. This study is far from the first to rank airlines on sustainability, but few predecessors have accounted for passenger volumes and all five efficiency drivers to provide as accurate a rating on real-world emissions per passenger per mile.

Among the 20 largest airlines by passenger volume, the cleanest, Ryanair, uses barely more than a third the fuel to transport its average passenger one mile compared to the least efficient, American Eagle. From a business perspective, as from an environmental one, this is nontrivial—higher efficiency is a boon that allows airlines to pass financial and environmental savings on to their customers.

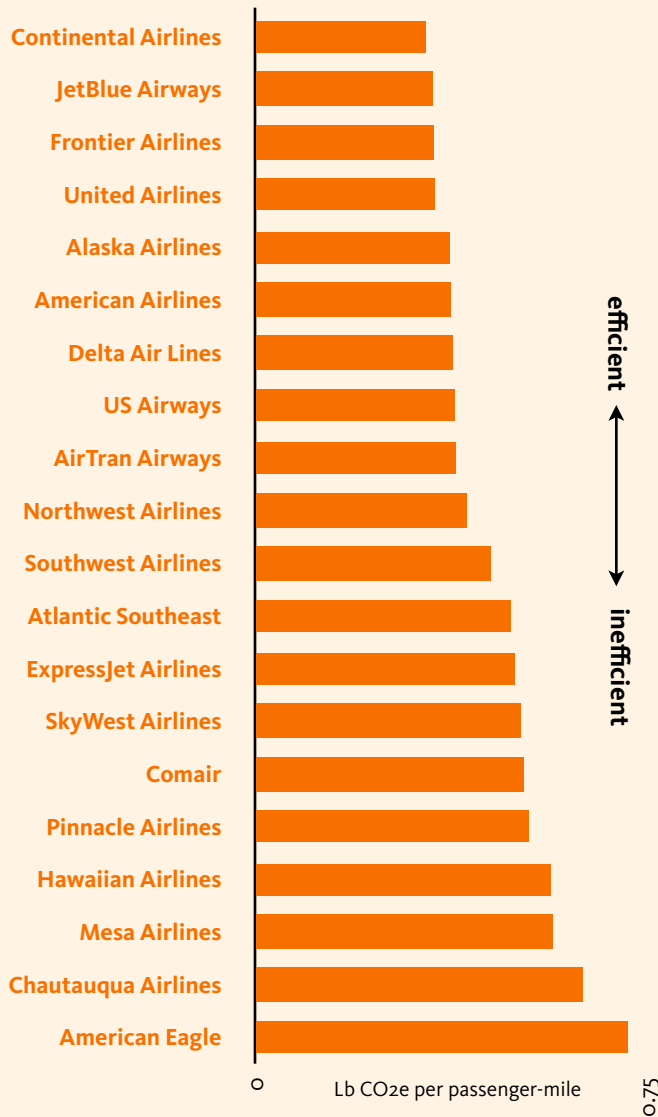
Ryanair succeeds by ranking first or second for efficiency in load factor and seating density, while runner-up Cathay Pacific ranks first on aircraft fuel economy, distance, and freight share.

It should be kept in mind that while enormous efficiency variation exists among airlines, the same is true within each airline. While the airline averages presented here are insightful in understanding air travel dynamics, using them in calculations for any specific flight commits the same error as failing to account for efficiency variation in the first place.

## OVERALL INDUSTRY

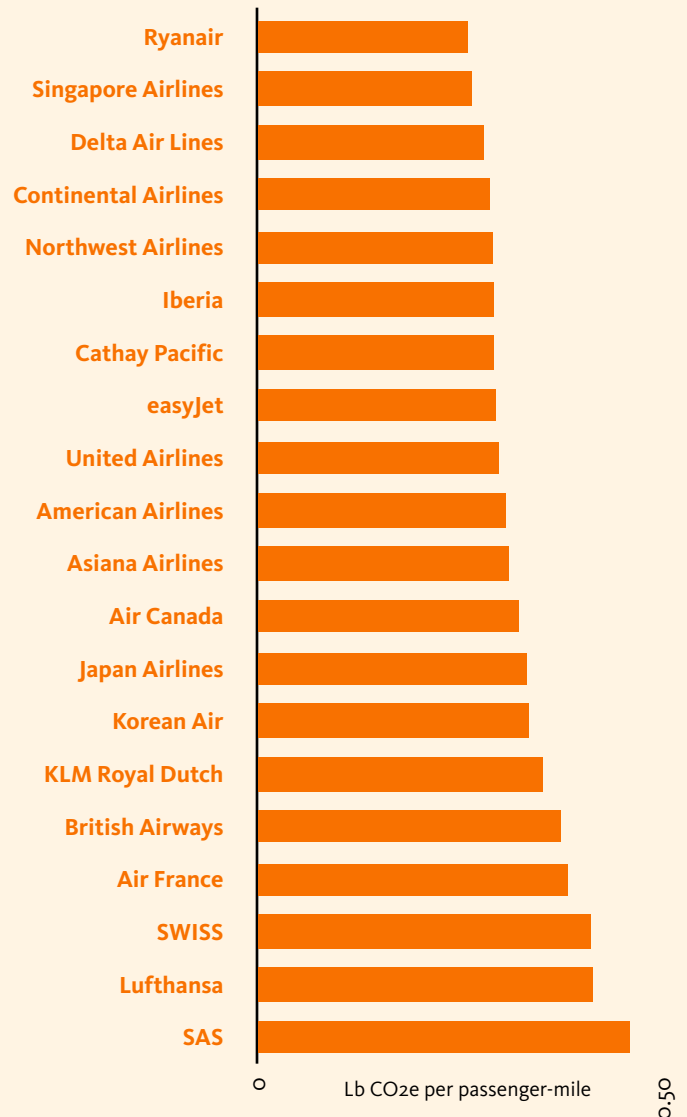


## U.S. DOMESTIC MARKET



In the US domestic market, the picture is similar. Among the 20 largest airlines, Continental, JetBlue, and Frontier take the top three spots, while Mesa, Chautauqua, and American Eagle place last. These least efficient airlines are all regional carriers specializing in shorter flights on smaller aircraft—characteristics that predispose them to inefficiency.

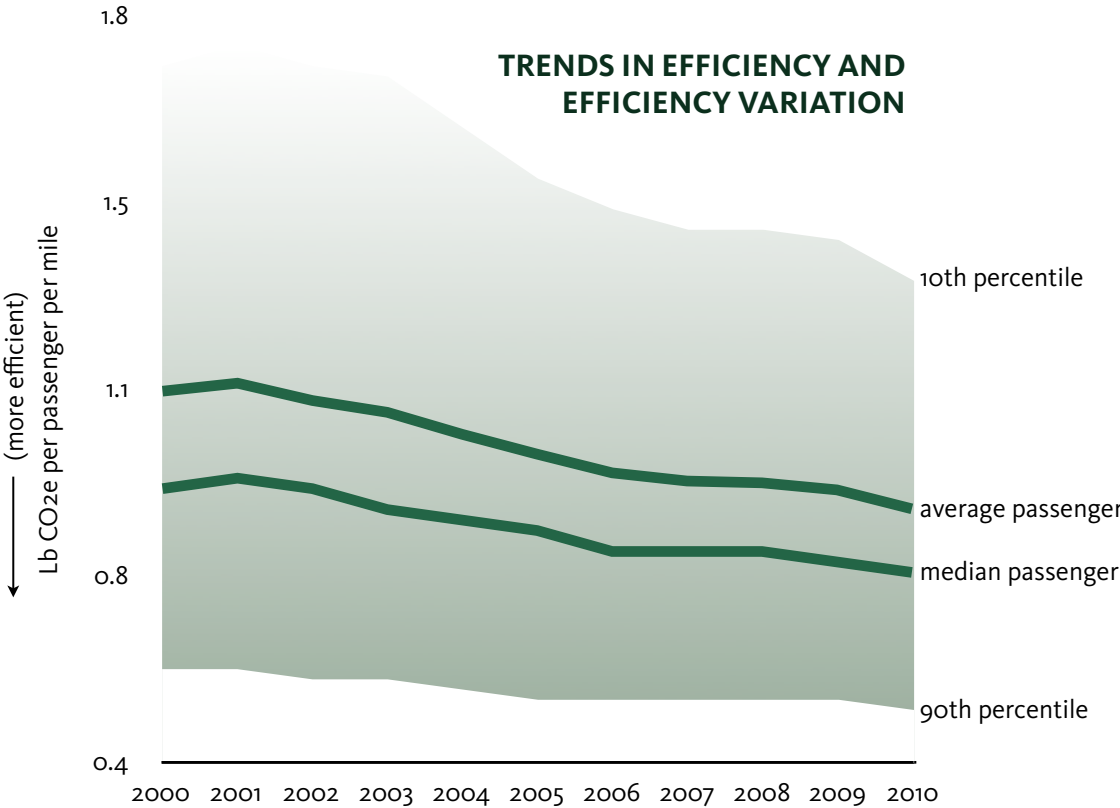
## INTERNATIONAL MARKET



Passenger air travel in the global international market is, on average, more efficient than in the US domestic market—again, a discrepancy due in part to flight distance and aircraft size. Ryanair, Singapore Airlines, and Delta take the top spots in this sector while SAS, Lufthansa, and SWISS bring up the rear as least efficient of the 20 largest airlines.

# Industry trends

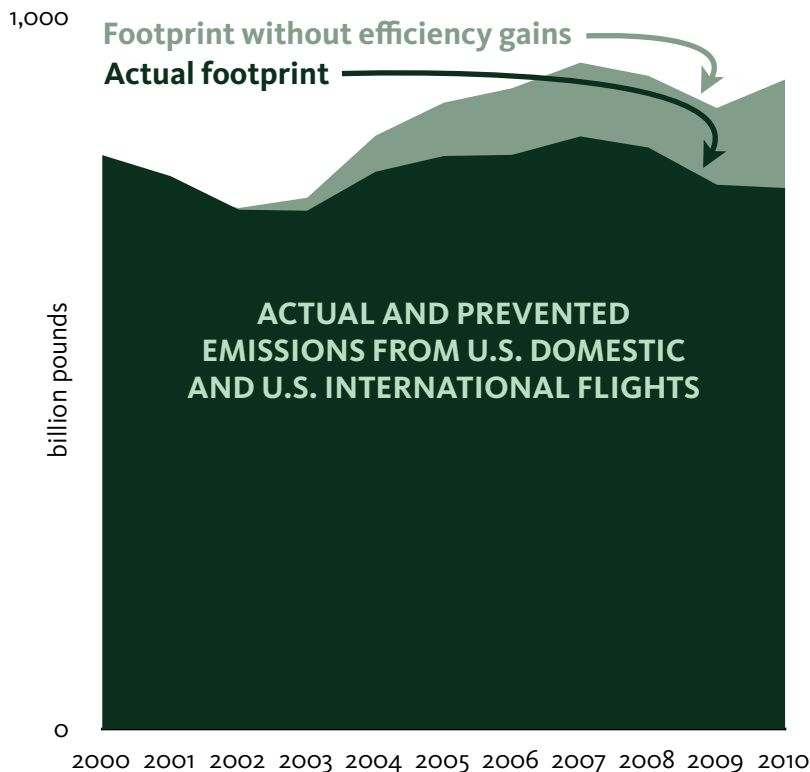
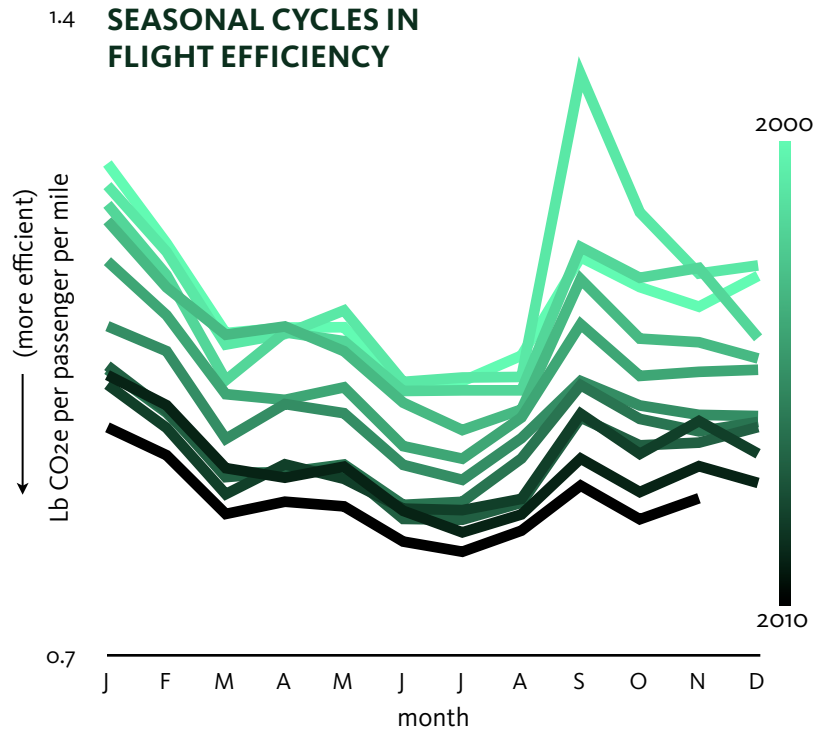
Global air travel efficiency has increased markedly over the last decade, driven by improvements in aircraft fuel economy, load factor, and flight distance, the three top drivers. All told, in 2010 it took 20% less fuel to transport the average passenger one mile than in 2000.



As emissions per passenger per mile has decreased, so too has efficiency variation across the market. While the spread between the 10th and 90th percentile passengers remains very large, it has slowly narrowed, with efficiency improving more rapidly among the dirtiest flights than the cleanest ones. This makes sense, as the least efficient end of the market has ample room for improvement in multiple areas, whereas more efficient flights are closer to natural limits and have less room for improvement outside slowly evolving variables like aircraft fuel economy.

Still, the inexorable rise in oil prices, the increased efficiency emphasis by aircraft manufacturers, the novel routing and air traffic control technologies currently under development, and the prospect of airline carbon regulation in Europe mean potential is strong for sustained or even accelerated efficiency gains over the coming decade.

In addition to having improved year-over-year, average efficiency also fluctuates month-to-month—at peak efficiency in July, the average passenger’s trip is 15–20% cleaner per mile than in January.<sup>8</sup> Load factor and distance are the main drivers of this cycle, as aircraft, seat density, and freight share show very little monthly variation. The chart at right shows seasonal efficiency cycles from left to right, and also shows the improvement in efficiency each year as lines move downward. (Note the temporary spike following the September 11, 2001 terrorist attacks, due to decreased load factors.)



Efficiency improvements between 2000 and 2010 made a very real impact on greenhouse gas emissions volumes, preventing 670 billion pounds of CO<sub>2</sub>e over that period from US flights alone—roughly an entire year’s worth of US air travel. This saved airlines 16 billion gallons of jet fuel valued at over \$33 billion<sup>9</sup>, an expense that would presumably have been passed on to travelers in the form of substantial airfare increases at a time when travelers and travel providers were already struggling in an ailing economy.

<sup>8</sup> Studies suggest the phenomenon of higher-impact winter flights may be further exacerbated by seasonal variation in radiative forcing effects, increasing the importance of taking time of year into account when measuring and managing air travel climate impact (Stuber et al. 2006).

<sup>9</sup> Based on US Energy Information Association jet fuel pricing data.

## Latent opportunity

Travelers have great potential to achieve sustainability goals by leveraging the variation in efficiency among flights—a potential only a few leading organizations have begun to exploit. By adopting best practices to optimize for efficiency in air travel carbon management, sustainability officers, travel managers, and individuals can see significant sustainability gains.

Air travel carbon efficiency accounting can be a major part of an organization's sustainability strategy, helping increase the legitimacy of reporting, identify carbon savings not apparent in cruder analyses, and drive emissions reductions through selection of lower-impact flights during the procurement process.

Without an awareness of efficiency variation, the only recourse for businesses and individuals to reduce air travel emissions is a reduction in air travel. While cutting flights can and should be a part of sustainability strategies, it is often an impractical approach that can lead to resignation for travelers who are forced to fly. Selecting flights based on efficiency adds a new, complementary tool to the sustainability toolkit, empowering travelers to more effectively manage their impact.

***“ Selecting flights based on efficiency adds a new, complementary tool to the sustainability toolkit, empowering travelers to more aggressively manage their impact. ”***

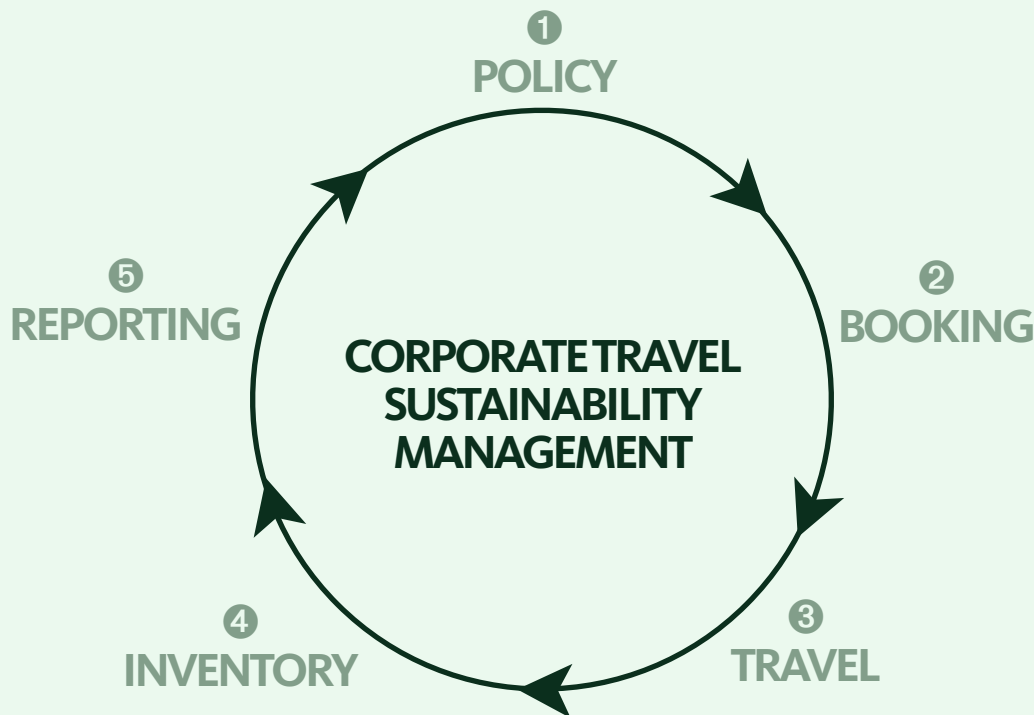
Preliminary analysis suggests there's no clear relationship between fuel efficiency and ticket price, indicating these carbon gains don't have to come at higher cost. This could be due to two opposing factors: on the one hand, airlines could be expected to reduce prices on efficient flights where costs per passenger are lower, as a competitive measure to win customers; on the other hand, the fullest flights, which are relatively efficient because of high load factors, are often priced higher due to supply and demand. In the end, the issue of air travel pricing strategies is a very complex one that demands detailed investigation beyond the scope of this paper.

In addition to slashing their own travel footprints, increased traveler focus on flight efficiency also has the potential to accelerate sustainability progress in the airline industry as a whole. Major organizations making travel procurement decisions based not just on price and convenience but also carbon could add a powerful market signal driving competition among air travel providers. Airlines, booking agencies, and aircraft manufacturers that can succeed in meeting fuel economy demands of the coming decades stand to gain enormous competitive advantages.

## Best practices:

# Business air travel carbon management

- ① Pursue carbon reduction goals through both increases in air travel efficiency and reduction in air travel volume.
- ② Implement proactive footprint calculation that allows carbon to be considered alongside price and convenience during booking.
- ③ Engage employees in meeting travel sustainability goals via education and incentives.
- ④ Account for each flight's unique aircraft, load factor, and other characteristics rather than treating all flights as generic.
- ⑤ Set goals for, measure, and report emissions per passenger per mile in addition to total emissions.



# Appendices

## Methodology notes

The flight carbon and energy model used to calculate emissions for this analysis has been reviewed in detail by leading carbon validator Det Norske Veritas, and certified as compliant with the Greenhouse Gas Protocol, ISO 14064, and the Climate Registry, three leading international carbon accounting standards.

Airline industry data used in this analysis come from BTS and ICAO, the authoritative sources for air travel data. The combined database, with 4.5 million nonstop routes, covers international flights worldwide since 2007 and domestic flights in the US since 2000; non-US domestic flights and any international flights not reported to ICAO are not included.

Long-term trend analysis of market evolutions since 2000 is based on domestic and international flights at US airports. All other analyses, including airline rankings, are based on US and global data from 2007 through 2009, the latest years for which complete data is available.

Unless expressly noted, all averages reported in charts and figures are weighted by passenger volume to reflect the likelihood of any given passenger falling on a given flight.

Brighter Planet uses a multiplier of 2.0 in all our flight emissions calculations to account for extra climate impact beyond the standard warming caused by carbon dioxide. This impact is caused by the complex effects of water vapor and engine exhaust at high altitudes. The exact magnitude of these effects is still the subject of research, but authorities agree that the net result is increased warming. A multiplier of two is a widely-recommended best estimate<sup>10</sup>, and we use it on the basis that it is preferable to possibly overestimate the emissions of some flights than to certainly underestimate the emissions of all flights. Since the multiplier is a constant applied to every calculation, it does not affect the concepts, rankings, or trends described in this paper.

---

<sup>10</sup> Stockholm Environment Institute; GHG Management Institute

## CM1 overview

Brighter Planet CM1, the software platform used to perform the calculations for this report, is a cloud-based web service designed to enable flexible, accurate footprint analysis across a wide range of emissions sources. Learn more at <http://carbon.brighterplanet.com/>.

CM1 flight carbon and energy model performance for this analysis	
Total nonstop routes processed	4,479,135
Sub-calculations per emissions computation	21
Emissions computations per second	63
Total processing time	15 hours
External data references	36

## References

**The sources for outside statistics cited in this report and for raw data powering the CM1 flight carbon and energy model are as follows:**

Airports Council International (ACI)

- World Airport Traffic Report for 2009 ([http://www.airports.org/cda/aci\\_common/display/main/aci\\_contento7\\_c.jsp?zn=aci&cp=1-5-54\\_666\\_2\\_](http://www.airports.org/cda/aci_common/display/main/aci_contento7_c.jsp?zn=aci&cp=1-5-54_666_2_))

Carbon Disclosure Project (CDP)

- 2010 Global 500 Report (<https://www.cdproject.net/en-US/Results/Pages/All-Investor-Reports.aspx>)
- 2009 Global 500 Report (<https://www.cdproject.net/en-US/Results/Pages/All-Investor-Reports.aspx>)

European Environment Agency (EEA)

- Air Pollution Emission Inventory Guidebook 2009 (<http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009>)
- Annual European Union Greenhouse Gas Inventory 1990–2009 and Inventory Report 2011 (<http://www.eea.europa.eu/publications/european-union-greenhouse-gas-inventory-2011>)

International Air Transport Association (IATA)

- Airline Codes (<http://www.iata.org/ps/publications/Pages/code-search.aspx>)
- Fact Sheet: Economic & Social Benefits of Air Transport ([http://www.iata.org/pressroom/facts\\_figures/fact\\_sheets/Pages/economic-social-benefits.aspx](http://www.iata.org/pressroom/facts_figures/fact_sheets/Pages/economic-social-benefits.aspx))
- Industry Statistics June 2011 ([http://www.iata.org/pressroom/facts\\_figures/fact\\_sheets/Documents/Industry-Facts-June2011.pdf](http://www.iata.org/pressroom/facts_figures/fact_sheets/Documents/Industry-Facts-June2011.pdf))



#### International Civil Aviation Organization (ICAO)

- Carbon Emissions Calculator Methodology (<http://www2.icao.int/en/carbonoffset/Documents/ICAO%20MethodologyV3.pdf>)
- Environmental Report 2010 (<http://www.icao.int/env/Pubs/EnvReport10.htm>)
- Traffic by Flight Stage (TFS) (<http://icaodata.com/default.aspx>)

#### International Organization for Standardization (ISO)

- Country Codes ([http://www.iso.org/iso/english\\_country\\_names\\_and\\_code\\_elements](http://www.iso.org/iso/english_country_names_and_code_elements))

#### Kettunen et al. (2005)

- Flight Efficiency Studies in Europe and the United States ([http://www.atmseminar.org/seminarContent/seminar6/papers/p\\_055\\_MPM.pdf](http://www.atmseminar.org/seminarContent/seminar6/papers/p_055_MPM.pdf))

#### OpenFlights.org

- Airports Database (<http://openflights.org/data.html#airport>)

#### Stockholm Environment Institute (SEI) and GHG Management Institute (GHGMI)

- Kollmuss & Crimmins (2009): Carbon Offsetting & Air Travel Part 2: Non-CO<sub>2</sub> Emissions Calculations (<http://sei-us.org/publications/id/13>)

#### Stuber et al. (2006)

- The importance of the diurnal and annual cycle of air traffic for contrail radiative forcing (<http://www.nature.com/nature/journal/v441/n7095/abs/nature04877.html>)

#### U.S. Bureau of Transportation Statistics (BTS)

- Aircraft Type Lookup ([http://www.transtats.bts.gov/Download\\_Lookup.asp?Lookup=L\\_AIRCRAFT\\_TYPE](http://www.transtats.bts.gov/Download_Lookup.asp?Lookup=L_AIRCRAFT_TYPE))
- Carrier Code Lookup ([http://www.transtats.bts.gov/Download\\_Lookup.asp?Lookup=L\\_CARRIER\\_HISTORY](http://www.transtats.bts.gov/Download_Lookup.asp?Lookup=L_CARRIER_HISTORY))
- DB1B Airline Origin and Destination Survey ([http://www.transtats.bts.gov/DatabaseInfo.asp?DB\\_ID=125](http://www.transtats.bts.gov/DatabaseInfo.asp?DB_ID=125))
- Air Carrier Statistics (T-100) ([http://www.transtats.bts.gov/DatabaseInfo.asp?DB\\_ID=111](http://www.transtats.bts.gov/DatabaseInfo.asp?DB_ID=111))

#### U.S. Energy Information Administration (EIA)

- Monthly Energy Review (<http://www.eia.gov/mer/contents.html>)
- Annual U.S. Kerosene-Type Jet Fuel Retail Sales by Refiners ([http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=EMA\\_EPJK\\_PTG\\_NUS\\_DPG&f=A](http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=EMA_EPJK_PTG_NUS_DPG&f=A))

#### U.S. Environmental Protection Agency (EPA)

- Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2008 ([http://www.epa.gov/climatechange/emissions/usgginv\\_archive.html](http://www.epa.gov/climatechange/emissions/usgginv_archive.html))

#### U.S. Federal Aviation Administration (FAA)

- JO 7340.2B Contractions ([http://www.faa.gov/air\\_traffic/publications/atpubs/CNT/5-2.htm](http://www.faa.gov/air_traffic/publications/atpubs/CNT/5-2.htm))