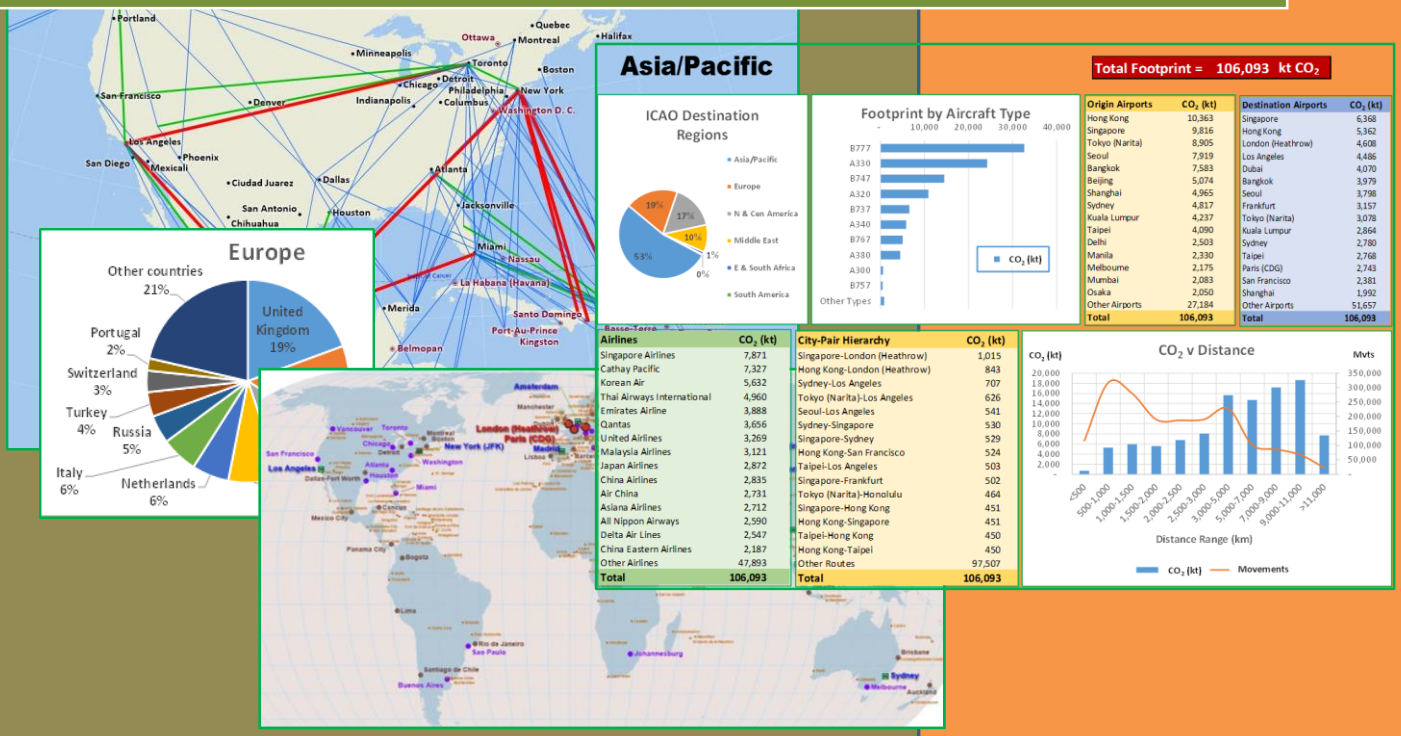
Aviation Carbon Footprint

Global Scheduled International Passenger Flights - 2012



This report provides a detailed breakdown of CO_2 emissions from global scheduled international passenger aircraft operations in 2012. The carbon footprint of the operations is disaggregated at the regional, country and airport level. The footprint is also examined from the perspective of the airlines. In addition, the document provides a breakdown of the carbon costs and revenues associated with scheduled international passenger operations.

Dave Southgate

April 2013

FOREWORD

In October 2012 I published a document examining the carbon footprint of Australian aircraft operations – *The Carbon Footprint of Aircraft Operations in Australia* – 2011. This report on the global footprint of scheduled international passenger operations builds on that earlier work. I have tried as far as possible to retain the style and feel of the original document by adopting the same data analysis approaches and by using similar visualisations to present the information.

Due to data constraints, the footprinting in this report relates only to global scheduled international passenger operations. It is estimated that this captures about 80% of the total carbon footprint for international aircraft operations. The carbon footprint of international aviation is currently an issue of key importance due to the anticipated discussions on climate change at the upcoming meeting of the International Civil Aviation Organization (ICAO) Assembly in September 2013.

The document does not suggest policy options for managing international aviation's carbon footprint but rather is intended as a data resource to assist deliberations on options for addressing the issue. The carbon footprint information is presented in a number of different graphical formats. I hope this will generate debate on ways in which ongoing footprint reports for international aviation can be presented. Clearly any climate change management regime for international aviation will need to include a comprehensive and transparent measurement, reporting and verification system.

The information in the document has been generated from a publicly available dataset of global international scheduled passenger services in 2012. The data analysis and report generation has been carried out using readily available software applications.

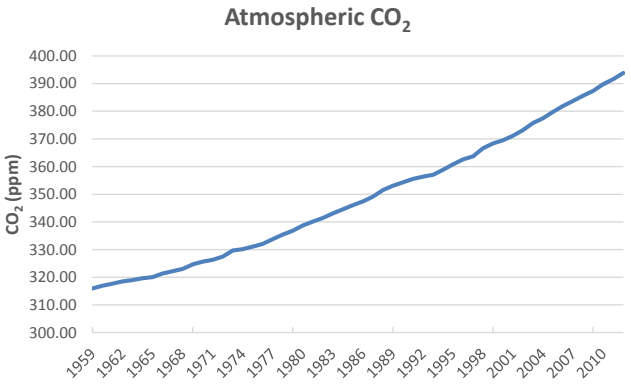
Dave Southgate

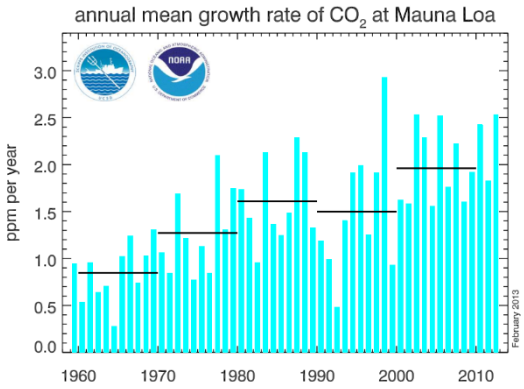
Canberra
April 2013

CONTENTS

The Carbon Context

The concentration of carbon dioxide in the world's atmosphere is continuing to rise. The figure to the right shows the growth of global background CO_2 levels measured by the United States National Oceanographic and Atmospheric Administration (NOAA)[1]. It can be seen that over the period 1959-2010 the concentration of CO_2 in the atmosphere has grown at a rate of about 1-2 ppm per year.





The figure to the left, also generated by NOAA, illustrates that the rate of growth in atmospheric CO_2 is increasing[2].

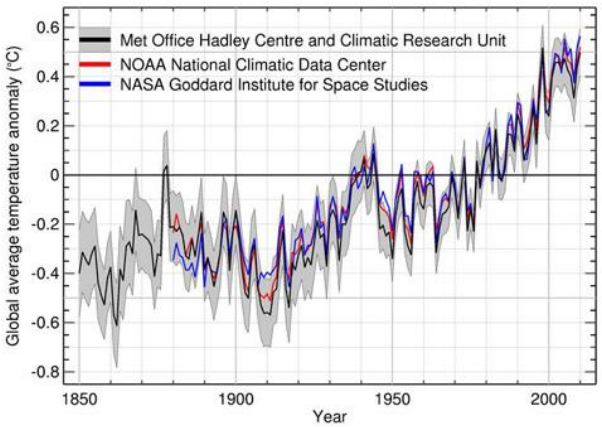
The Intergovernmental Panel on Climate Change issued a summary report for policy makers in 2007[3] which reported observed effects of climate changes such as:

The average atmospheric water vapour content has increased since at least the 1980s over land and ocean as well as in the upper troposphere. The increase is broadly consistent with the extra water vapour that warmer air can hold.

Observations since 1961 show that the average temperature of the global ocean has increased to depths of at least 3000 m and that the ocean has been absorbing more than 80% of the heat added to the climate system. Such warming causes seawater to expand, contributing to sea level rise.

Mountain glaciers and snow cover have declined on average in both hemispheres. Widespread decreases in glaciers and ice caps have contributed to sea level rise (ice caps do not include contributions from the Greenland and Antarctic Ice Sheets).

Since the start of the 20th century, the Earth's surface has warmed by about 0.74°C. The warming trends are illustrated in the figure to the right. *Globally, the decade of 2001 to 2010 was the world's warmest decade on record, warmer than the 1990s which in turn was warmer than the 1980s—1998, 2005 and 2010 are the warmest years on record*[4].



[1] NOAA CO_2 observations: ftp://ftp.cmdl.noaa.gov/ccg/co2/trends/co2_annmean_mlo.txt
[2] NOAA analysis of CO_2 trends: http://www.esrl.noaa.gov/gmd/ccgg/trends/
[3] IPCC 2007: Summary report for policymakers: http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-spm.pdf
[4] Australian Government Dept of Climate Change: http://www.climatechange.gov.au/climate-change/understanding-climate-change/recent-trends-global-warming.aspx

The Context

The International Transport Forum (ITF) has reported that in 2008 transport generated 23% of the world's total carbon footprint derived from fuel combustion (*Figure C.1*). Emissions from international aviation, which made up about 7% of the transport footprint, constituted about 1.5% of the global footprint.[5]

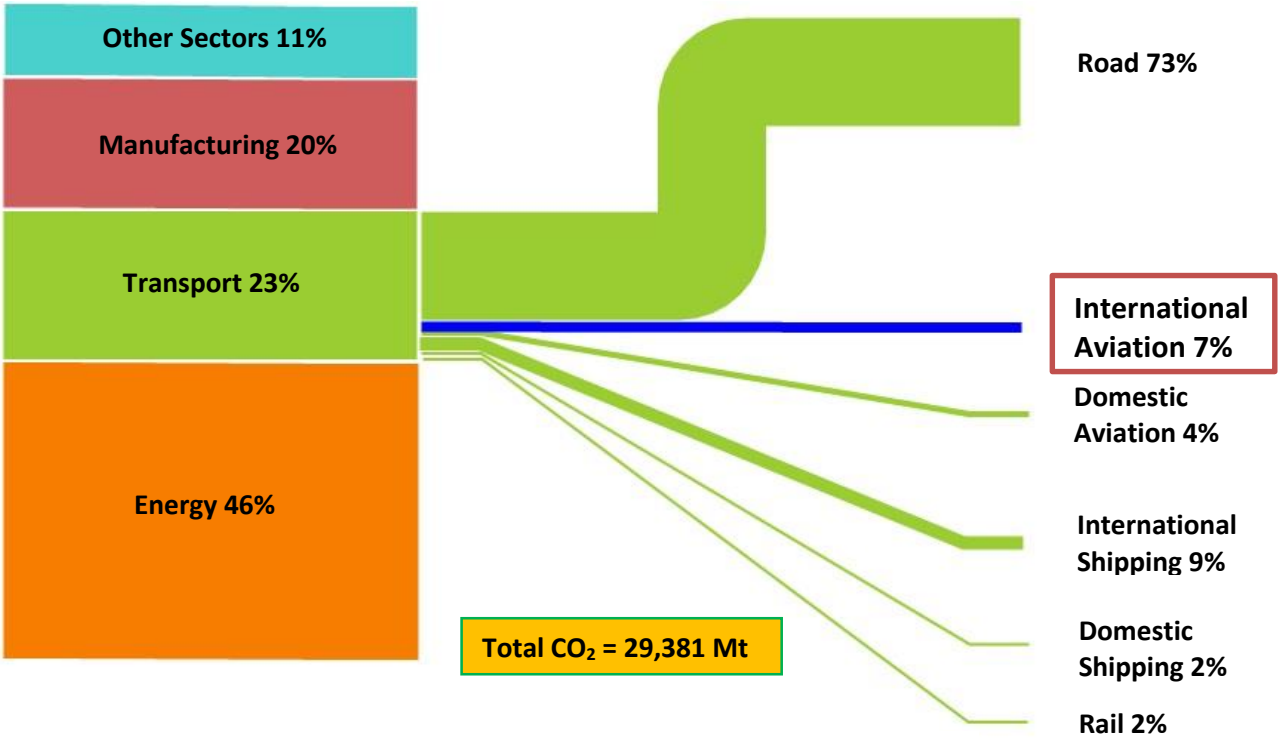
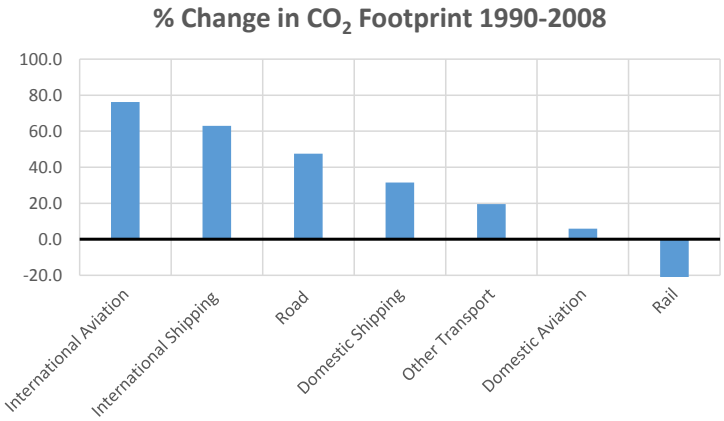


Figure C.1: Sectoral composition of the global carbon footprint from fuel combustion 2008

While the aviation contribution to the transport sector's carbon footprint is around 10%, and significantly less than road transport, the ITF report shows that the carbon footprint of international aviation is growing at a greater rate than that of the other transport modes (*Figure C.2*).

Figure C.2: Change in global CO_2 footprint by mode 1990-2008



[5] *Transport Greenhouse Gas Emissions 2010*. The International Transport Forum: World data sheet - p8. http://www.internationaltransportforum.org/Pub/pdf/10GHGCountry.pdf

The ITF report also shows that in 2008 the fuel uplifted for global international aviation was the source of 455 Mt of CO_2 – this had grown from a figure of around 250 million tonnes in 1990 (*Figure C.3*).

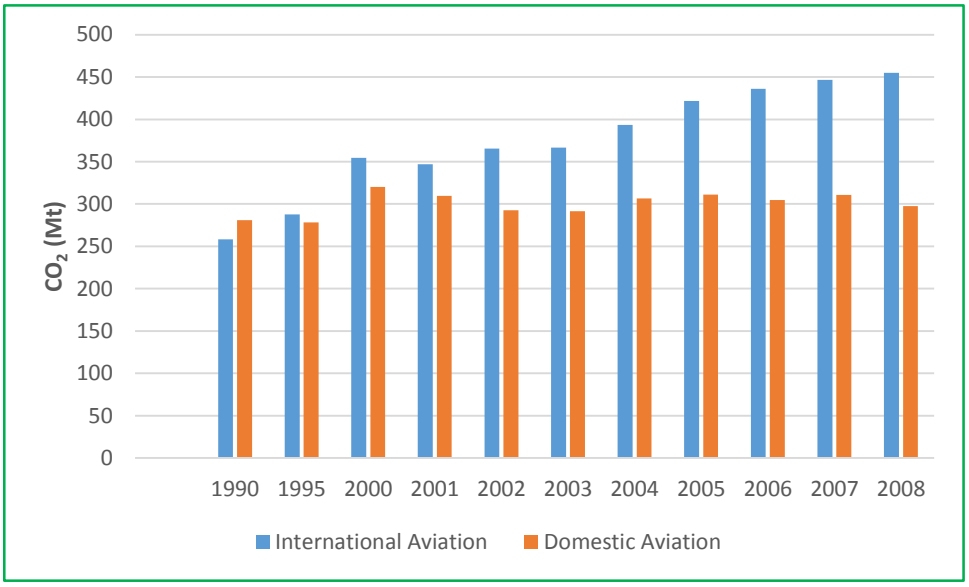


Figure C.3: Trends in Global Aviation CO_2 footprint 1990-2008

During the period 1990-2008 the carbon footprint of international aviation grew at around 3.2% per annum while domestic aviation's footprint growth was significantly less at about 0.3% per annum.

PART I

DISCUSSION & ANALYSIS

Chapter 1

Introduction

This report is based on the author's earlier work, released in October 2012, *The Carbon Footprint of Aircraft Operations in Australia – 2011*.[6] As far as possible, this book uses the previous work as a template. The same great circle carbon footprinting approach has been used in both documents to present a picture of the carbon footprint of a network of aircraft operations – this book examines the global footprint of scheduled international passenger movements in 2012. In some instances the same graphics have been used in both books and elements of the original text have had minimal modification where a particular message applies equally to both reports. The broad style of presentation has been retained and the footprint examination from the perspective of the airport and the airline has also been retained.

Like its predecessor, this document is designed as a data resource for researchers, aviation professionals, decision makers and members of the public. As such it is directed at describing the carbon footprint of international aviation and is not aimed at discussing or promoting particular policy options for managing that footprint.

The earlier work was also directed at testing the application and robustness of great circle carbon footprinting techniques to the carbon footprinting of an aviation network. That exercise generated results that gave good agreement with the available validation points at the aggregated level and indicated that great circle techniques can be used to generate a good indicative carbon footprint picture. These 'footprint pictures' can be used, for example, as the basis for the broad consideration of options in a policy debate or in overview environmental reporting.

At the time of writing there is an on-going debate about the management of carbon associated with international aviation. The European Union has put on hold the application of its Emissions Trading Scheme (ETS) to international flights to/from Europe pending the outcome of discussions within the International Civil Aviation Organization (ICAO). The triennial ICAO Assembly is due to be held in September 2013 and it is anticipated that efforts will be made to reach agreement at the Assembly on the application of Market Based Measures (MBMs) to managing the CO_2 emissions of international aviation. Clearly, if this debate is to be informed it will be necessary for the participants to have access to carbon footprinting information which allows them to understand the potential impacts of the options under consideration.

1.1 Measurement, Reporting and Verification

The ultimate success of any climate change management regime depends on transparent and comprehensible measurement, reporting and verification (MRV) of CO_2 emissions. The ultimate aim of the management regime is to constrain growth in CO_2. Even if a carbon management regime is successfully controlling carbon it will be unlikely to achieve support from either the decision makers or the public if the CO_2 gains cannot be rigorously determined and transparently reported.

If international agreement is reached on managing the carbon footprint of international aviation, it is clear that the establishment of a robust MRV regime will need to be a fundamental part of the decision. At the very least it should be consistent with the MRV requirements set up under the

[6] *The carbon footprint of aircraft operations in Australia – 2011,* D Southgate, 2012: http://www.scribd.com/doc/110857161/The-Carbon-Footprint-of-Aircraft-Operations-in-Australia-2011

UNFCCC for domestic aviation. Ideally it should be an advance on that regime since at present the UNFCCC essentially solely reports aggregated data for aviation with no detail on the constituent parts of the sector. However, given the plethora of operational data that exists for aviation there would appear to be no technical impediment to providing disaggregated carbon footprint reports for the sector. Disaggregated reporting would allow more robust assessment of the effectiveness of the climate change policy response and would also enable more informed debate of future options.

In preparing this report the author found it very difficult to find solid data to use for validation purposes. There are significant holes in the data that is available to the public on international aviation operations and hence this report only reports on one (albeit by far the largest) area of international aviation's carbon footprint – scheduled passenger operations. This 'data gap' is discussed in Section 8.4.

A prime driver behind the production of this report has been the author's longstanding interest in public access to data and in transparency in environmental decision making. If there is to be an effective response to climate change, decision makers need to be provided with information they can understand and trust. If there is to be public support for those decisions, members of the public need to be in a position which enables them to understand why decisions have been made and to easily track whether the outcomes of decisions are achieving proclaimed goals.

In order to fit in with transparency principles, the work in this report has been based on publicly available data and on the use of inexpensive non-expert data analysis and reporting software (see Chapter 8).

1.2 Footprint Constrained to International Aviation

Under formal climate change management regimes domestic and international aviation are treated as separate entities:

- under the UNFCCC the CO_2 emissions of **domestic** aviation are managed and reported by the governments of individual countries as a component of their ageed country CO_2 targets

- the rules and arrangements governing **international** aviation are decided on through international agreement under the auspices of the United Nations International Civil Aviation Organization (ICAO) and the management of the climate change impacts of international aviation is being negotiated through ICAO.

This report has been restricted to the examination of international aircraft operations for a number of reasons, not least to keep the task to a manageable size. While at the global level domestic aviation comprises a lesser part (about 40%) of the total carbon footprint of aircraft operations, it is more complex as it involves many more flights, airports and airlines. For example, Australia effectively has 10 international airports but around 130 airports which handle domestic scheduled passenger traffic. The carbon footprint of international aviation is also a topic of special interest since climate change will be one of the main discussion items at the forthcoming ICAO Assembly.

Ideally this report would capture all of international aviation but, as mentioned in the previous section, there are significant data gaps which make this impractical at the present time (see Section 8.4). The analysis in Chapter 8 indicates that the footprint of scheduled international passenger operations is about 80% of the total carbon footprint of international aircraft operations.

1.3 Methodology

In essence the carbon footprint information in this report has been derived by computing and aggregating the carbon footprints of individual flights contained in a database of global scheduled international passenger aircraft operations carried out in 2012. The flight by flight carbon footprints have been computed using a great circle computation tool –*TNIP Carbon Counter*- developed by the Australian Government Department of Infrastructure and Transport.[7] The algorithms in this software tool are based on those contained in the ICAO Carbon Calculator.[8]

The reader is encouraged to examine Chapter 8 to learn about the methodology adopted to compute the CO_2 data in this report and to compare this data against the published validation points.

Input Data

All the CO_2 computations in this report are based on a publicly available database of 2012 global scheduled international passenger services. This database was sourced from Innovata, a provider of data for global aviation.[9] This dataset is discussed further in Chapter 8.

Scope

The carbon footprint computations relate only to the CO_2 generated by **scheduled international passenger** services in the year 2012. The footprinting does not extend to ground based non-aircraft activities such as the operation of ground service equipment or energy use associated with the operation of airport terminals.

The carbon computations for any given entity (eg country, airport, etc) are confined solely to departing aircraft to avoid double counting of carbon. This methodology, which effectively computes notional global aviation fuel uplifted for scheduled international passenger services, is consistent with the UNFCCC carbon reporting regime.[10] Under the UNFCCC regime the carbon generated by an international operation is counted under the inventory of the country from which the flight departed.

The UNFCCC carbon accounting regime is based on computing the weight of six greenhouse gases.[11] When reporting total greenhouse gases, the six gases are converted to CO_2 equivalent (CO_2-e). However, the accepted practice within ICAO when carbon footprinting aviation is to generally only compute and report CO_2 emissions since the quantity of the other five UNFCCC greenhouse gases produced by aviation is small compared to the quantity of CO_2.[12]

The literature commonly raises the question of whether, or how, to include the non-CO_2 impacts of aviation in carbon footprint reporting. These impacts are taken into account by the incorporation of a multiplier, usually referred to as the 'Radiative Forcing Index (RFI)', into carbon computations. At the present time there is no agreement on how the RFI should be applied and accordingly the accepted ICAO practice is to use 'RFI=1' when carbon footprinting.[13] This is the approach adopted in this document. Should the reader wish to incorporate a different RFI value into the results in this

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[7] TNIP Carbon Counter: http://www.infrastructure.gov.au/aviation/environmental/transparent_noise/tnip_CC.aspx
[8] ICAO Carbon Calculator: http://www.icao.int/environmental-protection/CarbonOffset/Pages/default.aspx
[9] Innovata: http://www.innovata-llc.com/
[10] *IPCC Guidelines for National Greenhouse Gas Inventories*, p1.6. http://www.ipcc-nggip.iges.or.jp/public/gl/guidelin/ch1ref1.pdf
[11] UNFCCC Fact Sheet: http://unfccc.int/files/press/backgrounders/application/pdf/press_factsh_mitigation.pdf
[12] See Table 3.1 in reference 3.
[13] ICAO Carbon Calculator. FAQ No 1: http://www.icao.int/environmental-protection/CarbonOffset/Pages/FAQCarbonCalculator.aspx

report, this can be done simply by multiplying any of the reported CO_2 values by the RFI value. Interesting discussion on the RFI can be found in the Intergovernmental Panel on Climate Change (IPCC) report on Aviation and the Global Atmosphere.[14]

Limitations

It is important that the reader is aware of the limitations of, and the likely confidence that can be placed on, the carbon footprint values reported in this document. This topic is discussed in some detail in Chapter 8. At the top level the broad limitations which are likely to influence the robustness of the reported CO_2 values include:

- The reported carbon data is based on computation. Ideally the figures would be based on actual fuel use data for every individual flight in 2012 but this information is owned by the airlines and is commercial in confidence.
- The carbon results are derived from a great circle computation methodology which provides average CO_2 information.
- The dataset used to compute the carbon footprint is a **scheduled passenger** movements dataset and does not contain information on unscheduled or dedicated freight movements.
- Information expressed in 'per passenger' metrics (CO_2/PAX and litres of jet fuel/100 RPK) relies on assumptions relating to both load factors and seat configurations and has greater uncertainty than the results solely reporting CO_2.

1.4 Report Structure

This document provides an example of the type of picture that can be presented of an aircraft operations network carbon footprint through the use of 'simple' great circle techniques. It is divided into two Parts. Part I is the main body of the report and contains the discussions and the prime data analysis. Part II essentially contains carbon footprint datasheets for the network components (eg region, country, etc) introduced in Part I.

In Part I of the report the underlying dataset is filtered to generate subsets which capture the CO_2 emissions of the key entities ('entity' being region, country, airport or airline) – the 'top 10'. Depending on the level of disaggregation and the component type, this involves in practice providing footprint information for the top 3 to the top 30 entities. The broad aim is to identify the contributors of at least 50% of the global carbon footprint in Part I. Footprint information on some of the remaining entities is shown in Part II.

The report is structured in a way that progressively examines the carbon footprint of global scheduled international passenger flights in 2012 by initially breaking down the global footprint into layers and then by separately examining the footprint from the perspective of the airports and the airlines.

Chapter 2 gives a disaggregated overview of the carbon footprint at the global level. Chapters 3 and 4 examine the global footprint by going down two layers. The initial level of disaggregation in Chapter 3 divides the footprint into ICAO Regional components and examines both inter and intra region footprints. The footprint is further subdivided into country components in Chapter 4. The next two chapters examine the footprint from the perspective of the airports (Chapter 5) and the airlines (Chapter 6).

[14] *Aviation and the Global Atmosphere*. IPCC. http://www.ipcc.ch/ipccreports/sres/aviation/index.php?idp=64

In keeping with the current discussions within ICAO, Chapter 7 reports the carbon information in the early chapters in terms of monetary values.

Chapter 8 is particularly important as it describes the computational approach used to generate the information in Chapters 2 to 7 and assesses the robustness of the computations by comparison with publicly available validation points.

Part II of the report – entitled 'footprint profiles' – is a data resource which provides about 100 pages of carbon footprint information for the key entities.

Chapter 2

The Global Network

2.1 Introduction

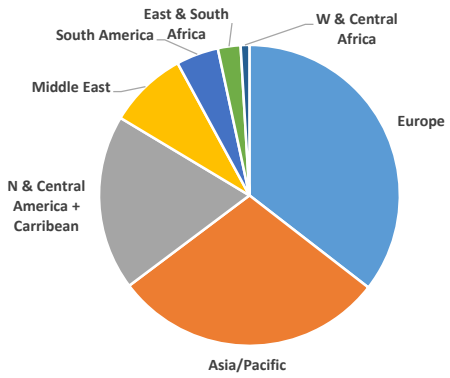
The computational method used in this report indicates that 360 million tonnes of CO_2 were emitted by scheduled international passenger aircraft operations in 2012. As suggested earlier, the reader is encouraged to peruse Chapter 8 to gain an understanding of the reliability that can be placed on this number and on the other figures in the coming chapters. All carbon computations are based on aircraft departures in order to avoid double counting.

The broad thrust of this document is to provide illumination on the carbon footprint by disaggregating the top level figure into its components and sub-components.

At the first level of disaggregation, the picture of the global carbon footprint of international passenger aircraft operations is shown by dividing the footprint into regional areas based on the seven ICAO regions. The ICAO regions broadly represent area demarcations which are commonly used when global data is broken down to the regional level.

Figure 2.1 shows the breakdown of the global CO_2 footprint into the seven ICAO regions (see Section 3.1). It can be seen that that aircraft departures in three of the regions dominate the global carbon footprint (constituting about 85% of the footprint). This is discussed further in Chapter 3.

Total CO_2 = 360.9 Mt



ICAO Region	CO_2 (kt)	%
Europe	128,052	36
Asia/Pacific	105,596	29
N & Central America + Caribbean	68,049	19
Middle East	30,566	8
South America	16,402	5
East & South Africa	8,795	2
W & Central Africa	3,396	1
Total	**360,857**	**100**

Figure 2.1: Components of the global network CO_2 footprint – ICAO Regions

Fuel (carbon) efficiency is an indicator of particular interest when carbon footprinting aviation. However, largely due to data availability constraints this is an issue which essentially falls outside the scope of this report. It is briefly discussed in Section 2.5.

A commonly quoted means of reducing the aviation carbon footprint, and indeed the overall transport footprint, is to introduce policies designed to force a modal shift from 'inefficient' aviation

to other modes of transport. This is commonly raised in the context of substituting either rail, bus or car for 'short haul' aviation. This topic is briefly discussed in Section 2.6.

2.2 Overview of Country Contributions

Figure 2.2 shows the hierarchy of the CO_2 footprint of scheduled international passenger aircraft operations for the top 30 countries. The CO_2 is based on the notional quantity of jet fuel uplifted in each country. It can be seen that departures from these countries constituted about 80% of the global CO_2 footprint in 2012.

The footprint for the United States, the top country, is approximately twice the size of that of the United Kingdom. It is interesting to note that over 25% of the global footprint arises from departures from the top three countries. The top 10 countries constitute 50% of the footprint

Australia, followed closely by Brazil and South Africa, generates the greatest weight of CO_2 per passenger. This reflects the relative geographic isolation of the population centres in these countries.

Country	CO_2 (kt)	CO_2/PAX (kg)	Cumulative %
United States	49,949	494	14
United Kingdom	24,811	298	21
Germany	18,757	259	26
United Arab Emirates	14,547	377	30
Japan	13,960	427	34
China	13,872	342	38
France	13,821	286	41
Spain	10,648	224	44
Hong Kong	10,363	368	47
Singapore	9,816	381	50
Australia	9,497	626	53
Canada	8,366	355	55
South Korea	8,292	334	57
Thailand	8,209	366	60
Netherlands	7,539	320	62
Italy	7,488	193	64
India	7,182	360	66
Brazil	5,932	606	67
Russia	5,736	263	69
Turkey	5,026	235	70
Malaysia	4,494	282	72
Switzerland	4,397	202	73
Taiwan	4,292	236	74
Mexico	3,950	281	75
Qatar	3,881	329	76
Saudi Arabia	3,857	257	77
South Africa	3,616	568	78
Indonesia	3,065	269	79
Philippines	2,633	326	80
Portugal	2,496	229	81
Other countries	70,364	213	100
Total	**360,857**	**300**	

Figure 2.2: Global CO_2 footprint by country

A picture of the global distribution of the footprint by number of countries is shown in *Figure 2.3.* This indicates that in 2012 the top 50 countries constituted about 90% of the footprint and that the top 100 countries made up in excess of 95% of the footprint.

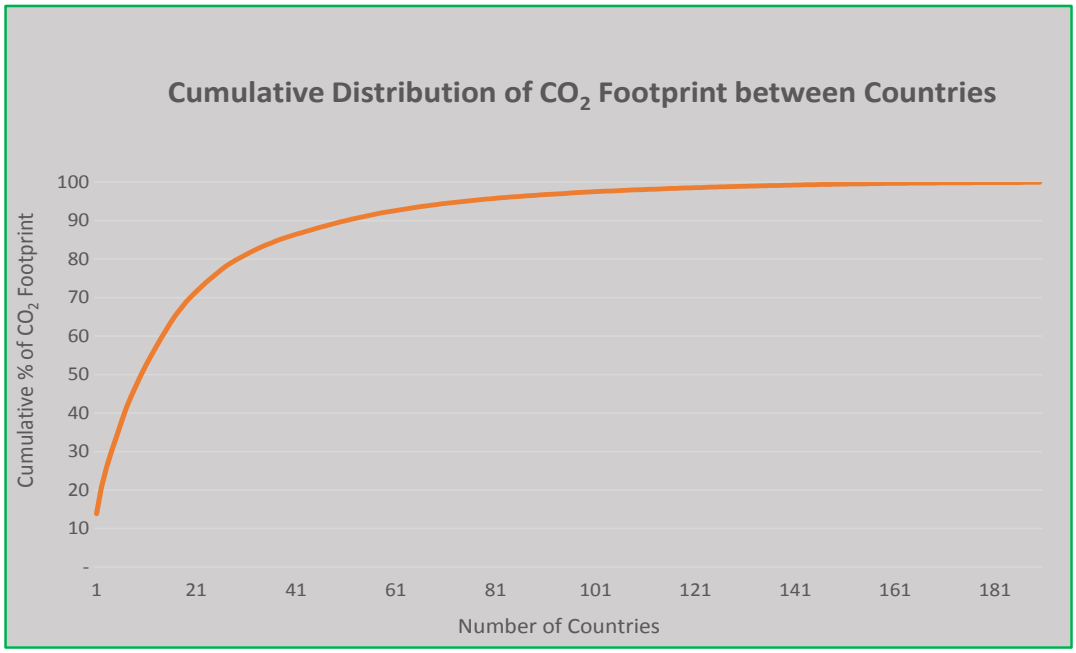


Figure 2.3: Cumulative distribution of country contributions to the global footprint

The Carbon Footprint Profile

A standard indicator template has been used throughout this report as a way to capture and report some key elements of the global CO_2 footprint for each of the components of the global footprint (eg country, airport, airline). *Figure 2.4* is the first example of this template. Throughout the report this template is referred to as a 'carbon footprint profile' – these profiles facilitate rapid comparisons between the contributions made to the global footprint by the footprint constituent elements. In most places in the report the template contains seven elements which are largely self-explanatory (these vary slightly depending on the footprint component being examined). *Figure 2.4* is an overview profile of the global network and the elements contain information that is discussed in other places in the report:

- *ICAO Origin Region* - this shows the distribution of the CO_2 footprint between departures from the seven ICAO regions – it replicates the information in *Figure 2.1.* In many of the profiles this element is *ICAO Destination Region* which shows the CO_2 split between destinations for departures from the location (eg country, airport), or by the entity (eg airline), shown at the head of the chart. The areas shown in the pie diagrams include both inter and intra region operations (ie it includes flights which have both the origin and destination in the same region).

- *Country* – is an extract of the country footprint hierarchy shown in *Figure 2.2*.

- *Footprint by Aircraft Type* – this graphic breaks the footprint down by aircraft type; the aircraft types have been categorised by aircraft family (eg A320, B737) to aid clarity.

- *Origin Airports* – this table gives a footprint hierarchy for the notional fuel uplifted at the top 15 airports in the component being examined (eg country). In many of the profiles an

element headed *Destination Airports* is used to show a CO_2 footprint hierarchy (top 15) based on the notional fuel uplifted by aircraft operating from the component (eg country, airport) to the destination airports.

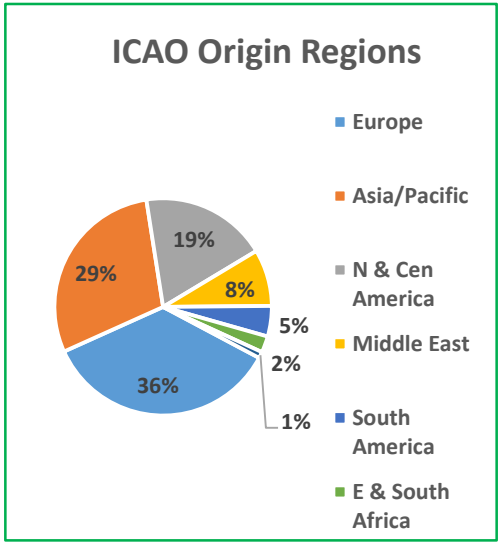
- *Airlines* – this shows a CO_2 hierarchy for the footprint disaggregated by airline (top 15) for departures operating from the component under examination (eg country, airport).
- *City-pair Hierarchy* – this breaks the component footprint into a hierarchy of routes (top 15).
- *CO2 v Distance* – this breaks the component footprint down by distance ranges and shows the relationship between the number of movements and the CO_2 footprint for each of the discrete distance ranges. This is discussed in Section 2.6.

Each element provides an independent view of the footprint. The total carbon in each element equals the total footprint for the component being examined (eg country, airport, airline).

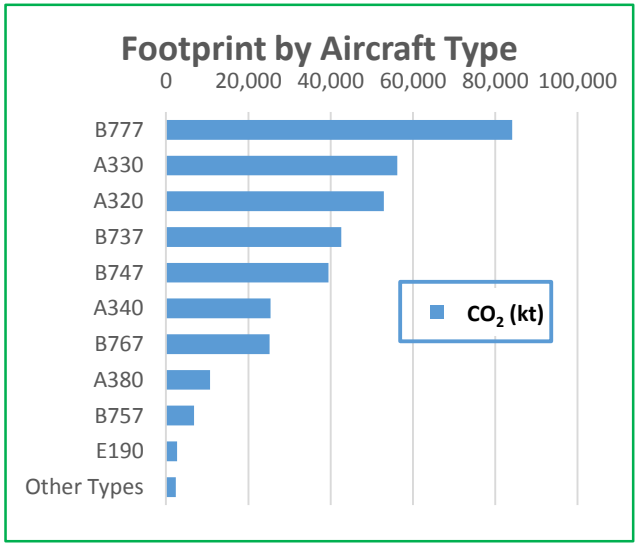
It is important to note that the scales on the *Footprint by Aircraft Type* and *CO2 v Distance* elements are generated automatically to present the best view of the data being shown. This means that the scales can vary widely from profile to profile and care must be taken when cross comparing between profiles.

Global Network

Total Footprint = 360,857 kt CO_2



Country	CO_2 (kt)
United States	49,949
United Kingdom	24,811
Germany	18,757
United Arab Emirates	14,547
Japan	13,960
China	13,872
France	13,821
Spain	10,648
Hong Kong	10,363
Singapore	9,816
Australia	9,497
Canada	8,366
South Korea	8,292
Thailand	8,209
Netherlands	7,539
Other Countries	138,410
Total	**360,857**



Origin Airports	CO_2 (kt)
London (Heathrow)	16,394
Dubai	10,976
Hong Kong	10,363
Frankfurt	10,193
Paris (CDG)	10,132
Singapore	9,816
Tokyo (Narita)	8,905
New York (JFK)	8,201
Seoul	7,919
Bangkok	7,583
Amsterdam	7,300
Los Angeles	7,007
Beijing	5,074
Shanghai	4,965
Sydney	4,817
Other Airports	231,213
Total	**360,857**

Airlines	CO_2 (kt)
Emirates Airline	17,333
British Airways	15,808
Lufthansa	15,344
United Airlines	14,828
Delta Air Lines	12,743
Air France	12,389
Singapore Airlines	10,498
Cathay Pacific	10,135
American Airlines	10,030
KLM Royal Dutch Airlines	9,079
Korean Air	7,982
Qatar Airways	7,330
Ryanair	6,803
Thai Airways International	6,311
Air Canada	6,179
Other Airlines	198,063
Total	**360,857**

City-Pair Hierarchy	CO_2 (kt)
London (Heathrow)-Singapore	1,015
Singapore-London (Heathrow)	1,015
New York (JFK)-London (Heathrow)	1,000
London (Heathrow)-New York (JFK)	1,000
London (Heathrow)-Hong Kong	843
Hong Kong-London (Heathrow)	843
Sydney-Los Angeles	707
Los Angeles-Sydney	705
Los Angeles-London (Heathrow)	664
London (Heathrow)-Los Angeles	664
Los Angeles-Tokyo (Narita)	628
Tokyo (Narita)-Los Angeles	626
London (Heathrow)-Dubai	542
Dubai-London (Heathrow)	542
Los Angeles-Seoul	541
Other Routes	349,524
Total	**360,857**

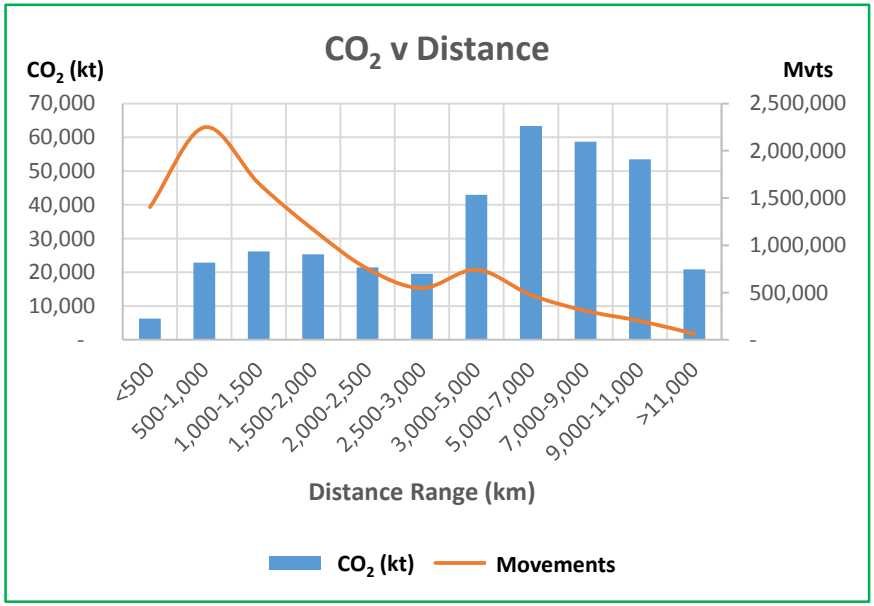


Figure 2.4: Carbon footprint profile – global network for scheduled international passenger aircraft movements 2012

2.3 The carbon footprint by route

Figure 2.5 shows the 31 most CO_2 intensive scheduled international passenger aircraft routes for 2012. To assist with interpretation the hierarchy has been colour coded into groups – the colours in *Figure 2.*5 correspond to the colours in the route visualisations shown in *Figures 2.6 & 2.7*.

It can be seen that London Heathrow is associated with five of the top ten routes. Heathrow is the only European airport in the top 10. In other ICAO regions the footprint is more dispersed between airports. It can be seen that generally there are not major differences in the CO_2 footprint between the routes and that for the most part the footprint is well dispersed across routes - the 31 routes in *Figure 2.5* make up less than 10% of the global footprint.

The geographic spread of the routes can be appreciated by reference to *Figures 2.6 & 2.7*. These figures have been split, for reasons of clarity, into views from essentially opposite sides of the globe.

Route	CO_2 (kt)	CO_2/PAX
London (Heathrow)-Singapore	2,030	1,149
London (Heathrow)-New York (JFK)	2,000	556
London (Heathrow)-Hong Kong	1,686	1,034
Los Angeles-Sydney	1,412	1,336
London (Heathrow)-Los Angeles	1,328	902
Los Angeles-Tokyo (Narita)	1,254	939
London (Heathrow)-Dubai	1,084	543
Los Angeles-Seoul	1,082	1,046
Singapore-Sydney	1,059	629
San Francisco-Hong Kong	1,048	1,262
Los Angeles-Taipei	1,006	1,243
Frankfurt-Singapore	1,004	1,092
London (Heathrow)-Johannesburg	967	929
London (Heathrow)-San Francisco	951	940
Honolulu-Tokyo (Narita)	928	566
Hong Kong-Singapore	902	275
Taipei-Hong Kong	901	129
London (Heathrow)-Chicago	884	607
Hong Kong-Sydney	837	703
Chicago-Tokyo (Narita)	828	1,106
London (Heathrow)-Miami	821	743
New York (JFK)-Tokyo (Narita)	816	1,191
London (Heathrow)-Bangkok	804	932
London (Heathrow)-Newark	780	527
Paris (CDG)-Tokyo (Narita)	771	1,038
Singapore-Melbourne	751	613
New York (JFK)-Paris (CDG)	745	564
San Francisco-Seoul	736	1,016
New York (JFK)-Seoul	734	1,200
London (Heathrow)-Washington	720	587
London (Heathrow)-Mumbai	709	796
Other Routes	329,281	285
Total	**360,857**	**300**

Figure 2.5: Global CO_2 hierarchy by route

The reported quantity of CO_2 per passenger is largely driven by the distance between the cities involved (given the relatively narrow spread in aircraft types (see Section 2.4)). The route between Los Angeles and Sydney generates the highest CO_2/PAX figure. It can be seen that some of the major routes have relatively small CO_2/PAX values (in particular Taipei-Hong Kong).

An alphabetical listing of the top 1,000 international city-pairs, showing simple carbon footprint information, is contained in *Profile F5* in Part II.

Note – this section refers to CO_2 footprints for 'routes': in this context CO_2 computations for 'routes' capture all traffic between the two airports/cities cited (ie traffic both ways). Commonly throughout the report CO_2 computations are based on 'city-pair' (ie one way) footprints.

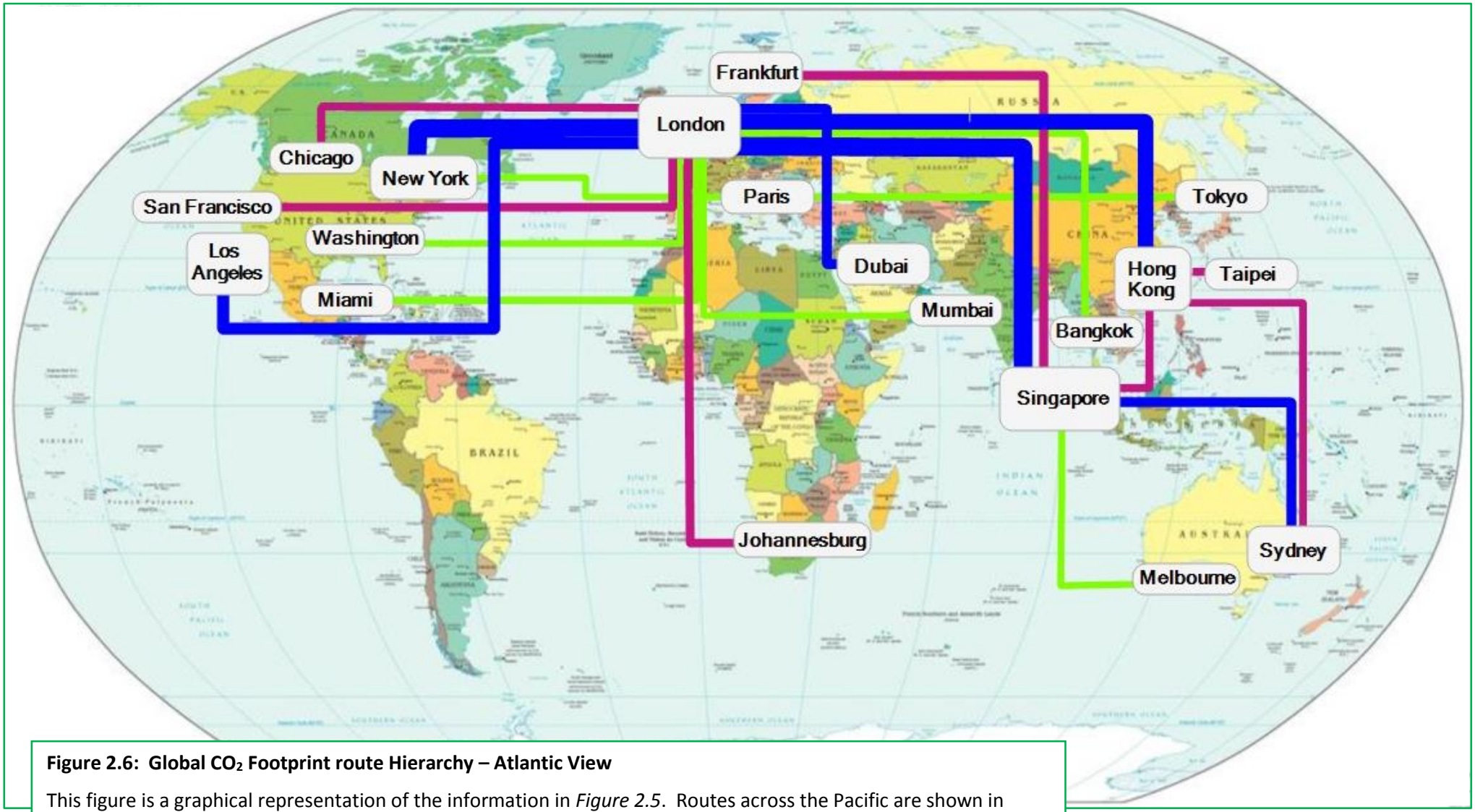


Figure 2.6: Global CO_2 Footprint route Hierarchy – Atlantic View

This figure is a graphical representation of the information in *Figure 2.5*. Routes across the Pacific are shown in *Figure 2.7*. The thickness of the lines is proportional to the quantity of CO_2. The figure clearly illustrates the dominant position of London (Heathrow) as the focus of the most carbon intensive routes.

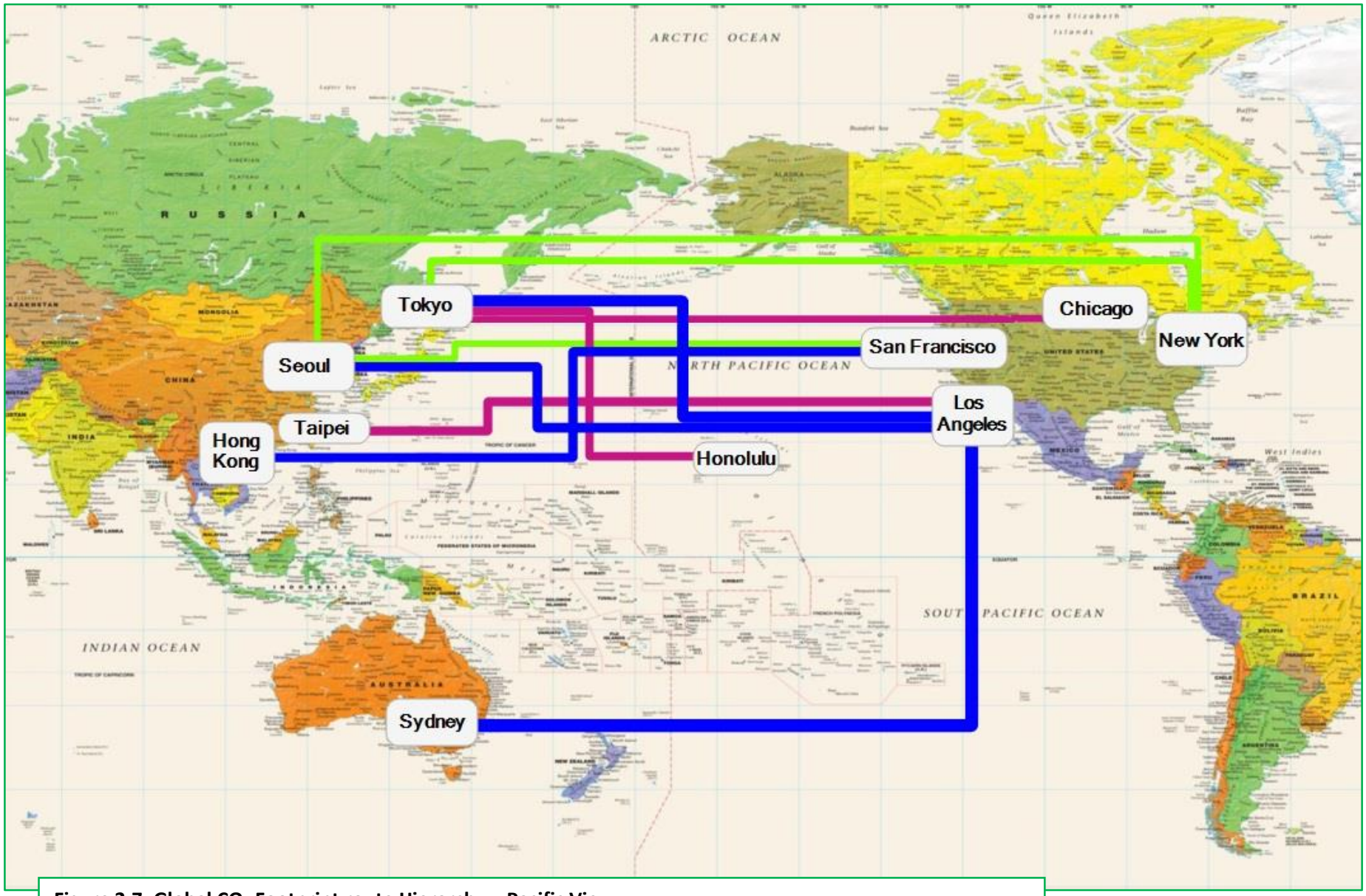


Figure 2.7: Global CO_2 Footprint route Hierarchy – Pacific View

This figure is a graphical representation of the information in *Figure 2.5*. The thickness of the lines is proportional to the quantity of CO_2. The figure illustrates that Los Angeles is the focus of the most carbon intensive routes across the Pacific.

2.4 Aircraft Types

Figure 2.8 shows a breakdown of the global scheduled international passenger movements carbon footprint by aircraft type. The table shows the top 10 aircraft types, by carbon footprint, that were used for scheduled international passenger aircraft operations in 2012. The aircraft types have been grouped into broad 'families' to aid clarity – most of these 'families' include a number of versions and variants.

Aircraft Type	CO_2 (kt)	% of CO_2	Cumulative %
B777	84,107	23.3	23.3
A330	56,206	15.6	38.9
A320	52,959	14.7	53.6
B737	42,552	11.8	65.4
B747	39,461	10.9	76.3
A340	25,382	7.0	83.3
B767	25,149	7.0	90.3
A380	10,662	3.0	93.2
B757	6,835	1.9	95.1
E190	2,714	0.8	95.9
Other Types	14,828	4.1	100.0
Total	**360,857**	**100.0**	

Figure 2.8: CO_2 hierarchy by aircraft type

It is interesting to note the very concentrated nature of the footprint when examined by aircraft type – 5 aircraft types generated 80% of the global carbon footprint; 10 aircraft types generated 95% of the footprint.

Twin engine aircraft dominated the footprint – constituting about 80% of the footprint. The B777 and A330 families for wide bodied aircraft and the A320 and B737 for the narrow bodied aircraft. Four engine aircraft provided about 20% of the footprint.

2.5 Efficiency

One of the key goals for managing the carbon footprint of aviation is to improve its efficiency to the greatest extent possible. The ICAO goal for climate change management which was agreed at the 2010 ICAO Assembly is to achieve a 2% improvement in fuel efficiency per year until 2050. It was accepted that this goal will be tracked using the metric 'litres of fuel / RTK (Revenue Tonne Kilometre)'. Globally the fuel efficiency of aviation has improved at a rate of around 2% per year for the past two decades while at the same time the carbon footprint has grown at a rate of about 3% per year. The ICAO Environmental Report 2010 provides a good overview of trends in aviation CO_2 emissions.[15]

The reliability of efficiency computations is inherently uncertain since, in the absence of detailed information, assumptions have to be made about both load factors and seat configurations across aircraft types of many different airlines operating in a range of countries. In the case of the RTK metric, knowledge of the weight of freight carried is also required.

[15] *ICAO Environmental Report 2010*, Chapter 1. http://www.icao.int/environmental-protection/Documents/Publications/ENV_Report_2010.pdf

Given the overview nature of this document, and the significant uncertainties in computing aviation efficiencies without specific detailed information, this report does not delve into the question of efficiency. Nevertheless, it is straightforward to compute a figure for the efficiency of the global network from the database that underpins this report. The database indicates that the weight of fuel used in 2012 for global scheduled international passenger operations was 1.14 x 10^{11} kg; and the total RPK (Revenue Passenger Kilometres) was 3.48 x 10^{12}. Assuming a global load factor of 78%[16] gives:

Efficiency across the global network = 4.1 litres of fuel/100RPK

This value compares well with published airline efficiency data. For example, Emirates reported an efficiency of 4.12 litres of fuel/100PK for 2010/11.[17]

2.6 CO_2 Contribution by Trip Length

As pointed out earlier, the standard carbon footprint profile used throughout this report contains an element examining the relationship between the quantum of CO_2 emissions, the number of aircraft operations and the distance travelled. The global network CO_2 v distance element in *Figure 2.4* shows the somewhat complex relationship between the three factors. It can be seen that the most common distance travelled on scheduled international passenger operations in 2012 was in the range 500 - 1,000 km. However, it can also be seen that the contribution to the carbon footprint from aircraft operations in this distance range was relatively small. This is illustrated more clearly in *Figure 2.9.*

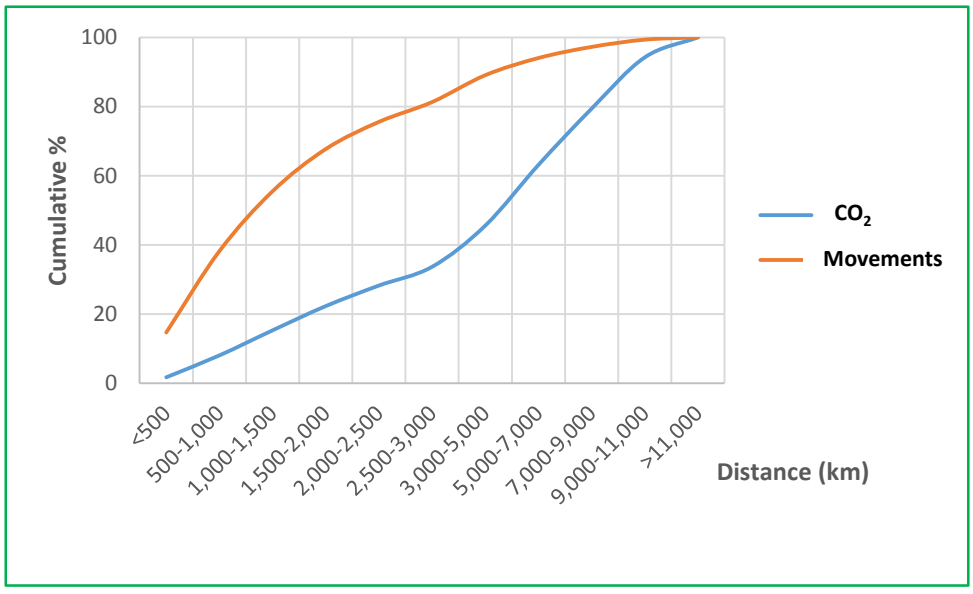


Figure 2.9: Cumulative comparison CO_2 v Distance

This figure reveals that about 60% of the scheduled international passenger aircraft operations in 2012 travelled less than 1,500 km and these flights made up about 20% of the global carbon footprint. By way of contrast about 50% of the total footprint is generated by around 10% of the flights (flights travelling more than 5,000 km) – these flights carried about 20% of the total number of international passengers in 2012. The Figure is consistent with the statement made by the Air

[16] IATA, *2012 Annual Review*, p12: http://www.iata.org/about/Documents/annual-review-2012.pdf
[17] Reference 22, p49.

Transport Action Group (ATAG) that "*Around 80% of aviation CO_2 emissions are emitted from flights of over 1,500 kilometres.*"[18] [Note the scale on the distance axis is not linear.]

It is interesting to contrast this relationship with the CO_2 v distance relationship for motor cars. *Figure 2.10*, extracted from a report by the UK Department for Transport[19], shows that almost 80% of UK car trips are for very short journeys – less than 16 km. These journeys comprise about 40% of the motor car carbon footprint.

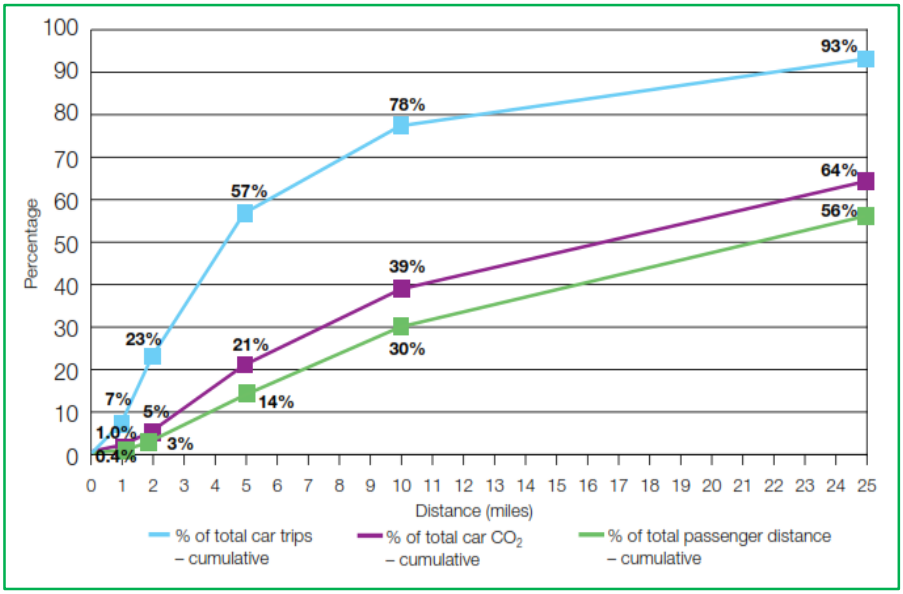


Figure 2.10: Cumulative comparison CO_2 v Distance for motor cars – UK

It can be seen throughout this report, by reference to the carbon footprint profiles, that with aviation there are high numbers of international movements in the short haul range but these make only a minor contribution to the overall footprint. This is more pronounced when domestic aviation is included. For example, in Australia about 30% of the scheduled aircraft movements travel less than 500 km – these operations contribute about 3% of the country's aviation carbon footprint.[20]

[18] ATAG, *Facts and Figures*: http://www.atag.org/facts-and-figures.html
[19] UK Dept for Transport, *Low Carbon Transport: A Greener Future*, 2009: http://www.official-documents.gov.uk/document/cm76/7682/7682.pdf
[20] *The carbon footprint of aircraft operations in Australia – 2011,* D Southgate, 2012, p23: http://www.scribd.com/doc/110857161/The-Carbon-Footprint-of-Aircraft-Operations-in-Australia-2011

Chapter 3

The ICAO Regions

3.1 Introduction

When examining global data it is common practice to break it down into regional subsets. As this report relates to international aviation, the data has been broken down at the first level of disaggregation into datasets for each of the ICAO regions. There are currently nine formal ICAO regions which are coordinated from seven regional offices.[21] For the purposes of this report the ICAO regions have been split into the seven consolidated regions which equate to the areas covered by the regional offices. The boundaries of these regions are shown in *Figure 3.1* (which was sourced from ICAO[22]). The black dots on the figure show the location of the regional offices. Abbreviated names are used throughout the report to identify these regions.

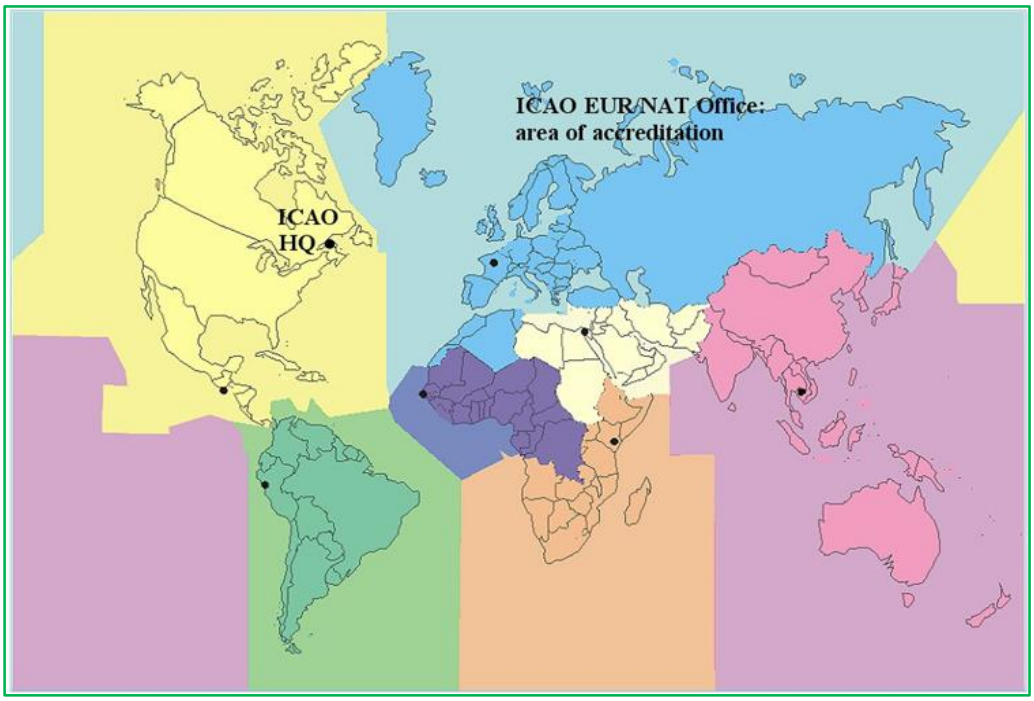


Figure 3.1: Boundaries of the consolidated ICAO regions

Breaking down the global data into regional subsets assists with the understanding and analysis of the global carbon footprint. In addition, during the lengthy ongoing debates on the establishment of a regime to manage the carbon footprint of international aviation, the concept of setting up regional schemes as an initial step is commonly raised. Therefore breaking down the global carbon footprint in this way may assist in the understanding of the potential for establishing carbon management schemes at the regional level. The carbon footprint of intra region operations is discussed in Section 3.3.

[21] ICAO, *Present Regional Structure*: http://www.icao.int/Pages/ro-structure.aspx
[22] ICAO regions map: http://www2.icao.int/en/ism/iStars/PublishingImages/Map-icao-regions-small.jpg

3.2 Carbon Footprint by Region

Overview

It was shown in *Figure 2.1* that aircraft operations arising from three of the ICAO regions dominate the global carbon footprint – Europe, Asia/Pacific and N & Central America + Caribbean. The operations from these regions constitute around 85% of the global footprint. As indicated earlier, the aim in Part I of the report is to focus discussion on the key, 'top-10', CO_2 generators. Accordingly in this chapter the detailed information relates to the three just mentioned key regions – carbon footprint information for the other four ICAO regions is shown in *Profile F1* in Part II. The information is shown using the carbon footprint profile concept introduced in *Figure 2.4*.

As an initial step, *Figure 3.2* shows an overview of the carbon footprint for each of the ICAO regions broken down by country. For reasons of clarity each of the regional pies is made up of the top 10 countries (+ an 'Other countries' category). It can be seen that for five of the regions there is one dominant country – the other two regions, Asia/Pacific and Europe, have a much more even split across countries. For the Asia/Pacific, Europe and W and Central Africa regions the 'Other countries' category is prominent (15% or greater) while for the N & Central America + Caribbean and the Middle East regions the 'Other countries' category makes up 3% of the pie.

Carbon footprint profiles are provided on the following pages for the top 3 ICAO regions – Europe, Asia/Pacific and N & Central America + Caribbean.

Europe

The Europe ICAO region carbon footprint profile shows that:

- the proportion of the Europe footprint that is intra region is somewhat less than that in the Asia/Pacific region but greater than that for the N & Central America and the Caribbean region (see Section 3.3)
- narrow bodied aircraft occupy the two top positions on the aircraft type hierarchy – this presumably reflects the fact that, due to the political boundaries, many international flights in Europe would be domestic flights in the larger countries in the other regions
- three airports are prominent as origin airports – London (Heathrow) occupies a particularly dominant position (aircraft departures from Heathrow generate about 13% of the region's CO_2 footprint)
- six of the top 15 destination airports are in Europe (ie associated with intra regional flights)
- low cost carriers occupy two of the top six positions on the airlines list
- London Heathrow dominates the city pair hierarchy; there are no intra Europe flights in the top 15 city pairs
- on the CO_2 v Distance chart the numbers of movements have a very prominent peak in the 500-1,000km range and there is a marked amount of CO_2 in the range up to 2,500km; the highest CO_2 load is generated by flights in the 5,000 km to 11,000 km range with about 45% of the footprint being generated by flights travelling greater than 5,000 km.

The intra Europe CO_2 footprint is discussed in Section 3.3.

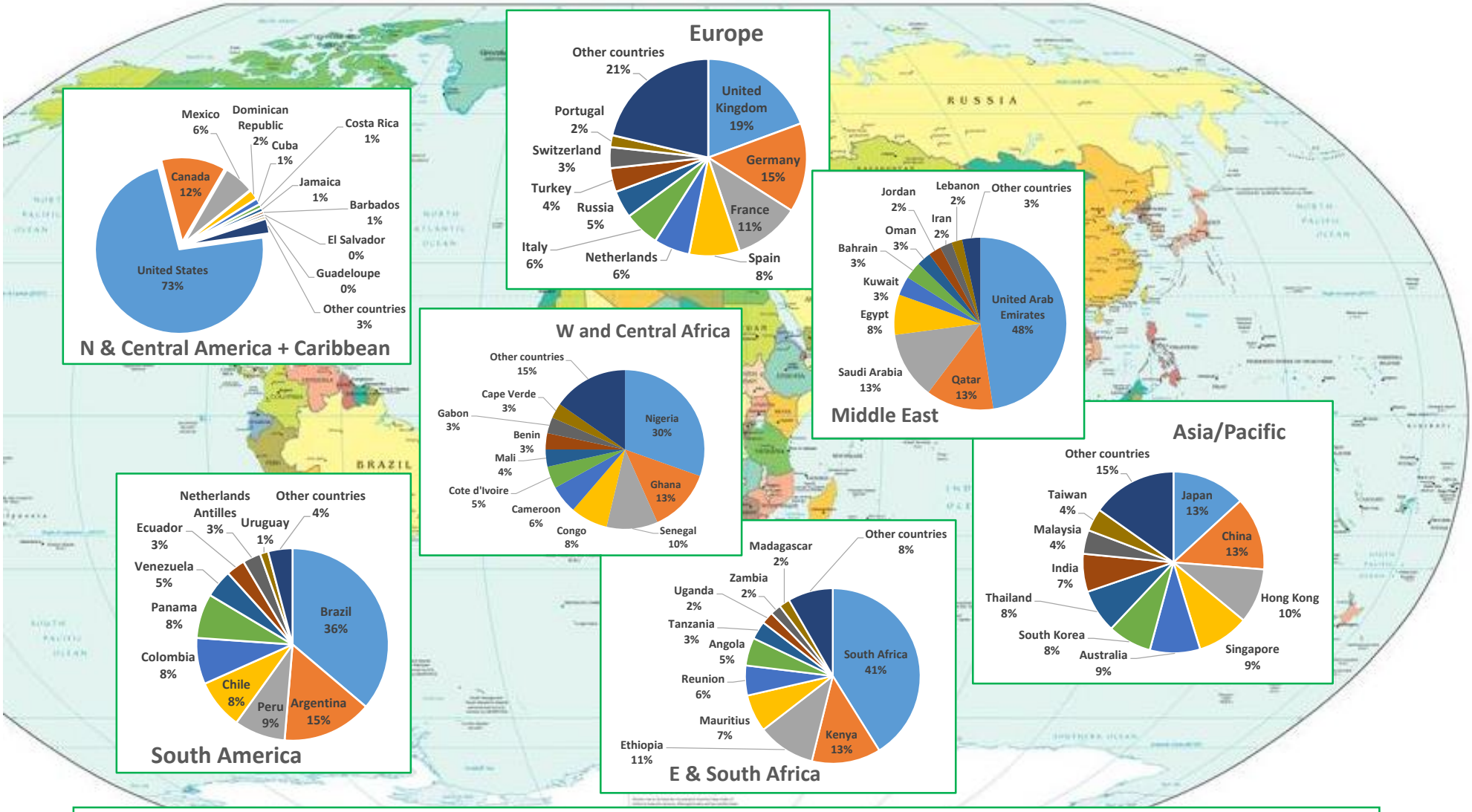
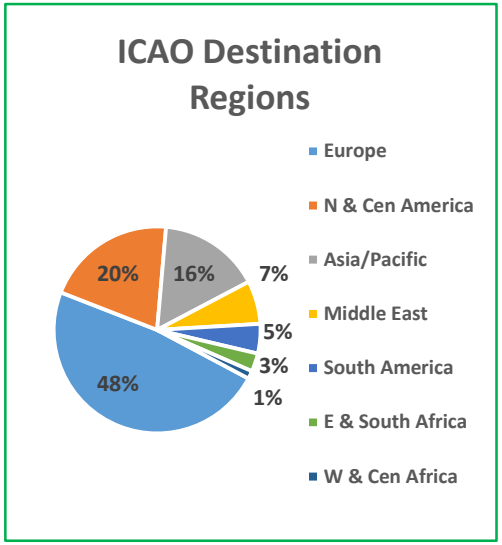


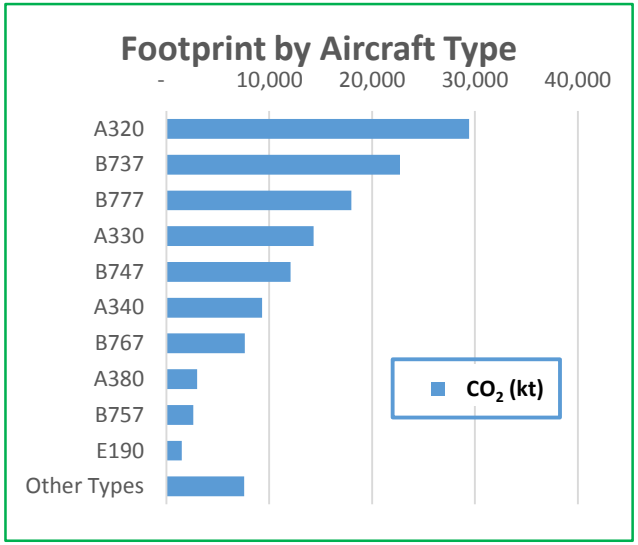
Figure 3.2: Top 10 country carbon footprint breakdown within each ICAO region

For each ICAO region the figure shows how the regional carbon footprint is shared between the top 10 countries. The magnitude of the regional footprints is shown in *Figure 2.1*. The carbon footprint relates to CO_2 associated with aircraft departures from the specified countries.

Europe

Total Footprint = 128,052 kt CO_2



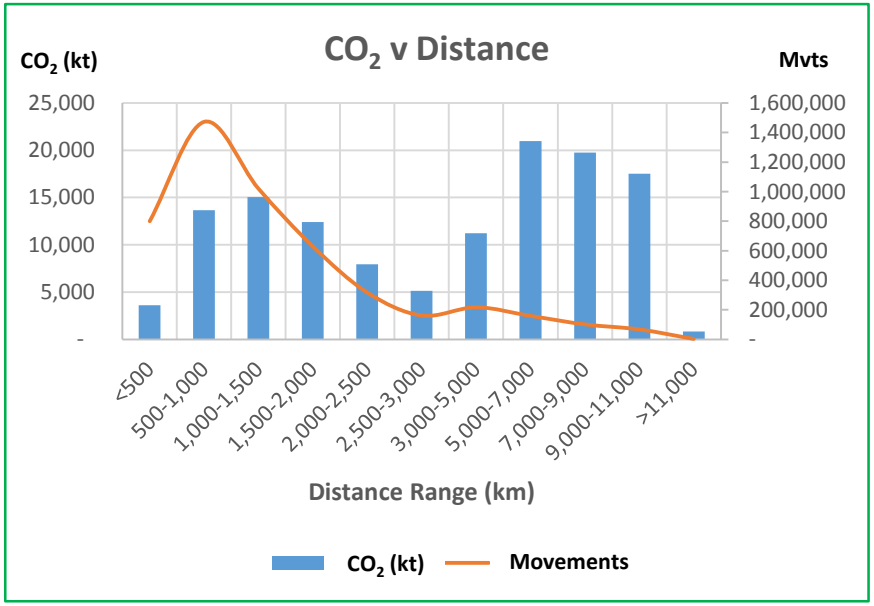


Origin Airports	CO_2 (kt)
London (Heathrow)	16,394
Frankfurt	10,193
Paris (CDG)	10,132
Amsterdam	7,300
Madrid	4,788
Moscow	4,512
Istanbul	4,146
Roma	3,422
Munich	3,400
Zurich	3,120
London (Gatwick)	2,865
Brussels	2,094
Tel Aviv	1,945
Milano	1,944
Paris (Orly)	1,805
Other Airports	49,994
Total	**128,052**

Destination Airports	CO_2 (kt)
New York (JFK)	4,109
Dubai	3,291
Singapore	2,740
Bangkok	2,563
Moscow	2,447
Hong Kong	2,218
London (Heathrow)	2,086
Newark	2,065
Tokyo (Narita)	2,008
Istanbul	1,934
Paris (CDG)	1,928
Frankfurt	1,865
Beijing	1,861
Amsterdam	1,697
Los Angeles	1,672
Other Airports	93,571
Total	**128,052**

Airlines	CO_2 (kt)
Lufthansa	9,803
British Airways	9,052
Air France	7,307
Ryanair	6,802
KLM Royal Dutch Airlines	5,186
Easyjet	4,602
Turkish Airlines	4,300
Swiss European Air Lines	2,701
Iberia Airlines	2,679
Delta Air Lines	2,649
Air Berlin	2,607
United Airlines	2,599
Emirates Airline	2,553
Aeroflot Russian Airlines	2,362
Scandinavian Airlines System (	2,125
Other Airlines	60,726
Total	**128,052**

City-Pair Hierarchy	CO_2 (kt)
London (Heathrow)-Singapore	1,015
London (Heathrow)-New York (JFK)	1,000
London (Heathrow)-Hong Kong	843
London (Heathrow)-Los Angeles	664
London (Heathrow)-Dubai	542
Frankfurt-Singapore	502
London (Heathrow)-Johannesburg	483
London (Heathrow)-San Francisco	476
London (Heathrow)-Chicago	442
London (Heathrow)-Miami	411
London (Heathrow)-Bangkok	402
London (Heathrow)-Newark	390
Paris (CDG)-Tokyo (Narita)	386
Paris (CDG)-New York (JFK)	373
London (Heathrow)-Washington	360
Other Routes	119,765
Total	**128,052**



Asia/Pacific

The Asia/Pacific carbon footprint profile shows that:

- more than half of the Asia/Pacific CO_2 footprint is generated by flights within the region (see Section 3.3)
- in contrast to Europe, wide bodied aircraft occupy the top three positions on the aircraft type hierarchy
- compared to Europe there is a greater spread in the origin airport CO_2 footprint between airports – there is no dominant airport in Asia/Pacific equivalent to Heathrow
- intra region flights occupy the top two positions on the destination airport hierarchy; nine of the top 15 destination airports are in the Asia/Pacific region (ie associated with intra region operations)
- the airlines hierarchy is, in a similar manner to Europe, dominated by operators from the region; Delta, Emirates and United, are the only operators in the list not based in Asia/Pacific (these airlines occupy a similar position in the hierarchy for Europe) – the footprint for these three airlines is somewhat greater in the Asia/Pacific region than in Europe
- the top five positions on the city pair hierarchy involve either London (Heathrow) or Los Angeles; there are three intra region routes in the city pair hierarchy
- the CO_2 v Distance chart shows a somewhat different profile to Europe; like Europe there is a peak in numbers of movements in the 500-1,000km range but these operations generate a relatively small proportion of the region's carbon footprint; also similar to Europe there is a drop off in the number of movements from 5,000km upward but the footprint is dominated by flights travelling further than 3,000 km (about 70% of the region's carbon footprint is generated by aircraft travelling more than 3,000 km).

The intra Asia/Pacific CO_2 footprint is discussed in Section 3.3.

N & Central America + Caribbean

The N & Central America + Caribbean carbon footprint profile figure shows that:

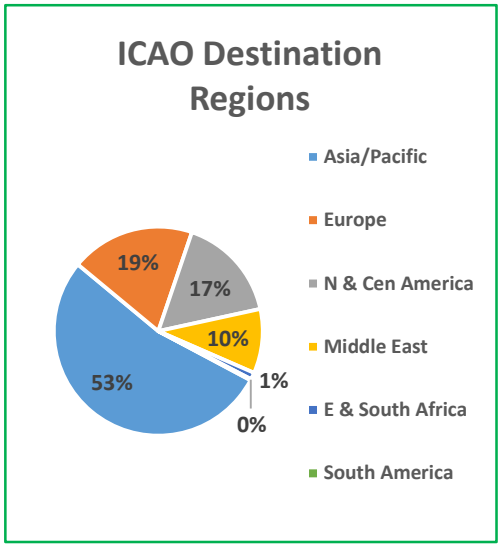
- the proportion of intra region operations is low compared to the other two regions (see Section 3.3)
- wide bodied aircraft occupy the top four positions on the aircraft type hierarchy; the B777 is particularly significant
- New York (JFK) and Los Angeles dominate as origin airports for the region's carbon footprint
- Toronto is the only destination airport in the region that appears in the destination airport hierarchy (ie associated with intra region operations)
- in contrast to the other regions, six of the operators in the airline hierarchy are not based in the region
- the New York (JFK) to London (Heathrow) city pair is the clear leader in the city pair hierarchy; in common with Europe there are no intra region city pairs in the top 15

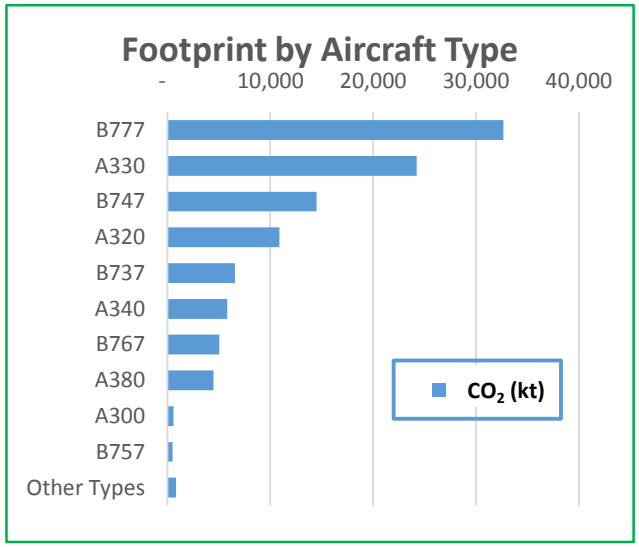
- the CO_2 v Distance chart shows a very strong influence of long haul flights in the compostion of the carbon footprint; flights travelling > 5,000km make up the bulk of the footprint (about 75% of the footprint)

The intra N & Central America + Caribbean region CO_2 footprint is discussed in Section 3.3.

Asia/Pacific

Total Footprint = 106,093 kt CO_2



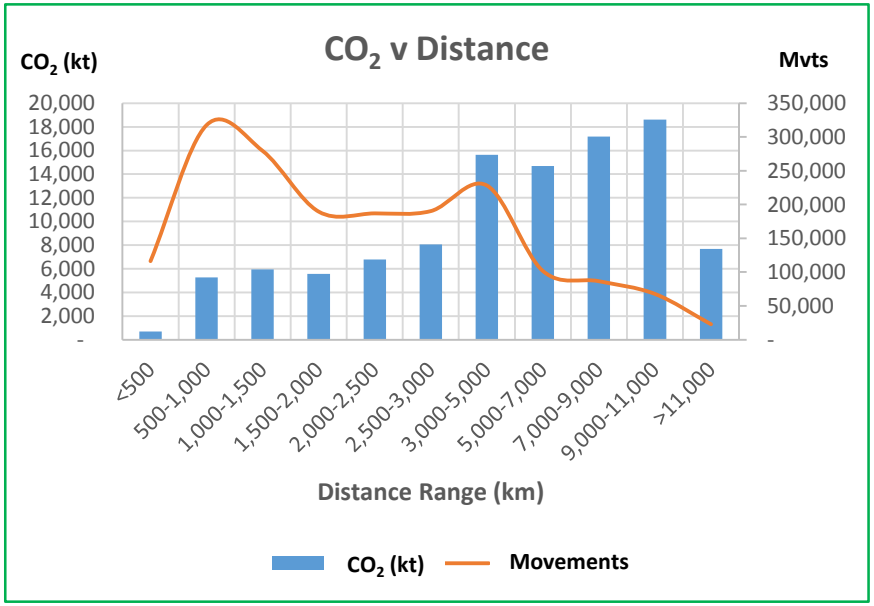


Origin Airports	CO_2 (kt)
Hong Kong	10,363
Singapore	9,816
Tokyo (Narita)	8,905
Seoul	7,919
Bangkok	7,583
Beijing	5,074
Shanghai	4,965
Sydney	4,817
Kuala Lumpur	4,237
Taipei	4,090
Delhi	2,503
Manila	2,330
Melbourne	2,175
Mumbai	2,083
Osaka	2,050
Other Airports	27,184
Total	**106,093**

Destination Airports	CO_2 (kt)
Singapore	6,368
Hong Kong	5,362
London (Heathrow)	4,608
Los Angeles	4,486
Dubai	4,070
Bangkok	3,979
Seoul	3,798
Frankfurt	3,157
Tokyo (Narita)	3,078
Kuala Lumpur	2,864
Sydney	2,780
Taipei	2,768
Paris (CDG)	2,743
San Francisco	2,381
Shanghai	1,992
Other Airports	51,657
Total	**106,093**

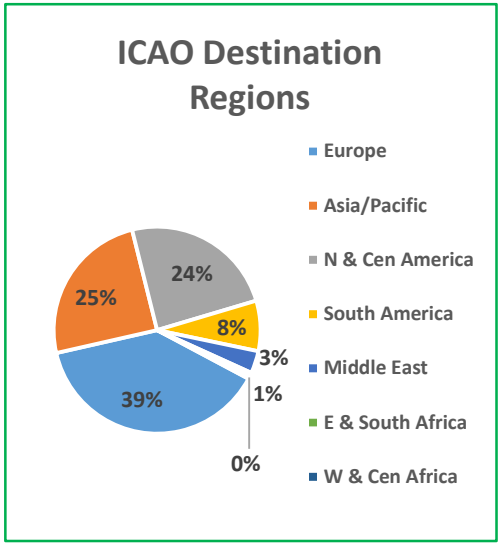
Airlines	CO_2 (kt)
Singapore Airlines	7,871
Cathay Pacific	7,327
Korean Air	5,632
Thai Airways International	4,960
Emirates Airline	3,888
Qantas	3,656
United Airlines	3,269
Malaysia Airlines	3,121
Japan Airlines	2,872
China Airlines	2,835
Air China	2,731
Asiana Airlines	2,712
All Nippon Airways	2,590
Delta Air Lines	2,547
China Eastern Airlines	2,187
Other Airlines	47,893
Total	**106,093**

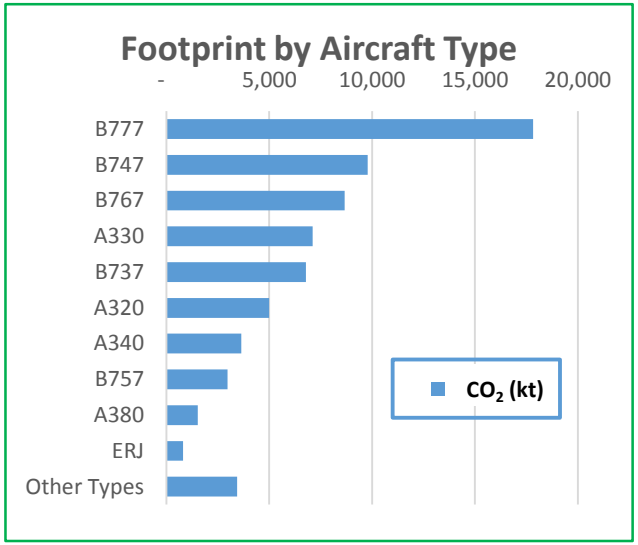
City-Pair Hierarchy	CO_2 (kt)
Singapore-London (Heathrow)	1,015
Hong Kong-London (Heathrow)	843
Sydney-Los Angeles	707
Tokyo (Narita)-Los Angeles	626
Seoul-Los Angeles	541
Sydney-Singapore	530
Singapore-Sydney	529
Hong Kong-San Francisco	524
Taipei-Los Angeles	503
Singapore-Frankfurt	502
Tokyo (Narita)-Honolulu	464
Singapore-Hong Kong	451
Hong Kong-Singapore	451
Taipei-Hong Kong	450
Hong Kong-Taipei	450
Other Routes	97,507
Total	**106,093**



N & Cen America

Total Footprint = 67,564 kt CO_2



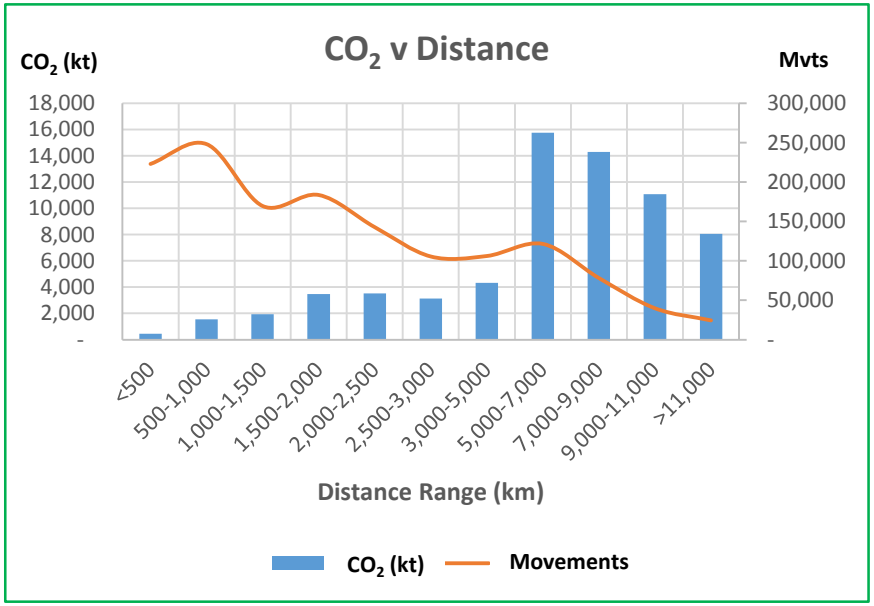


Origin Airports	CO_2 (kt)
New York (JFK)	8,201
Los Angeles	7,007
San Francisco	3,912
Toronto	3,698
Chicago	3,647
Newark	3,462
Miami	3,452
Washington	2,635
Atlanta	2,522
Vancouver	2,155
Houston	2,035
Mexico City	1,893
Dallas-Fort Worth	1,667
Honolulu	1,539
Montreal	1,261
Other Airports	18,476
Total	**67,564**

Destination Airports	CO_2 (kt)
London (Heathrow)	6,342
Tokyo (Narita)	3,656
Frankfurt	3,243
Paris (CDG)	2,791
Seoul	2,418
Hong Kong	2,212
Amsterdam	2,049
Beijing	1,378
Madrid	1,356
Sao Paulo	1,325
Shanghai	1,235
Dubai	1,230
Toronto	1,211
London (Gatwick)	1,137
Sydney	1,128
Other Airports	34,854
Total	**67,564**

Airlines	CO_2 (kt)
United Airlines	8,127
Delta Air Lines	6,687
American Airlines	6,317
Air Canada	4,043
British Airways	3,578
Lufthansa	2,315
US Airways	1,974
Air France	1,843
Korean Air	1,571
Cathay Pacific	1,494
Virgin Atlantic Airways	1,396
WestJet	1,169
JetBlue Airways	1,163
Continental Airlines	1,098
KLM Royal Dutch Airlines	1,096
Other Airlines	23,693
Total	**67,564**

City-Pair Hierarchy	CO_2 (kt)
New York (JFK)-London (Heathrow)	1,000
Los Angeles-Sydney	705
Los Angeles-London (Heathrow)	664
Los Angeles-Tokyo (Narita)	628
Los Angeles-Seoul	541
San Francisco-Hong Kong	524
Los Angeles-Taipei	503
San Francisco-London (Heathrow)	476
Honolulu-Tokyo (Narita)	464
Chicago-London (Heathrow)	442
Chicago-Tokyo (Narita)	414
Miami-London (Heathrow)	410
New York (JFK)-Tokyo (Narita)	408
Newark-London (Heathrow)	390
New York (JFK)-Paris (CDG)	372
Other Routes	59,622
Total	**67,564**



3.3 Intra Region Footprint

As indicated in Section 3.1 examination of the global footprint at the regional level is important as it may assist in understanding the potential for, or the impacts of, introducing carbon management regimes at this level.

Figure 3.3 breaks down the regional carbon footprint information shown in *Figure 2.1* into intra and inter regional parts. An intra region flight is one where an aircraft flies between two countries which are located within the same ICAO region. It can be seen that there are significant differences between the regions. In the Europe and Asia/Pacific regions about 50% of the regional footprint is generated by intra region operations while for the other regions the intra region proportion is around 20-25%. About 80% of the global intra region footprint is associated with the Europe and Asia/Pacific regions.

ICAO Origin Region	Inter region CO_2 (kt)	Intra region CO_2 (kt)	Total CO_2 (kt)	% Intra region
Europe	66,408	61,645	128,052	48
Asia/Pacific	49,614	56,479	106,093	53
N & Central America + Caribbean	51,152	16,412	67,564	24
Middle East	23,585	6,982	30,566	23
South America	11,936	4,454	16,390	27
East & South Africa	7,067	1,728	8,795	20
W & Central Africa	2,773	624	3,396	18
Total	**212,535**	**148,323**	**360,857**	**41**

Figure 3.3: Carbon footprint breakdown into inter and intra region components

Figure 3.4 provides a further insight into the intra region footprint. This shows the very different make-up of the footprint between, in particular, the Europe and Asia/Pacific regions. The Europe footprint results from a high number of flights with relatively small footprints compared to the Asia/Pacific where the CO_2/flight is approx. three times that of Europe. This is consistent with the distinct differences in geopolitical make-up between the two regions (many international flights in Europe, a continent comprising a number of relatively small countries, are broadly equivalent to domestic flights in the large countries in the other regions).

Intra region	CO_2 (kt)	Movements	CO_2 (t)/mvt
Europe	61,645	4,464,432	13.8
Asia/Pacific	56,479	1,458,956	38.7
N & Central America + Caribbean	16,412	1,083,555	15.1
Middle East	6,982	394,607	17.7
South America	4,454	233,099	19.1
East & South Africa	1,728	139,792	12.4
W & Central Africa	624	55,338	11.3
Total	**148,323**	**7,829,779**	**18.9**

Figure 3.4: Intra region footprint – average carbon intensity of flights

To provide further understanding of the intra region carbon footprint, *Figures 3.5, 3.6 and 3.7* show the carbon footprint by route for the three top ICAO regions. It is important to note the differences in scale between the three diagrams. The carbon intensity of the Asia/Pacific routes is significantly higher than that for the other two regions.

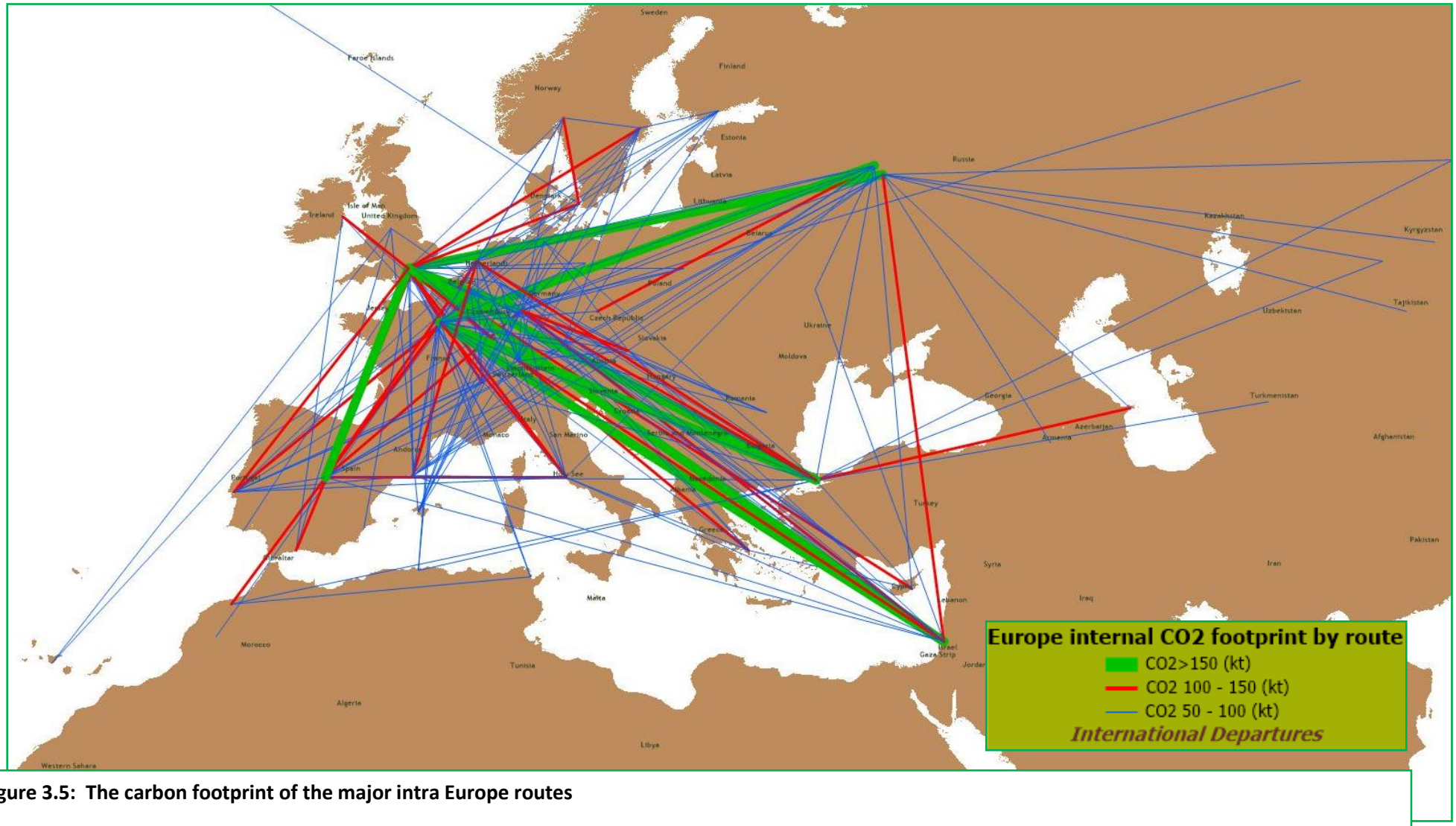


Figure 3.5: The carbon footprint of the major intra Europe routes

This chart gives an overview of the carbon intensity hierarchy for intra Europe international routes. There are eight routes in the top category (green); 29 routes in next category (red) and 176 in the blue category. There were 6,732 routes with a carbon footprint of less than 50 kt in 2012 which are not shown on the map. Collectively the routes shown on the map comprise about 25% of the carbon footprint for international intra region operations in the Europe region. Labelling of place and airport names has been omitted in an attempt to improve clarity.

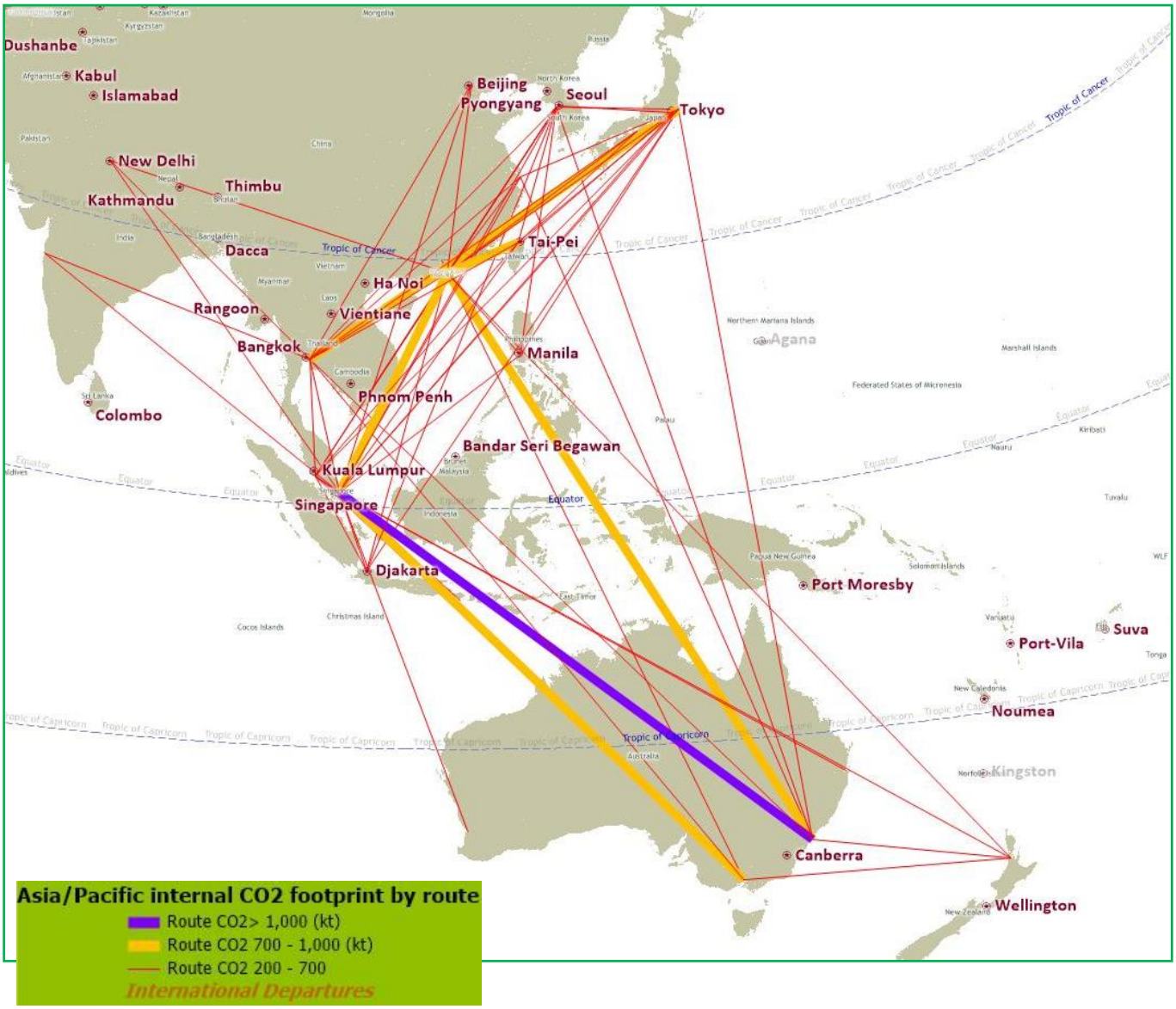


Figure 3.6: The carbon footprint of the major intra Asia/Pacific routes

This chart gives an overview of the carbon intensity hierarchy for intra Asia/Pacific international routes. There is one route in the top category (purple); 5 routes in next category (yellow) and 66 in the red category. There were 1,120 routes with a carbon footprint of less than 200 kt in 2012 which are not shown on the map. Collectively the routes shown on the map comprise about 50% of the carbon footprint for international intra region operations in the Asia/Pacific region.

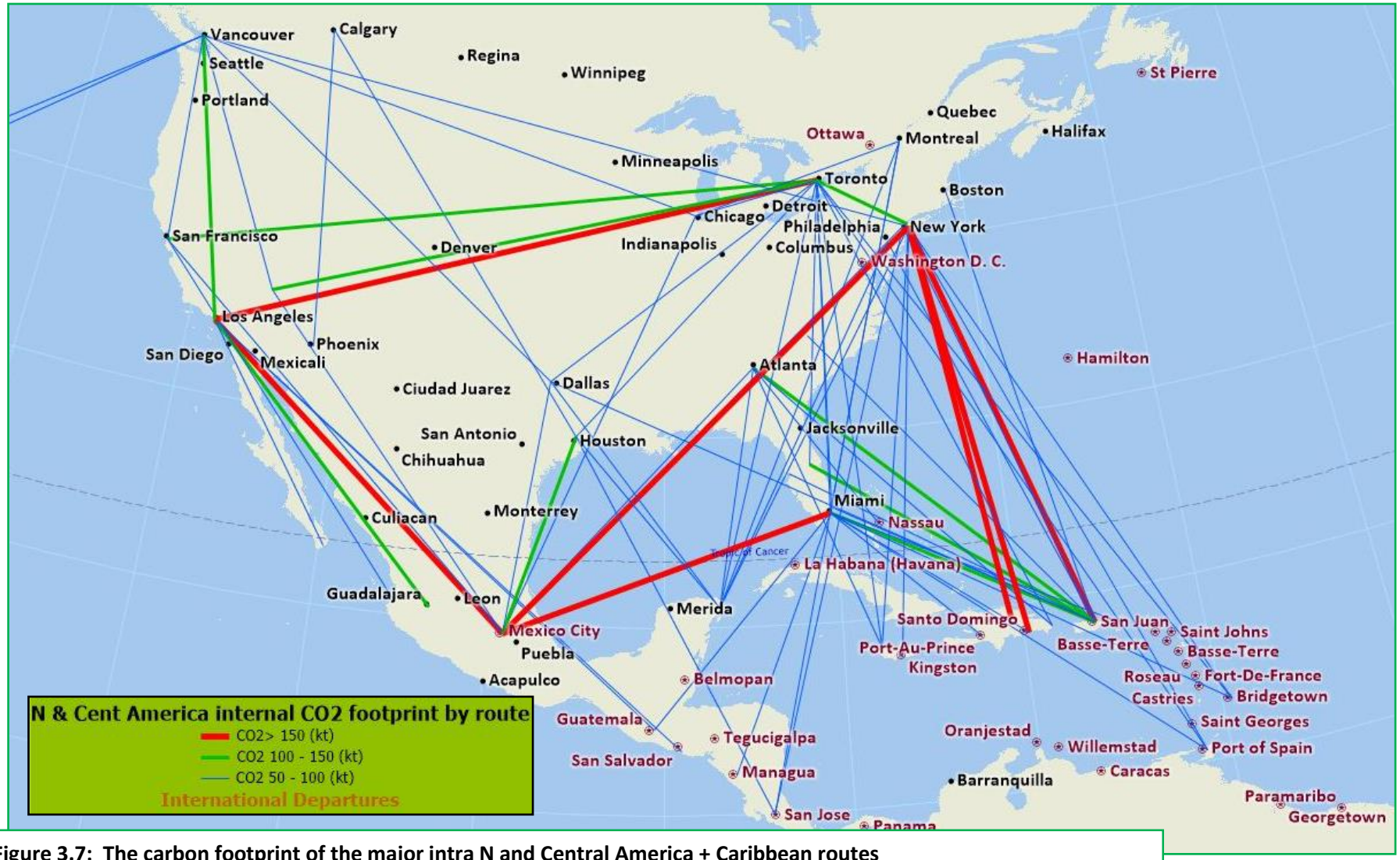


Figure 3.7: The carbon footprint of the major intra N and Central America + Caribbean routes

This chart gives an overview of the carbon intensity hierarchy for international routes within the N and Central America and the Caribbean region. There are seven routes in the top category (red); 9 routes in the next category (green) and 61 in the blue category. There were 993 routes with a carbon footprint of less than 50 kt in 2012 which are not shown on the map. Collectively the routes shown on the map comprise about 45% of the carbon footprint for international intra region operations in the N and Central America and the Caribbean region.

Chapter 4

The Countries

4.1 Introduction

Examining the footprint by country is the next logical level of disaggregation of the global carbon footprint. In addition to providing transparency in the footprinting, disaggregation at the country level is important since the deliberations currently taking place within ICAO on the management of international aviation's climate change impacts are focussed on determining liabilities and actions for individual countries.

The question of carbon footprinting at the country level has been a vexed question within the ICAO negotiations and a lot of effort has been spent on finding an acceptable way to apportion carbon between countries. At the time of writing this issue remains unresolved, nevertheless as indicated in Section 1.3, the carbon accounting in this report applies the methodology set up under the UNFCCC for defining international aviation operations and for allocating carbon. In essence in this report the CO_2 is allocated between countries by computing the CO_2 emitted by aircraft on flights between any two countries and allocating the CO_2 to the country from which the aircraft departed (notional fuel uplifted).

Figure 4.1 is a thematic map showing the distribution between countries of the global footprint for scheduled international passenger flights in 2012.

It was shown in *Figure 2.3* that the top 50 CO_2 emitting countries make up around 90% of the carbon footprint for global international scheduled passenger services. This report contains a separate CO_2 footprint profile for each of these countries. In order to avoid information overload this chapter contains, and discusses, the profiles for the top 5 countries. The profiles for the remaining 45 countries are contained in *Profile F2* in Part II.

4.2 Carbon Footprint Profile - Top 5 Countries

This section briefly discusses the carbon footprint profiles contained in this section for the top five emitting countries (ie those countries which have the greatest notional fuel uplift for international scheduled passenger departures from their territories).

United States

The United States carbon footprint profile shows:

- only a small proportion of the US international operations are within its ICAO region; the footprint is dominated by operations to the Europe and Asia/Pacific regions
- the B777 is the dominant aircraft type; the B747 also has a significant presence – these two types make up around 45% of the footprint
- there are two clear leading departure airports - New York (JFK) and Los Angeles; the top 15 origin airports make up about 90% of the footprint
- two destination airports predominate - London (Heathrow) in Europe and Tokyo (Narita) in the Asia/Pacific region; the top 15 destination airports make up about 55% of the footprint; the top 3 airlines (US carriers) make up about 35% of the footprint

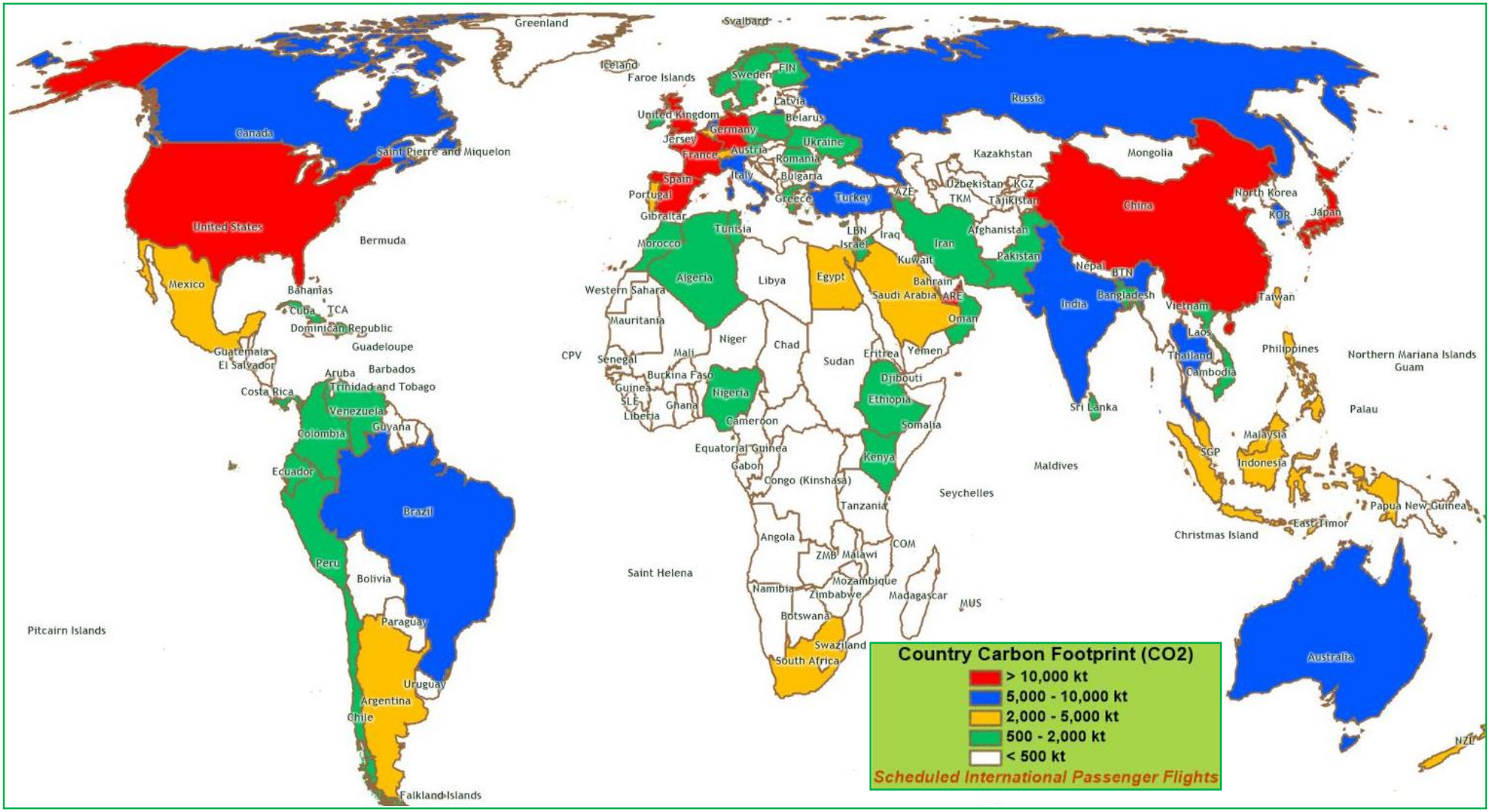
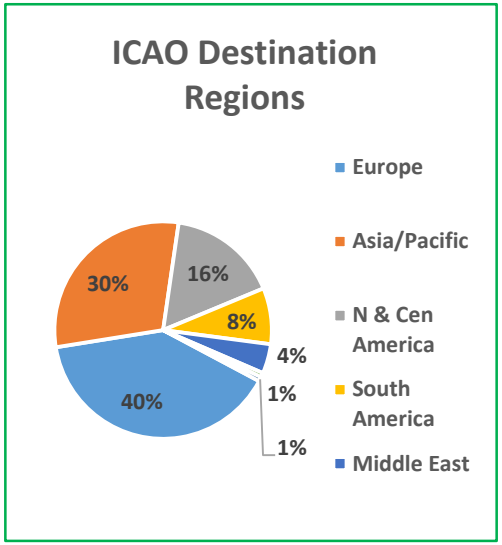


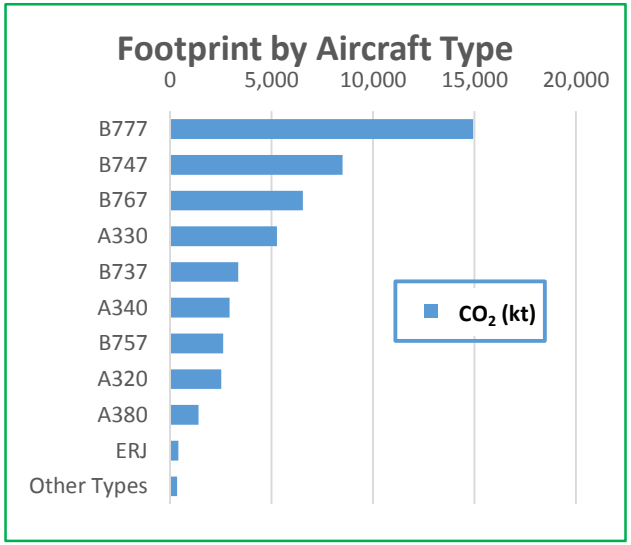
Figure 4.1: Country carbon footprints – scheduled international passenger flights 2012

This figure is a thematic map giving a visualisation of the data displayed in *Figure 2*.2. The colour relates to the quantum of the country footprint – the values are shown in the legend. There are nine countries in the first category (> 10,000 kt of CO_2); 11 countries in the second category; 14 countries in the third category and 38 countries in the fourth category. The remaining countries, with CO_2 emissions of less than 500 kt, are in the last category.

United States

Total Footprint = 49,949 kt CO_2



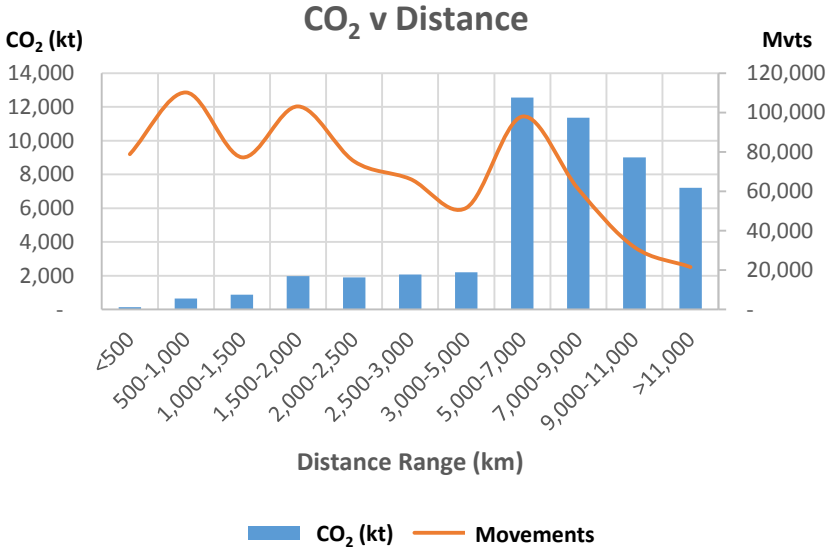


Origin Airports	CO_2 (kt)
New York (JFK)	8,201
Los Angeles	7,007
San Francisco	3,912
Chicago	3,647
Newark	3,462
Miami	3,452
Washington	2,635
Atlanta	2,522
Houston	2,035
Dallas-Fort Worth	1,667
Honolulu	1,539
Detroit	1,124
Boston	1,007
Philadelphia	987
Seattle	941
Other Airports	5,810
Total	**49,949**

Destination Airports	CO_2 (kt)
London (Heathrow)	5,492
Tokyo (Narita)	3,530
Frankfurt	2,516
Seoul	2,296
Paris (CDG)	2,002
Hong Kong	1,621
Amsterdam	1,570
Dubai	1,165
Sao Paulo	1,132
Beijing	1,111
Sydney	1,009
Shanghai	943
Taipei	943
Toronto	840
Munich	716
Other Airports	23,064
Total	**49,949**

Airlines	CO_2 (kt)
United Airlines	7,347
Delta Air Lines	6,137
American Airlines	5,231
British Airways	2,829
Lufthansa	2,009
US Airways	1,568
Korean Air	1,501
Air France	1,145
Virgin Atlantic Airways	1,122
Cathay Pacific	1,069
Emirates Airline	944
Continental Airlines	924
JetBlue Airways	863
Qantas	830
Air Canada	752
Other Airlines	15,679
Total	**49,949**

City-Pair Hierarchy	CO_2 (kt)
New York (JFK)-London (Heathrow)	1,000
Los Angeles-Sydney	705
Los Angeles-London (Heathrow)	664
Los Angeles-Tokyo (Narita)	628
Los Angeles-Seoul	541
San Francisco-Hong Kong	524
Los Angeles-Taipei	503
San Francisco-London (Heathrow)	476
Honolulu-Tokyo (Narita)	464
Chicago-London (Heathrow)	442
Chicago-Tokyo (Narita)	414
Miami-London (Heathrow)	410
New York (JFK)-Tokyo (Narita)	408
Newark-London (Heathrow)	390
New York (JFK)-Paris (CDG)	372
Other Routes	42,007
Total	**49,949**



- New York (JFK)-Heathrow is the dominant route; the city-pair hierarchy is interesting for its spread of departure airports compared to the other four countries in the top 5 (the top routes from the other countries originate in just one or two airports); the top 15 routes make up less than 10% of the footprint

- the CO_2 v Distance profile indicates that almost all the CO_2 is generated by operations travelling further than 5,000 km; the two distinct peaks in the number of movements curve in the 500-1,000 and 1,500-2,000 km ranges make little contribution to the footprint.

United Kingdom

The United Kingdom carbon footprint profile shows:

- in terms of the major regions there is a strong bias toward N and Central America + Caribbean compared to Asia/Pacific; there is somewhat less focus on intra Europe flights compared to Frankfurt

- the B777 occupies a similar dominant position as in the US for aircraft types; the B747 has a relatively greater presence in the UK; narrow bodied aircraft make up about 25% of the footprint

- London (Heathrow) is overwhelmingly the lead origin airport for the UK generating about 70% of the footprint; the top three airports make up over 85% of the footprint

- there are three dominant destination airports with similar footprints followed by a good spread of other destination airports across the world; the top 15 destination airports make up about 35% of the footprint

- the top 4 airlines make up about 50% of the footprint; these airlines are UK carriers – two of these are low cost carriers

- all of the top 15 UK routes originate from Heathrow; all of these routes are to destinations outside Europe

- the CO_2 v Distance profile reveals a greater footprint contribution by short haul flights than in the US; there is a distinct peak in the carbon footprint in the 5,000-7,000 km range.

Germany

The Germany carbon footprint profile shows:

- a greater focus on Europe than the UK; there is a reasonable balance between N America and the Asia/Pacific regions

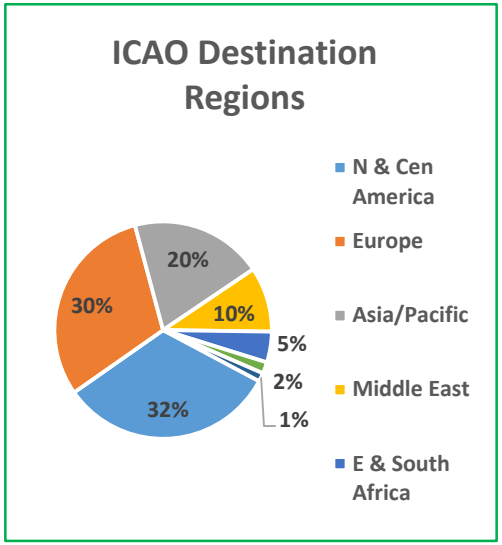
- this is the only country of the top 5 where narrow bodied aircraft are the top aircraft type; there is a significant B747 presence and a notable lack of dependence on the B777 compared to the other four countries in the top 5

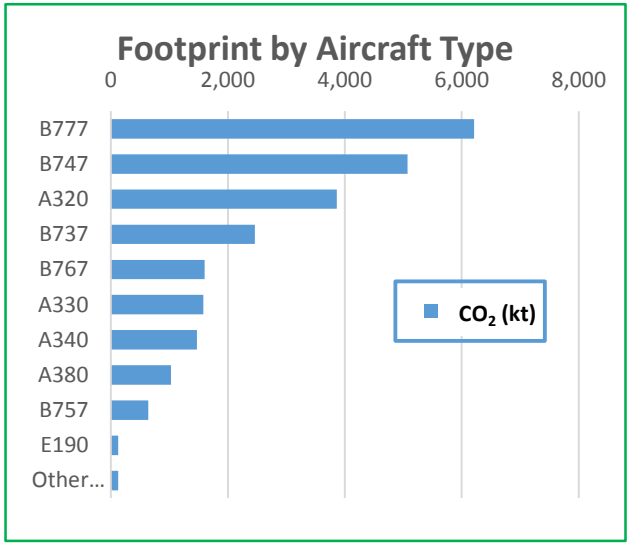
- Frankfurt is the clear leader as an origin airport; the top four origin airports make up about 90% of the footprint

- the top 5 destination airports are in the Asia/Paific or Middle East regions; two of the top 15 destination airports are in Europe

United Kingdom

Total Footprint = 24,811 kt CO_2



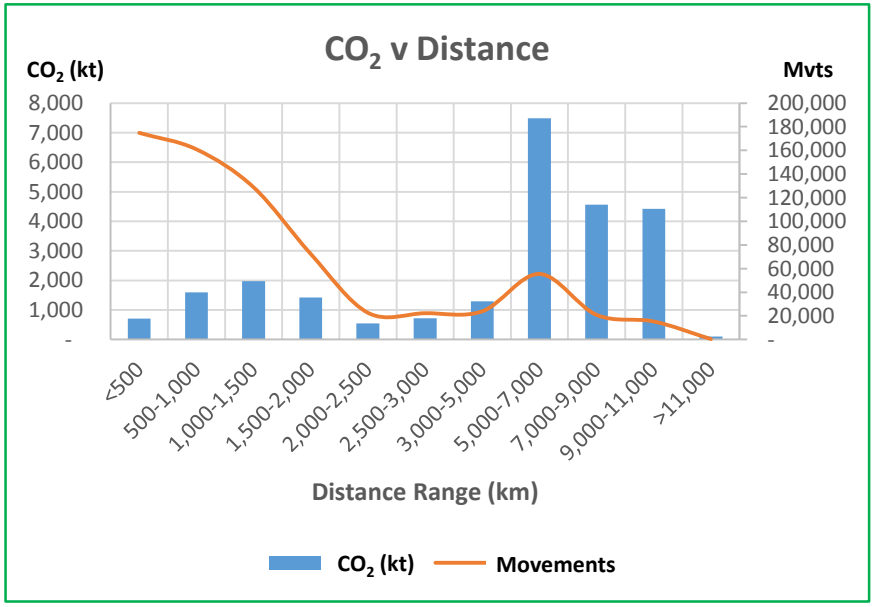


Origin Airports	CO_2 (kt)
London (Heathrow)	16,394
London (Gatwick)	2,865
Manchester	1,516
London (Stansted)	807
Birmingham	512
London (Luton)	480
Glasgow	324
Edinburgh	287
Bristol	233
Liverpool	217
Derby	201
Newcastle	190
Leeds/Bradford	172
London (City)	159
Belfast	105
Other Airports	351
Total	**24,811**

Destination Airports	CO_2 (kt)
Dubai	1,094
New York (JFK)	1,046
Singapore	1,015
Hong Kong	886
Los Angeles	664
Newark	517
Johannesburg	483
San Francisco	476
Chicago	473
Miami	411
Bangkok	402
Washington	375
Toronto	365
Mumbai	354
Delhi	352
Other Airports	15,899
Total	**24,811**

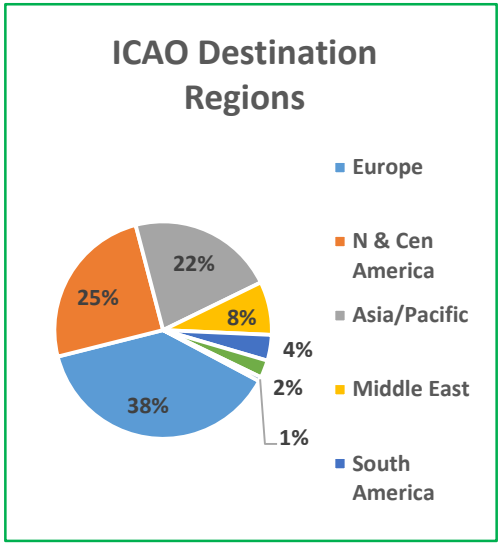
Airlines	CO_2 (kt)
British Airways	7,749
Virgin Atlantic Airways	1,958
Easyjet	1,505
Ryanair	1,411
American Airlines	905
Emirates Airline	866
United Airlines	822
Singapore Airlines	458
Cathay Pacific	432
Air Canada	431
Thomson	423
Delta Air Lines	369
Monarch Airlines	349
Qantas	348
Jet2.com	341
Other Airlines	6,446
Total	**24,811**

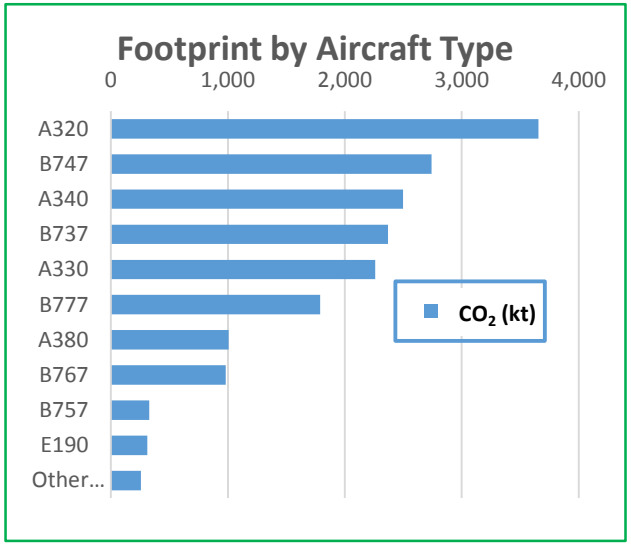
City-Pair Hierarchy	CO_2 (kt)
London (Heathrow)-Singapore	1,015
London (Heathrow)-New York (JFK)	1,000
London (Heathrow)-Hong Kong	843
London (Heathrow)-Los Angeles	664
London (Heathrow)-Dubai	542
London (Heathrow)-Johannesburg	483
London (Heathrow)-San Francisco	476
London (Heathrow)-Chicago	442
London (Heathrow)-Miami	411
London (Heathrow)-Bangkok	402
London (Heathrow)-Newark	390
London (Heathrow)-Washington	360
London (Heathrow)-Mumbai	354
London (Heathrow)-Delhi	352
London (Heathrow)-Tokyo (Narita)	347
Other Routes	16,732
Total	**24,811**



Germany

Total Footprint = 18,757 kt CO_2



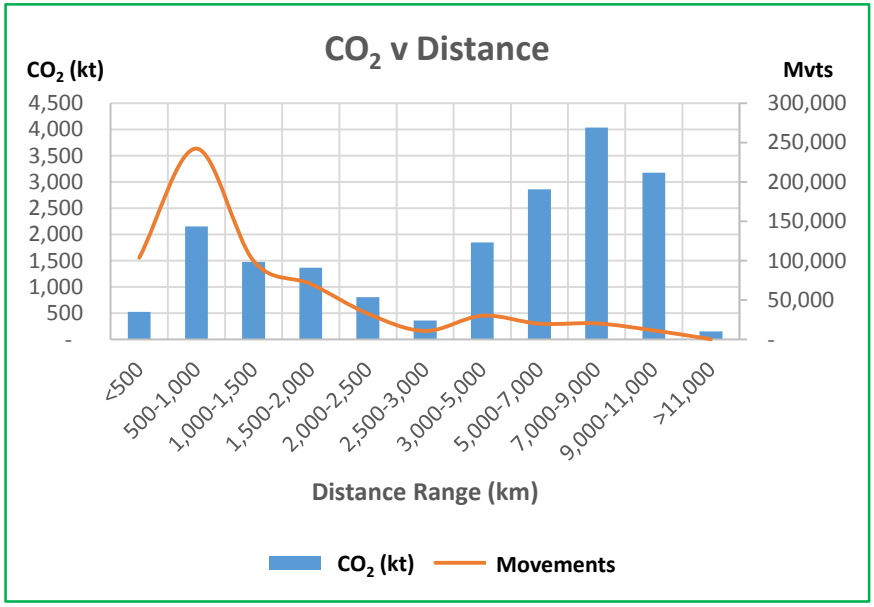


Origin Airports	CO_2 (kt)
Frankfurt	10,193
Munich	3,400
Dusseldorf	1,481
Berlin	1,180
Hamburg	581
Stuttgart	444
Cologne-Bonn	342
Hannover	235
Hahn	148
Nuremburg	132
Niederrhein	131
Bremen	83
Dortmund	82
Leipzig	72
Soellingen	51
Other Airports	203
Total	**18,757**

Destination Airports	CO_2 (kt)
Singapore	645
Dubai	492
Tokyo (Narita)	460
Bangkok	443
Beijing	420
Chicago	411
Palma de Mallorca	394
Newark	386
San Francisco	373
New York (JFK)	367
Washington	362
Shanghai	360
Istanbul	349
Seoul	325
Hong Kong	308
Other Airports	12,663
Total	**18,757**

Airlines	CO_2 (kt)
Lufthansa	7,605
Air Berlin	1,492
Condor Flugdienst	772
United Airlines	759
Ryanair	451
Singapore Airlines	416
Emirates Airline	405
Germanwings	326
TUIfly	313
Thai Airways International	311
Air China	308
Air Canada	296
Easyjet	261
Delta Air Lines	259
All Nippon Airways	254
Other Airlines	4,528
Total	**18,757**

City-Pair Hierarchy	CO_2 (kt)
Frankfurt-Singapore	502
Frankfurt-Bangkok	306
Frankfurt-Tokyo (Narita)	298
Frankfurt-Shanghai	289
Frankfurt-San Francisco	282
Frankfurt-Seoul	270
Frankfurt-Beijing	257
Frankfurt-Washington	256
Frankfurt-Chicago	255
Frankfurt-New York (JFK)	248
Frankfurt-Hong Kong	235
Frankfurt-Sao Paulo	218
Frankfurt-Johannesburg	186
Frankfurt-Dubai	176
Frankfurt-Toronto	169
Other Routes	14,809
Total	**18,757**



- Lufthansa is very dominant; the top two airlines (both German carriers) make up about 50% of the footprint
- Frankfurt is the origin airport for all of the top 15 routes; the top 15 routes make up about 25% of the footprint
- there is a significant contribution to the footprint by shorter range flights – this shows a noticeable difference when compared to the other four airports in the top 5; there are prominent spikes in CO_2 generation in the 500-1,000 km and the 7,000-9,000 km ranges.

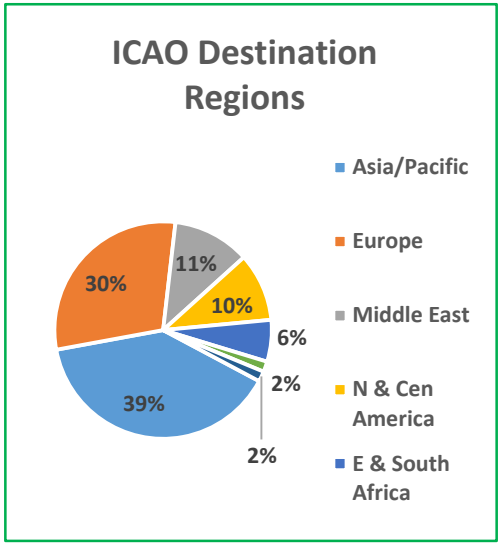
United Arab Emirates

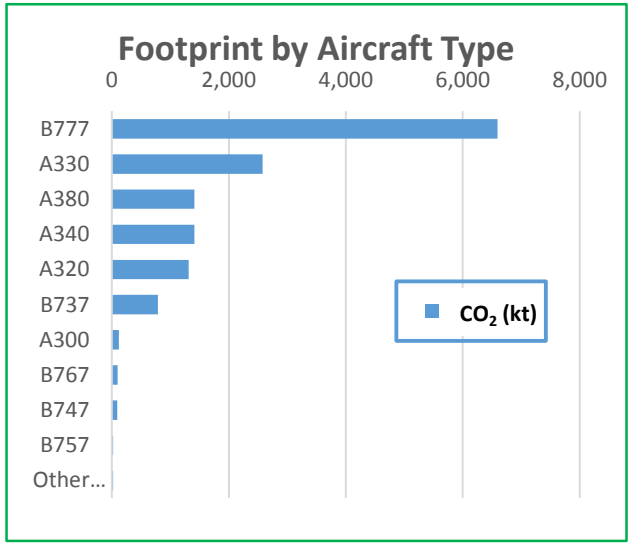
The United Arab Emirates carbon footprint profile shows:

- the largest segment of the footprint is focussed on the Asia/Pacific region with a somewhat smaller portion associated with operations to Europe; there is little contribution from flights to N America
- wide bodied aircraft occupy the top four positions in the aircraft type hierarchy; the B777 is very dominant (about 45% of the footprint); it is noteworthy that there is virtually no contribution to the footprint by the B747; the A380 makes a significant contribution (about 10% of the footprint)
- as an origin airport Dubai contributes about 75% of the UAE footprint; to all intents and purposes only two airports – Dubai and Abu Dhabi - are signficant (making up about 95% of the footprint)
- Heathrow is the major destination airport; most of the top 15 destinations have a similar sized footprint and have a wide geographic spread throughout the regions (11 of the top 15 destination airports have a footprint between 200 and 300 kt of CO_2): the top 15 destination airports make up about 30% of the footprint
- together Emirates and Etihad comprise just over 70% of the footprint; there is a very even footprint spread between the other airlines (there are nine airlines with a footprint contribution of between 111 and 133 kt of CO_2)
- the city pair hierarchy shows a similar broad sharing of the footprint to that revealed by the other elements of the profile; the top 15 routes comprise about 25% of the footprint
- the CO_2 v Distance chart shows that very little CO_2 is generated by flights travelling less than 3,000 km (there are similarities with the US and Japan); about 55% of the footprint derives from flights between 3,000 km and 7,000 km; there is a noticeable contribution from flights travelling more than 11,000 km.

United Arab Emirates

Total Footprint = 14,547 kt CO_2



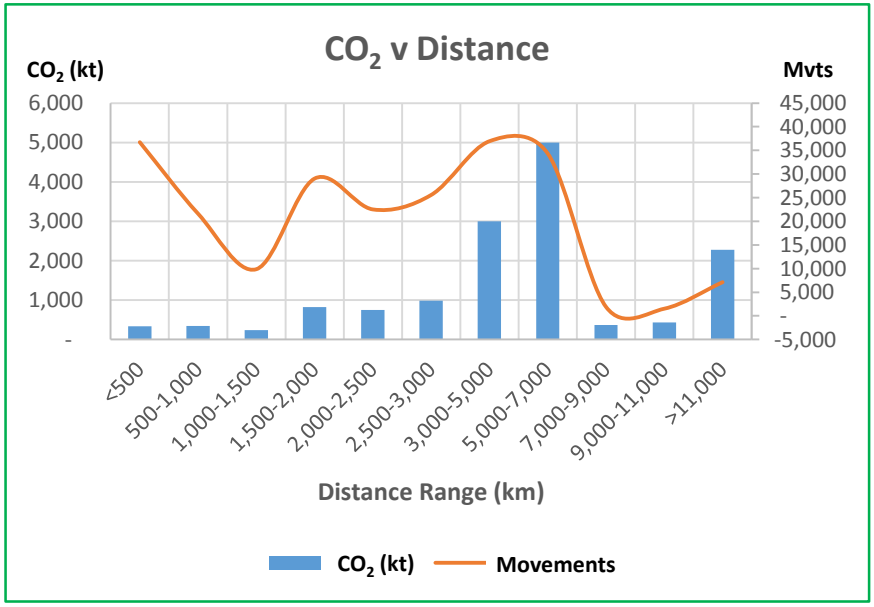


Origin Airports	CO_2 (kt)
Dubai	10,976
Abu Dhabi	2,970
Sharjah	559
Ras al Khaimah	38
Al Ain	4
Other Airports	0
Total	**14,547**

Destination Airports	CO_2 (kt)
London (Heathrow)	731
Sydney	489
Bangkok	363
New York (JFK)	348
Frankfurt	298
Paris (CDG)	279
Singapore	276
Manchester	263
Manila	253
Beijing	231
Johannesburg	231
Kuala Lumpur	229
Melbourne	222
Hong Kong	220
Jakarta	218
Other Airports	9,896
Total	**14,547**

Airlines	CO_2 (kt)
Emirates Airline	8,214
Etihad Airways	2,356
Air Arabia	427
Flydubai	399
British Airways	192
Cathay Pacific	133
Air India	121
Air Berlin	119
Lufthansa	119
Delta Air Lines	115
Singapore Airlines	114
Air India Express	114
United Airlines	112
Royal Brunei Airlines	111
Saudi Arabian Airlines	88
Other Airlines	1,816
Total	**14,547**

City-Pair Hierarchy	CO_2 (kt)
Dubai-London (Heathrow)	542
Dubai-Sydney	277
Dubai-New York (JFK)	253
Dubai-Bangkok	238
Dubai-Singapore	234
Abu Dhabi-Sydney	212
Dubai-Hong Kong	203
Dubai-Los Angeles	199
Abu Dhabi-London (Heathrow)	189
Dubai-Paris (CDG)	188
Dubai-Beijing	183
Dubai-Johannesburg	181
Dubai-Kuala Lumpur	180
Dubai-Frankfurt	176
Dubai-Perth	173
Other Routes	11,119
Total	**14,547**



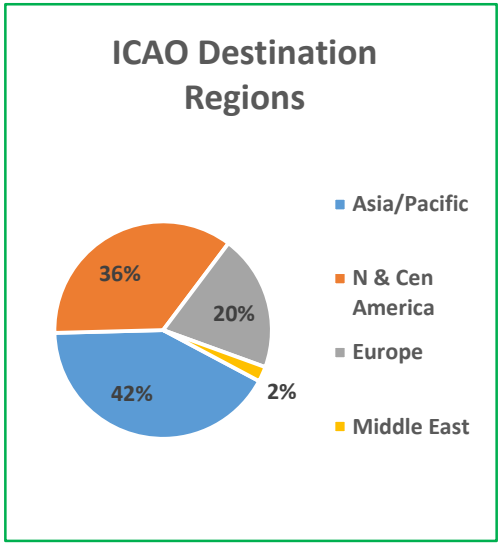
Japan

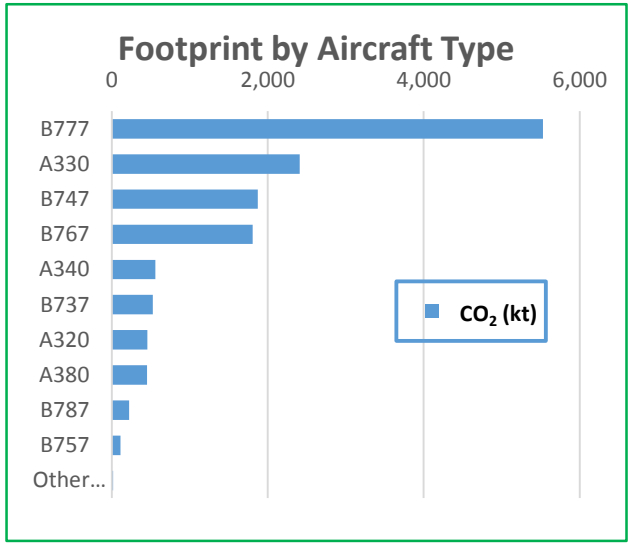
The Japan carbon footprint profile shows:

- flights to N America and to other countries within the Asia/Pacific region are the focus of the footprint; the proportion of the footprint associated with Europe is relatively small; in contrast to the other four countries, the footprint is made up from flights to only four of the seven ICAO regions
- in a similar manner to the other countries (except Germany) the B777 is the predominant aircraft type; about 85% of the footprint is generated by wide bodied aircraft
- the footprint is concentrated on three origin airports - about 90% of the footprint derives from these; flights from Narita make up about 65% of the footprint
- there are 5 Asia/Pacific airports in the top 10 destination airports; in common with Germany and the UAE there is not a great difference in the footprint across the top 15 destination airports; the top 15 destination airports make up about 60% of the footprint
- four airlines (2 Japan carriers and 2 US carriers) dominate the footprint (about 45% of the footprint)
- all but one of the city pairs originate from Narita; there is a good CO_2 spread across the routes; the top 15 routes generate about 35% of the footprint
- the CO_2 v Distance relationship shows the now familiar pattern of high movement numbers, but low carbon generation, in the short haul area; the major contribution to the footprint comes from operations in the 9,000 to 11,000 km range (about 30% of the footprint).

Japan

Total Footprint = 13,960 kt CO_2



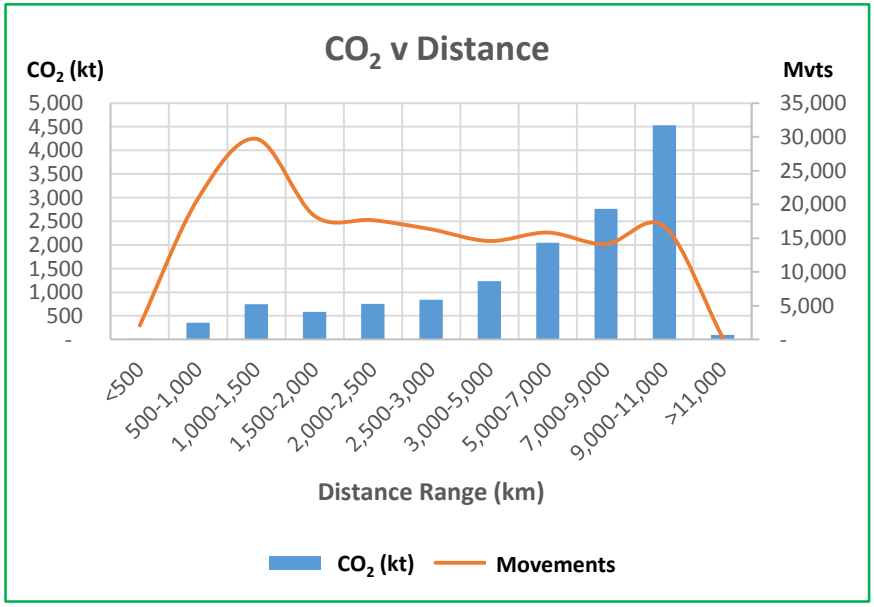


Origin Airports	CO_2 (kt)
Tokyo (Narita)	8,905
Osaka	2,050
Tokyo (Haneda)	1,575
Nagoya	787
Fukuoka	300
Sapporo/Chitose	138
Okinawa	43
Hiroshima	26
Sendai	18
Shizuoka	16
Okayama	15
Niigata	15
Komatsu	12
Toyama	9
Kagoshima	7
Other Airports	42
Total	**13,960**

Destination Airports	CO_2 (kt)
Honolulu	922
Los Angeles	777
Seoul	705
Taipei	662
Bangkok	646
Singapore	630
Frankfurt	575
Paris (CDG)	562
Hong Kong	555
New York (JFK)	531
San Francisco	422
Shanghai	420
Chicago	414
London (Heathrow)	405
Detroit	286
Other Airports	5,447
Total	**13,960**

Airlines	CO_2 (kt)
Japan Airlines	1,995
All Nippon Airways	1,844
Delta Air Lines	1,663
United Airlines	1,071
American Airlines	468
Singapore Airlines	457
Korean Air	434
Lufthansa	396
China Airlines	396
Cathay Pacific	389
Thai Airways International	351
Air France	291
KLM Royal Dutch Airlines	234
Alitalia	224
Asiana Airlines	224
Other Airlines	3,521
Total	**13,960**

City-Pair Hierarchy	CO_2 (kt)
Tokyo (Narita)-Los Angeles	626
Tokyo (Narita)-Honolulu	464
Tokyo (Narita)-Chicago	414
Tokyo (Narita)-New York (JFK)	408
Tokyo (Narita)-Paris (CDG)	386
Tokyo (Narita)-Bangkok	350
Tokyo (Narita)-London (Heathrow)	347
Tokyo (Narita)-Singapore	333
Tokyo (Narita)-Frankfurt	298
Tokyo (Narita)-San Francisco	272
Tokyo (Narita)-Taipei	216
Tokyo (Narita)-Hong Kong	211
Tokyo (Narita)-Washington	202
Tokyo (Narita)-Dallas-Fort Worth	193
Tokyo (Haneda)-Seoul	183
Other Routes	9,059
Total	**13,960**



Chapter 5

The Airports

5.1 Introduction

This chapter provides a breakdown of the global international passenger flights carbon footprint for 2012 from the perspective of the airports. The information relates to aircraft operations and not to the carbon footprint of the airports themselves. That is, this chapter does not compute or report on carbon footprint associated with airport buildings, ground transport or non-aircraft emissions.

It is difficult to find published carbon footprint reports for aircraft operations at airports. Seattle-Tacoma International Airport (SEA-TAC) in the United States carried out a comprehensive carbon footprinting exercise in 2006.[23] *Figure 22* summarises the key components of the SEA-TAC footprint – it can be seen that activities by the airport company itself make up a small proportion of the airport's carbon footprint. The footprint is dominated by en route aircraft. While this figure portrays the carbon footprint breakdown at one particular airport, it is likely that this is generally representative of major airports with international traffic.

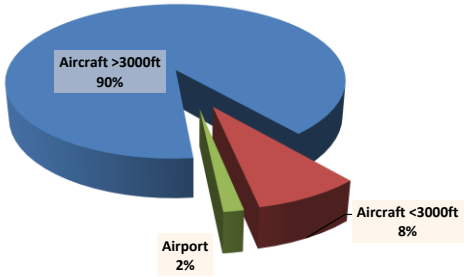


Figure 5.1: Breakdown of carbon footprint at SEA-TAC

While it is difficult to find published carbon footprint reports for airports which capture aircraft operations, the Airports Council International (ACI) has developed an airport carbon accreditation scheme which incorporates detailed carbon footprinting for activities within an airport's 'operational boundary'.[24] The ACI reported emissions for airports in Europe and Asia of around 4-5 kg CO_2/PAX is broadly consistent with the value of the airport's contribution to the aviation footprint of 2% shown in Figure 5.1 (cross-refer to *Figure 5.2)*.[25]

It is important for airports to at least be aware of, and ideally report, carbon footprint information capturing the carbon footprint associated with departing aircraft. While the airport is correct in reporting only the emissions for which it is directly responsible when considered from the point of view of incurring carbon charges, say under an emissions trading scheme, omitting this information leaves a major gap in any sustainability reporting. Members of the community and researchers typically think of an airport's carbon footprint as being associated with aircraft operations – there would be zero CO_2 emissions from aircraft operations in the absence of airports – and they discuss and report airport climate change emissions on this basis. [26,27]

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[23] *Greenhouse Gas Emissions Inventory 2006*. Seattle-Tacoma International Airport. http://www.airportattorneys.com/files/greenhousegas06.pdf

[24] ACI, *Airport Carbon Accreditation*: http://www.airportcarbonaccreditation.org/about.html

[25] ACI, *Airport Carbon Accreditation, Annual Report 2011-12*: http://www.aci-europe.org/component/downloads/downloads/3266.html

[26] Stop Stansted Expansion, *CO_2 emissions counter*: http://www.stopstanstedexpansion.com/

[27] A McIntosh, C Downie, *Aviation and Greenhouse Gas Emissions in the ACT*, Australia Institute, 2008: http://www.tai.org.au/file.php?file=web_papers/WP109.pdf

5.2 Airport Footprint Overview

Figure 5.2 shows the ranking of the top 45 airports in the world by CO_2 footprint of departing aircraft.

In this report airports have generally been grouped where there is more than one international airport in a city. In the case of the very large cities with multiple airports (viz London, New York, Tokyo and Paris) the airports have been separately identified. Therefore, while the term 'airport' is used throughout this report it should more correctly be termed 'city' in many of the citations. This issue is discussed in Section 8.2.

A map showing the carbon footprint associated with aircraft departing from specific airports on international flights is shown in *Figure 5.3*. The airports have been split into 4 categories based on the quantum of the footprint – this is shown in the legend on the map. The colour bands in *Figure 5.2* correspond with the first three categories shown on the map.

The CO_2 footprint of London (Heathrow) is significantly larger than the other airports demonstrating its role as the key global hub for scheduled international passenger services. Heathrow would occupy 4th position in the country hierarchy if it were a country. To place the footprint of scheduled international passenger departures from Heathrow into further context, Heathrow would be the 15th highest CO_2 emitting power plant in the United States if it were a US power station.[28]

It is interesting to note that there is only one airport from the United States (the country with the largest international passenger CO_2 footprint) in the top 10 airports (New York (JFK)), and only 2 in the top 20. This demonstrates the geographically dispersed nature of international passenger airports in the US.

The Table shows that the top 45 airports make up about 60% of the global CO_2 footprint. San Francisco is the airport with the greatest CO_2/PAX (CO_2/PAX figure) – this reflects the focus of the US west coast airports on long haul international services into the Asia/Pacific region.

Origin Airports	CO_2 (kt)	CO_2/PAX (kg)	Cumulative %
London (Heathrow)	16,404	458	5
Dubai	10,968	396	8
Hong Kong	10,367	368	10
Frankfurt	10,191	384	13
Paris (CDG)	10,127	385	16
Singapore	9,823	381	19
Tokyo (Narita)	8,912	556	21
New York (JFK)	8,220	589	24
Seoul	7,917	358	26
Bangkok	7,555	379	28
Amsterdam	7,304	336	30
Los Angeles	7,027	840	32
Beijing	5,076	504	33
Shanghai	4,965	392	35
Madrid	4,779	331	36
Sydney	4,653	710	37
Moscow	4,515	279	38
Kuala Lumpur	4,229	305	40
Istanbul	4,153	248	41
Taipei	4,077	247	42
San Francisco	3,938	856	43
Doha	3,878	328	44
Sao Paulo	3,771	631	45
Toronto	3,696	354	46
Chicago	3,646	620	47
Newark	3,463	519	48
Miami	3,443	324	49
Munich	3,401	240	50
Roma	3,344	254	51
Zurich	3,091	243	52
Johannesburg	2,990	540	53
Abu Dhabi	2,972	385	53
London (Gatwick)	2,863	250	54
Washington	2,600	634	55
Atlanta	2,522	472	56
Delhi	2,504	435	56
Buenos Aires	2,415	445	57
Vancouver	2,147	519	58
Melbourne	2,124	649	58
Brussels	2,093	216	59
Manila	2,093	311	59
Mumbai	2,081	418	60
Osaka	2,048	340	61
Houston	2,035	409	61
Milano	2,012	219	62
Other Airports	138,427	243	100
Total	**360,857**	**300**	**100**

Figure 5.2: Airport carbon footprint hierarchy

[28] *Carbon Dioxide Emissions From Power Plants Rated Worldwide*, Science News: http://www.sciencedaily.com/releases/2007/11/071114163448.htm

Figure 5.3: Carbon footprint by airport

This map shows the CO_2 footprint associated with aircraft departures from the top 310 international airports (ranked by carbon footprint). The quantum of the carbon footprints is shown in the legend. There are five airports in the first category; 15 in the second; 25 in the third; 36 in the fourth; and 229 in the fifth category. There are a further 1,058 international airports in the dataset which have a carbon footprint of less than 100 (kt) – these are not shown in order to assist clarity. This figure has been extracted from the core dataset and airports are not grouped (see for example Moscow which is grouped throughout the rest of the report – the figure shows it has two significant airports).

5.3 Carbon Footprint Profile - Top 5 Airports

In a similar manner to the previous two chapters, this chapter briefly discusses the carbon footprint profiles of the top 5 airports. Profiles of the next 15 airports (the blue category) are contained in *Profile F3* in Part II.

The carbon footprint profiles for the airports introduce an element that shows the carbon footprint distribution between airlines on the top 15 routes. This is of interest because if options for introducing route by route carbon management measures are being explored it is important to understand how many entities will be involved on each route and the likely imposts on each of those bodies.

London (Heathrow)

Given the extremely dominant position that Heathrow occupies in the United Kingdom aviation structure, it is interesting to note some differences between the UK and Heathrow profiles (see Section 4.2). The London (Heathrow) carbon footprint profile shows:

- in terms of the major regions there is a strong bias toward N and Central America + Caribbean compared to the Asia/Pacific region; there is somewhat less focus on intra Europe flights compared to Frankfurt and Paris
- the B777 and the B747 contribute about 60% of the footprint; there is a relatively small contribution from narrow bodied aircraft
- New York (JFK) and Singapore plus Hong Kong are significant hubs to the west and the east; outside these three airports there is a spread of destination airports which generate similar carbon footprints
- it is interesting to note that the top two airlines are the same as in the UK profile, however the two low cost carriers (Easyjet and Ryanair) which are prominent in the UK profile are not present in the Heathrow profile (ie they operate to/from other UK airports)
- compared to the UK CO_2 v Distance profile the Heathrow profile indicates a lower priority on short haul movements – there is a noticeable drop in the carbon contribution from these operations
- the element in the bottom right shows the CO_2 split between operators in the top city-pairs; all the routes have the footprint split between a number of airlines – the significant role played by British Airways can be seen across all routes.

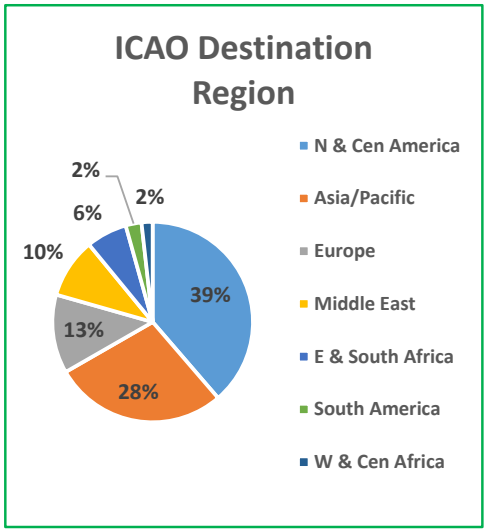
Dubai

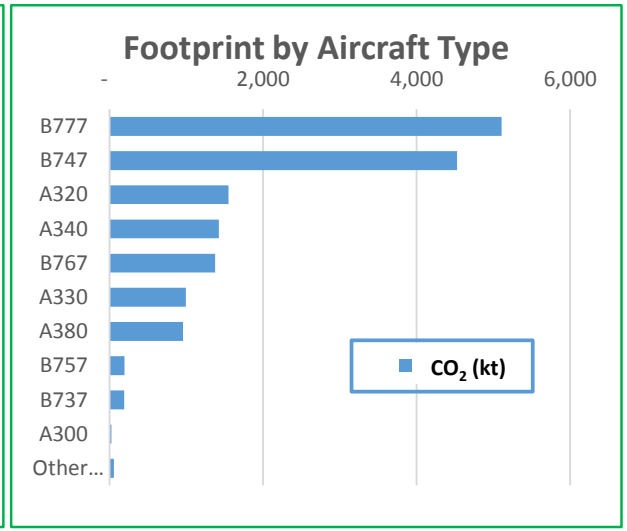
The Dubai carbon footprint profile shows:

- The main contribution to the carbon footprint is associated with the Asia/Pacific region; Europe makes a lesser contribution while N America is significantly less important
- the B777 is very dominant (about 55% of the footprint); in contrast to three of the other airports in the top 5, there is virtually no B747 presence; the A380 provides a significant contribution to the footprint
- Heathrow is the prominent destination airport; after this Dubai has a more diversified family of destination airports than the other airports in the top 5; the top 15 destination airports contribute about 30% of the footprint

London (Heathrow)

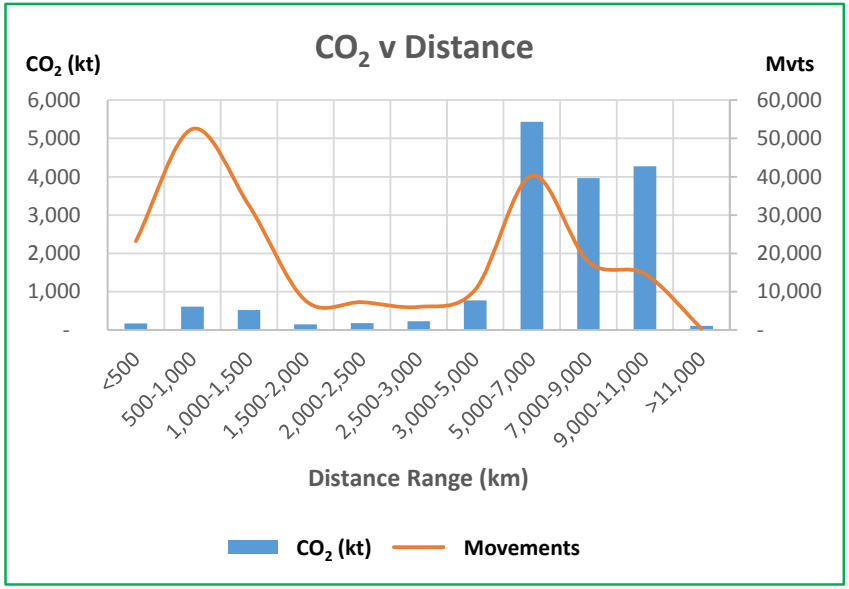
Total Footprint = 16,394 kt CO_2

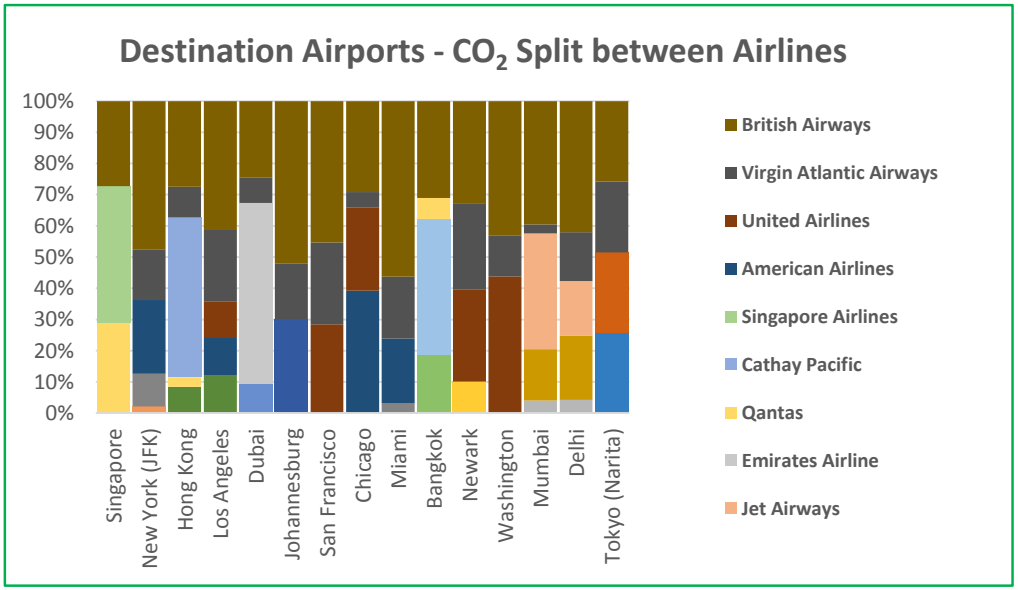




Destination Airports	CO_2 (kt)
Singapore	1,015
New York (JFK)	1,000
Hong Kong	843
Los Angeles	664
Dubai	542
Johannesburg	483
San Francisco	476
Chicago	442
Miami	411
Bangkok	402
Newark	390
Washington	360
Mumbai	354
Delhi	352
Tokyo (Narita)	347
Other Airports	8,314
Total	**16,394**

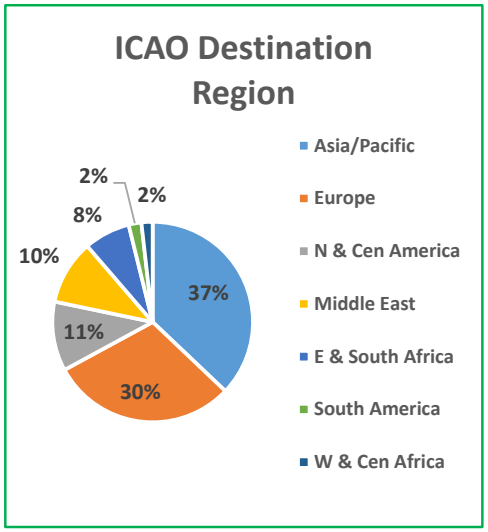
Airlines	CO_2 (kt)
British Airways	6,960
Virgin Atlantic Airways	1,325
American Airlines	849
United Airlines	708
Singapore Airlines	444
Cathay Pacific	432
Air Canada	431
Qantas	348
Delta Air Lines	321
Emirates Airline	314
Malaysia Airlines	282
Qatar Airways	212
Jet Airways	193
South African Airways	190
Thai Airways International	174
Other Airlines	3,212
Total	**16,394**

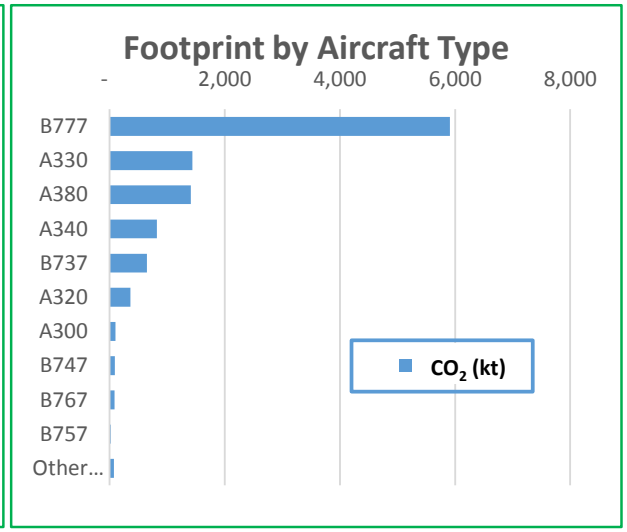




Dubai

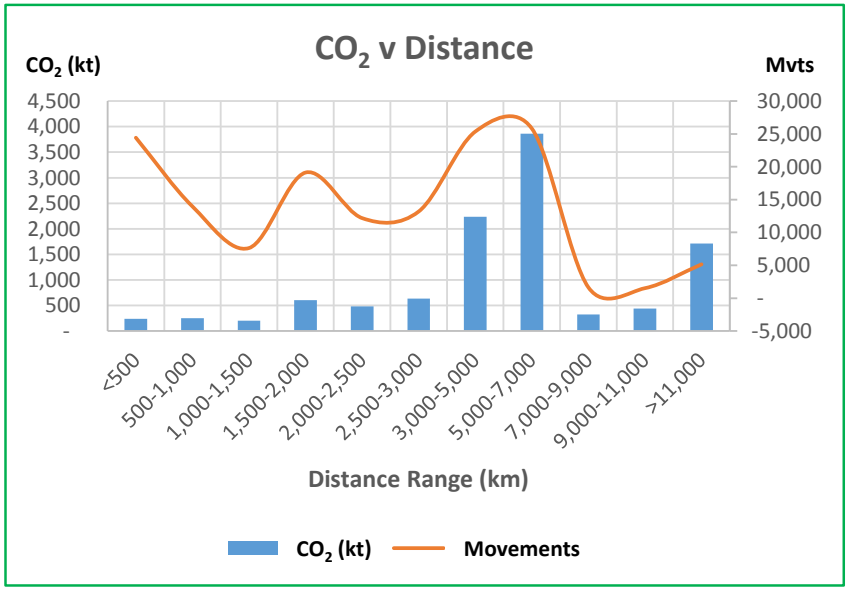
Total Footprint = 10,976 kt CO_2

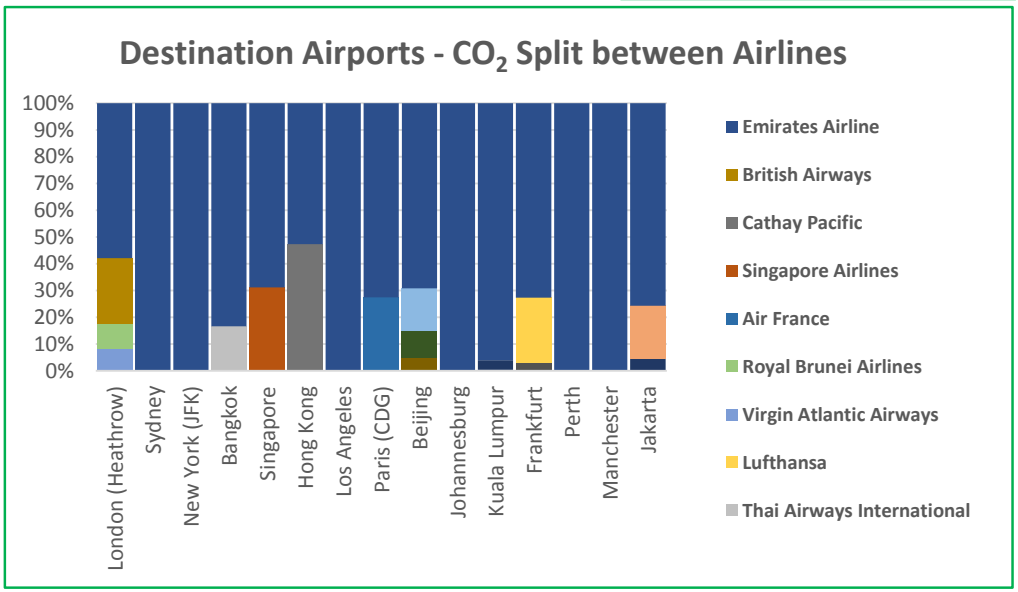




Destination Airports	CO_2 (kt)
London (Heathrow)	542
Sydney	277
New York (JFK)	253
Bangkok	238
Singapore	234
Hong Kong	203
Los Angeles	199
Paris (CDG)	188
Beijing	183
Johannesburg	181
Kuala Lumpur	180
Frankfurt	176
Perth	173
Manchester	172
Jakarta	157
Other Airports	7,620
Total	**10,976**

Airlines	CO_2 (kt)
Emirates Airline	8,214
Flydubai	399
British Airways	133
Delta Air Lines	115
United Airlines	112
Cathay Pacific	111
Royal Brunei Airlines	111
Singapore Airlines	86
Saudi Arabian Airlines	80
Lufthansa	79
China Southern Airlines	78
Air India Express	67
Air India	66
KLM Royal Dutch Airlines	60
Garuda Indonesia	56
Other Airlines	1,211
Total	**10,976**





- Emirates makes up about 75% of the footprint; the low cost carrier *Flydubai* makes a significant footprint contribution
- the CO_2 v Distance element is effectively the same as in the UAE profile discussed in the previous chapter; very little CO_2 is generated by flights travelling less than 3,000 km
- the route CO_2 distribution element shows a very different picture to Heathrow; on six of the top 15 routes Emirates is the only contributor to the carbon footprint; almost all the routes show much less diversification in operators than Heathrow.

Hong Kong

The Hong Kong carbon footprint profile shows:

- more than half of the footprint is associated with flights inside the Asia/Pacific region; flights to Europe and N America make an almost equal contribution to the footprint
- wide bodied twin engined aircraft dominate the footprint with respect to aircraft types; there is a significant contribution from the B747 (about 20% of the footprint); narrow bodied aircraft do not have a major presence
- Heathrow heads the list of destination airports but its footprint is of similar magnitude to a number of other airports; seven of the top 15 destination airports are in the Asia/Pacific region
- Cathay is the dominant airline (contributes about 45% of the footprint); Dragonair has a significant presence; the rest of the footprint is made up by a number of airlines with similar CO_2 contributions
- the CO_2 v Distance element reveals there is a contribution to the footprint across all distance ranges with more significant contributions from short haul operations than the other airports; flights travelling > 9,000 km are prominent
- the route CO_2 distribution element shows footprint contributions from a number of operators on most routes; Cathay's prominence is evident; there is a distinct contrast to the Dubai profile element.

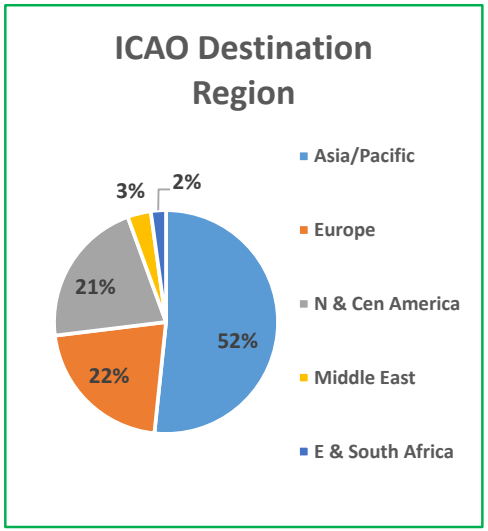
Frankfurt

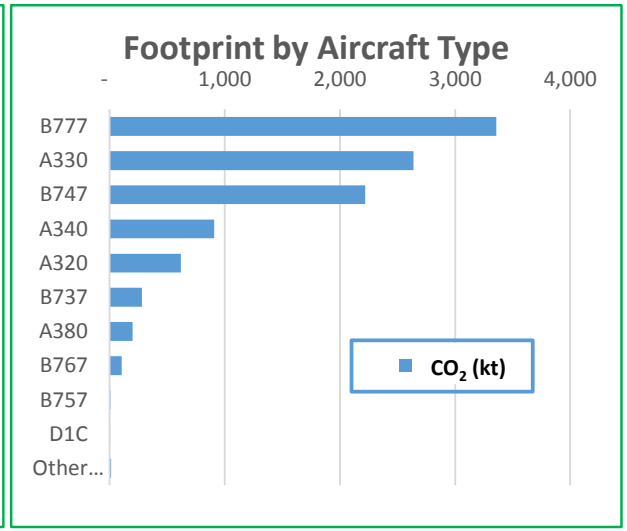
The Frankfurt carbon footprint profile shows:

- the destination footprint is dominated by flights to the Asia/Pacific and N America regions which have about equal shares; the intra Europe footprint share is similar to Paris (CDG) and greater than Heathrow
- Frankfurt is different to the other airports in that four engine aircraft dominate the footprint – the B747 and the A340 are the top 2 aircraft types and together contribute 40% of the footprint
- six of the top seven destination airports are in the Asia/Pacific region; most of the destination airports in the hierarchy have a footprint of similar magnitude
- Lufthansa generates more than 50% of the airport's footprint; United and Condor are also prominent; the other airlines in the top 15 have a footprint of a broadly similar magnitude and are associated with a wide spread of geographic locations

Hong Kong

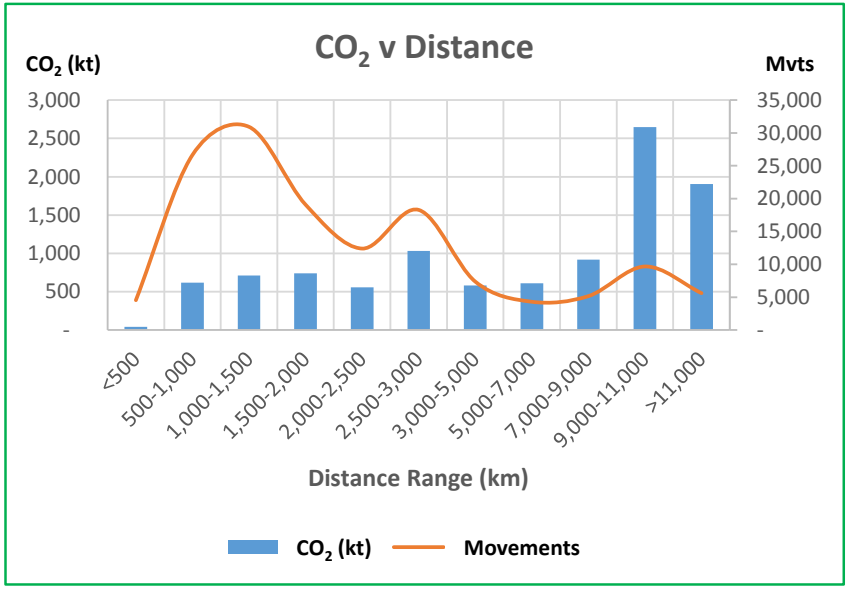
Total Footprint = 10,363 kt CO_2

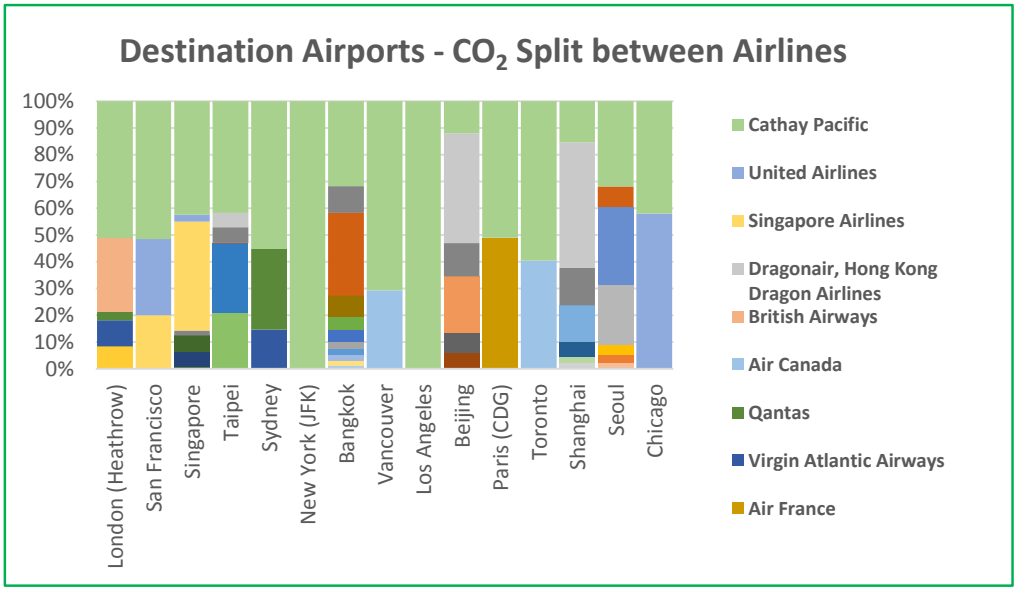




Destination Airports	CO_2 (kt)
London (Heathrow)	843
San Francisco	524
Singapore	451
Taipei	450
Sydney	419
New York (JFK)	348
Bangkok	323
Vancouver	305
Los Angeles	297
Beijing	292
Paris (CDG)	290
Toronto	290
Shanghai	285
Seoul	280
Chicago	280
Other Airports	4,688
Total	**10,363**

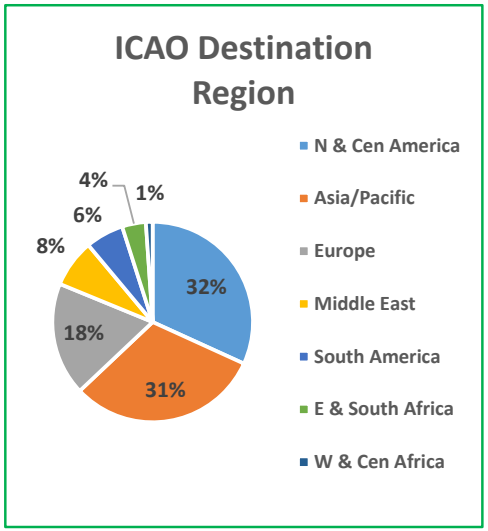
Airlines	CO_2 (kt)
Cathay Pacific	4,824
Dragonair, Hong Kong Dragon	609
United Airlines	429
Singapore Airlines	288
Hong Kong Airlines	286
Qantas	270
British Airways	232
Air Canada	207
Lufthansa	190
China Airlines	174
Air New Zealand	160
Virgin Atlantic Airways	144
Thai Airways International	143
Air France	142
Emirates Airline	133
Other Airlines	2,133
Total	**10,363**

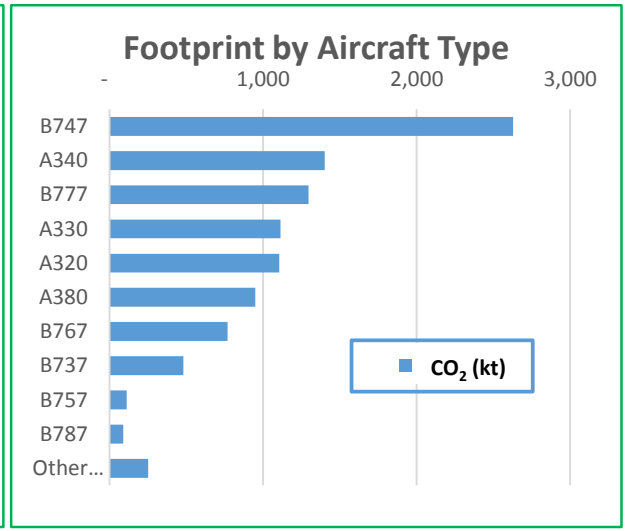




Frankfurt

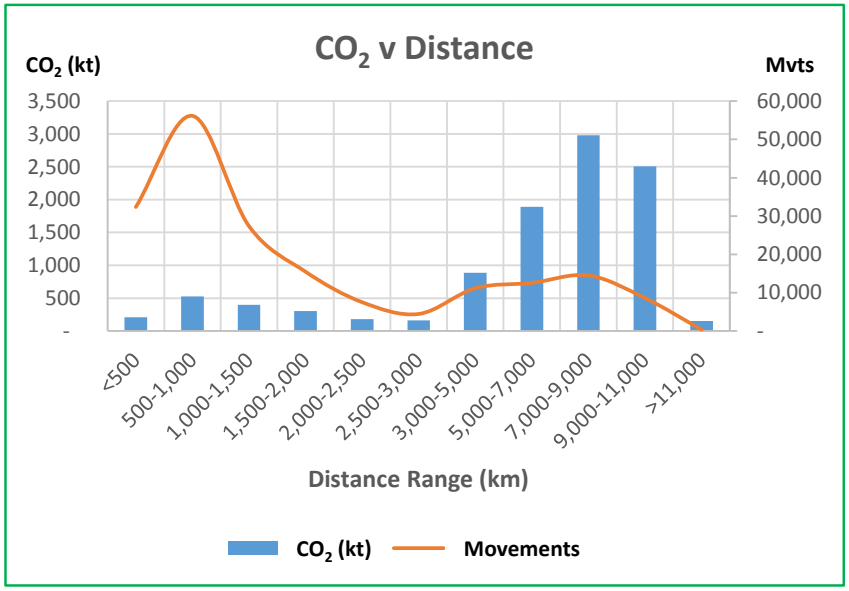
Total Footprint = 10,193 kt CO_2

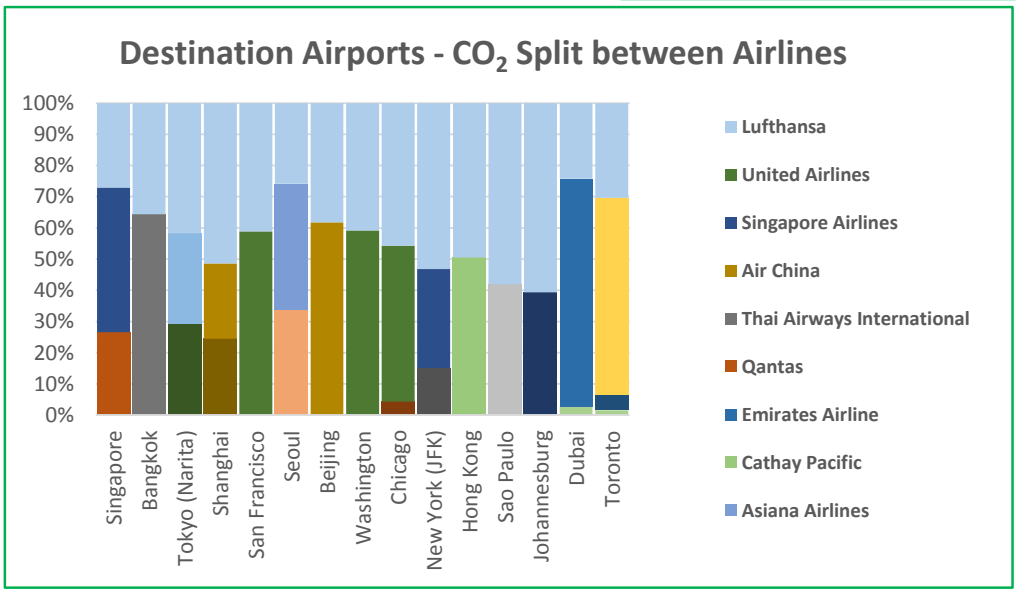




Destination Airports	CO_2 (kt)
Singapore	502
Bangkok	306
Tokyo (Narita)	298
Shanghai	289
San Francisco	282
Seoul	270
Beijing	257
Washington	256
Chicago	255
New York (JFK)	248
Hong Kong	235
Sao Paulo	218
Johannesburg	186
Dubai	176
Toronto	169
Other Airports	6,245
Total	**10,193**

Airlines	CO_2 (kt)
Lufthansa	5,284
United Airlines	549
Condor Flugdienst	484
Singapore Airlines	312
Air Canada	249
Air China	228
Thai Airways International	197
All Nippon Airways	167
US Airways	159
TAM Airlines (TAM Linhas Aere	135
Qantas	133
Emirates Airline	128
Delta Air Lines	127
Cathay Pacific	118
Asiana Airlines	109
Other Airlines	1,815
Total	**10,193**





- the carbon footprint is primarily generated by flights travelling between 5,000 km and 11,000 km (about 70% of the footprint); in common with the other European airports there is little footprint contribution by flights travelling more than 11,000 km

- the route CO_2 distribution is somewhat more concentrated than either Heathrow or Hong Kong with 3 or less operators on all routes; the Lufthansa prominence on the routes is evident.

Paris (CDG)

The Paris (CDG) carbon footprint profile shows:

- the Asia/Pacific and N America regions have more or less equal shares of the footprint; there is a significant contribution from the smaller regions

- the B777 is clearly the dominant aircraft type; there is a very much lower B747 contribution than at either Heathrow or Frankfurt

- there is a fairly even footprint spread across destination airports – the spread is across airports in the Asia/Pacific, N America and S America regions

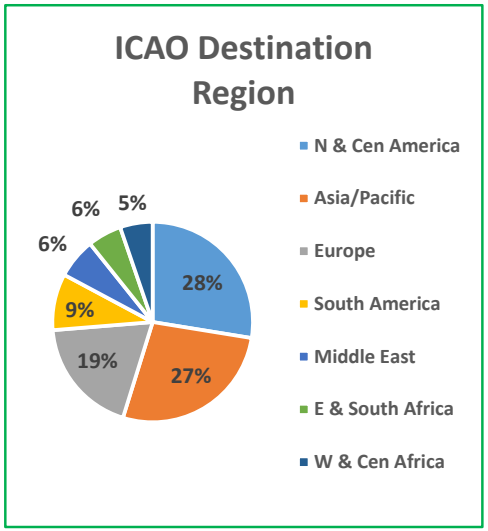
- Air France dominates the footprint (about 55% of the footprint); there is a reasonable spread between all the other entries in the airline hierarchy; it is interesting to note that Easyjet, which is not in the hierarchy for Heathrow or Frankfurt, is the 5th top airline

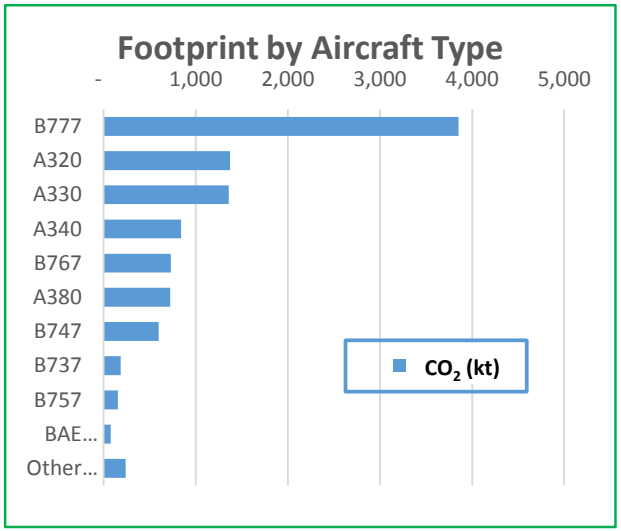
- the CO_2 v Distance element presents a similar picture to both Heathrow and Frankfurt with a low footprint contribution by short haul flights; in contrast to those two airports the biggest contribution is in the 9,000 km - 11,000 km range (the other two airports have the maximum footprint contribution in the 5,000 km – 7,000 km and the 7,000 km – 9,000 km ranges respectively)

- the route CO_2 share element has a similar form to that of Frankfurt; the Air France prominence is evident.

Paris (CDG)

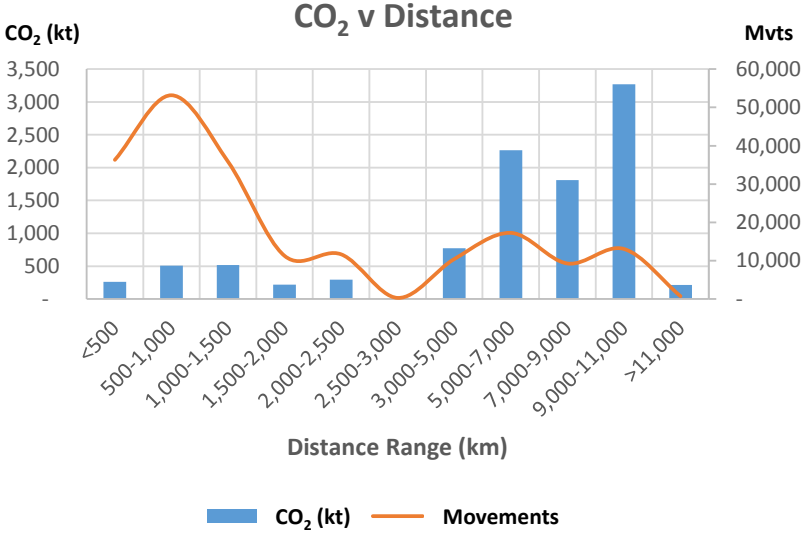
Total Footprint = 10,132 kt CO_2

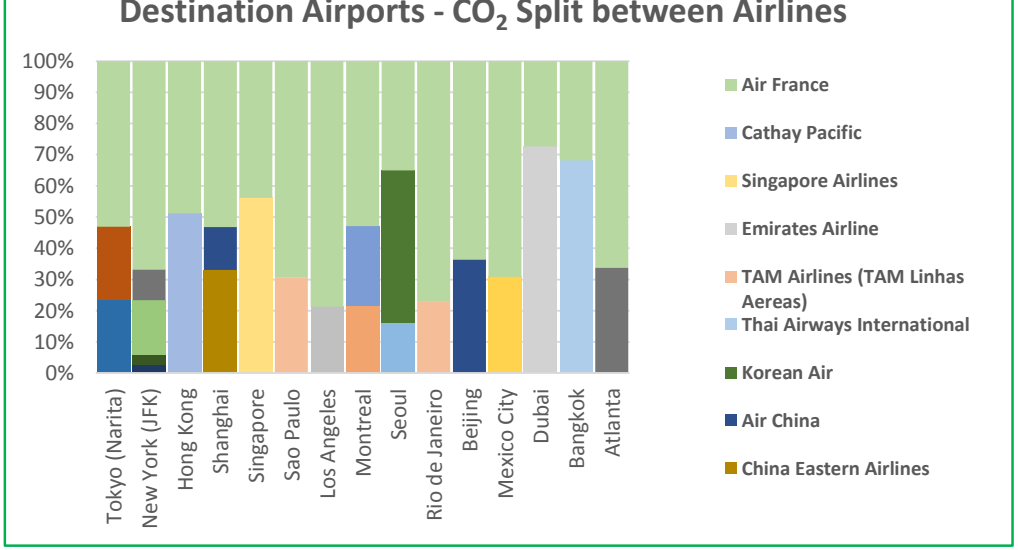




Destination Airports	CO_2 (kt)
Tokyo (Narita)	386
New York (JFK)	373
Hong Kong	290
Shanghai	289
Singapore	258
Sao Paulo	245
Los Angeles	238
Montreal	232
Seoul	230
Rio de Janeiro	227
Beijing	196
Mexico City	190
Dubai	188
Bangkok	174
Atlanta	172
Other Airports	6,442
Total	**10,132**

Airlines	CO_2 (kt)
Air France	5,539
Delta Air Lines	329
American Airlines	213
Japan Airlines	181
Easyjet	165
Cathay Pacific	154
Singapore Airlines	145
United Airlines	142
Emirates Airline	137
TAM Airlines (TAM Linhas Aere	127
Vietnam Airlines	123
Thai Airways International	118
Air Austral	117
Korean Air	113
Air China	111
Other Airlines	2,417
Total	**10,132**





Chapter 6

The Airlines

6.1 Introduction

This chapter examines the carbon footprint of the scheduled international passenger flights from the perspective of the airlines. Consistent with the earlier chapters the focus is on the top 5 airlines and the discussion revolves around the carbon footprint profiles. Profiles for the next 15 airlines in the hierarchy are shown in *Profile F4* in Part II.

Figure 6.1 gives the hierarchy for the top 30 airlines. Collectively these airlines comprise about 65% of the total footprint. The top 10 airlines make up about 35% of the footprint.

The top airlines make significant contributions. Emirates, the top airline, would occupy the 4th position in the country hierarchy if it were a country.

Several airlines are now publishing annual environmental/sustainability reports which provide very useful CO_2/fuel information. The publication of this data is fundamental to the aviation industry's building of its public climate change credentials. The data provides good validation points for independent scrutiny of the industry's carbon footprint. Examples of these reports are discussed, and used for validation purposes, in Chapter 8.

It is not the intention of this chapter to compare the relative climate change performance of competing airlines. The high level methodology adopted in this report would not allow robust comparisons even if this were a goal. This chapter is simply aimed at presenting a comprehensible picture of the composition of the airline footprints in order to raise awareness, aid understanding and to generate thinking on new approaches to managing aviation's carbon footprint.

Airlines	CO_2 (kt)	% of Total CO_2
Emirates Airline	17,333	4.8
British Airways	15,808	4.4
Lufthansa	15,344	4.3
United Airlines	14,828	4.1
Delta Air Lines	12,743	3.5
Air France	12,389	3.4
Singapore Airlines	10,498	2.9
Cathay Pacific	10,135	2.8
American Airlines	10,030	2.8
KLM Royal Dutch Airlines	9,079	2.5
Korean Air	7,982	2.2
Qatar Airways	7,330	2.0
Ryanair	6,803	1.9
Thai Airways International	6,311	1.7
Air Canada	6,179	1.7
Turkish Airlines	6,123	1.7
Qantas	5,181	1.4
Etihad Airways	4,779	1.3
Easyjet	4,645	1.3
Iberia Airlines	4,302	1.2
Air China	4,106	1.1
Virgin Atlantic Airways	4,046	1.1
Swiss European Air Lines	4,029	1.1
Japan Airlines	3,991	1.1
Malaysia Airlines	3,783	1.0
All Nippon Airways	3,689	1.0
China Airlines	3,656	1.0
Asiana Airlines	3,560	1.0
Air Berlin	3,219	0.9
Saudi Arabian Airlines	3,198	0.9
Other Airlines	135,755	37.6
Total	**360,857**	**100.0**

Figure 6.1: Airport carbon footprint hierarchy

6.2 Carbon Footprint Profile - Top 5 Airlines

In a similar manner to the previous chapter, this section uses indicators contained in carbon footprint profiles to provide an insight into the carbon footprints of the top five airlines by CO_2 footprint size.

Emirates Airline

The Emirates carbon footprint profile shows:

- the footprint associated with the Asia/Pacific region is somewhat bigger than that for Europe; the figure of 50% of the CO_2 footprint with destination 'Middle East' indicates that Emirates has limited intra regional operations in the Middle East – the 50% figure primarily relates to Emirates flights returning to Dubai from other regions
- Emirates has a strong focus on the B777 aircraft (about 65% of the footprint); the A380 is also a significant contributor to the footprint
- the preeminent position of Dubai as an origin airport (about 45% of the footprint) indicates that Emirates is essentially based in one airport; the footprint of the other airports in the origin airport list is broadly of the same magnitude
- not surprisingly the CO_2 v Distance element for Emirates is similar to that for Dubai (given the preeminent position of Emirates); the footprint has two prominent peaks – one in the 5,000 km - 7,000 km range (distance from Dubai to Europe, Singapore, Johannesburg, Shanghai) and another in the >11,000km range (Australia)
- for Emirates, and also British Airways which similarly dominates the movements at a single base airport, the values in the origin airport and in the city-pair hierarchy are very similar; in those instances where there is a simple return flight to/from Dubai the value is the same; in those cases where Emirates carries out an additional leg (eg Emirates flies Dubai-Sydney – Auckland – Sydney-Dubai) the numbers are different; all of the city-pairs in the hierarchy involve flights to/from Dubai.

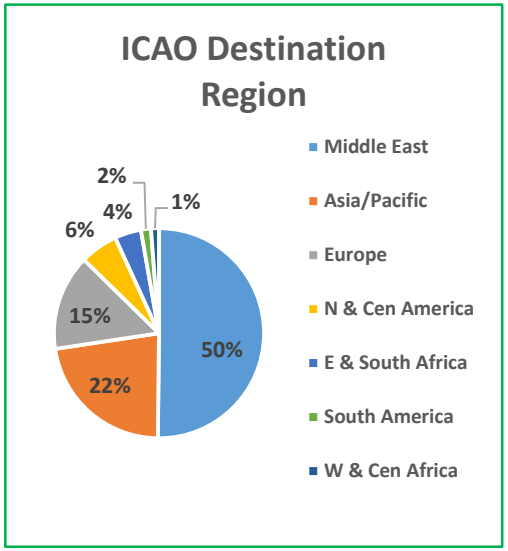
British Airways

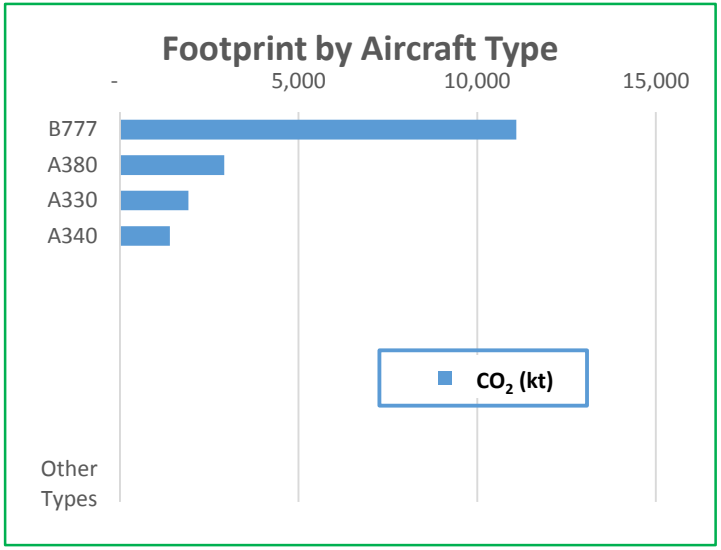
The British Airways carbon footprint profile shows:

- the prime focus is on flights to N America – the footprint to this region is more than twice the footprint of flights to Asia/Pacific; the 57% 'Europe' figure indicates some contribution to the footprint from intra Europe operations
- the B747 is the leading aircraft type (45% of the footprint); the B777 also makes a significant contribution (about 35% of the footprint); there is a relatively minor contribution from narrow bodied aircraft
- the airline has a very different CO_2 v Distance profile compared to Emirates; the numbers of movements peak in the 500-1,000 km range; almost all the footprint lies in the 5,000 to 11,000 km range (about 80% of the footprint); there is relatively little contribution from flights travelling > 11,000 km

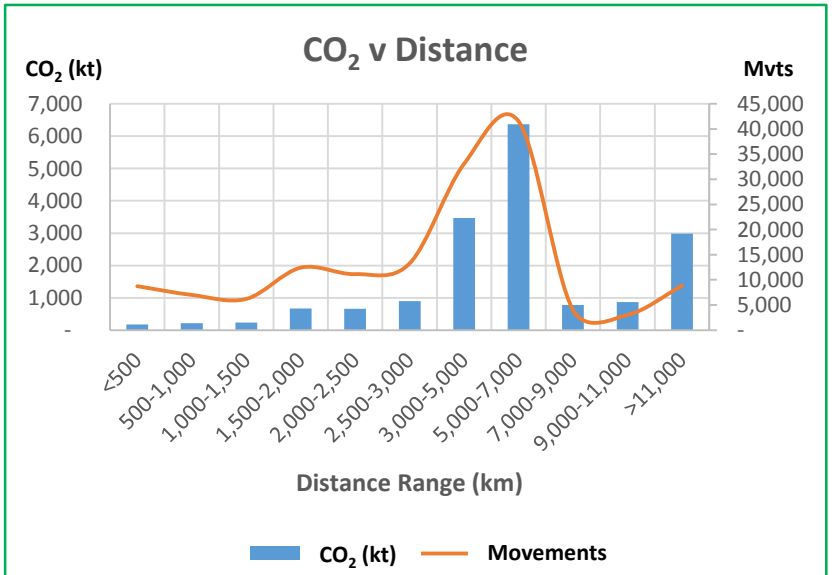
Emirates Airline

Total Footprint = 17,333 kt CO_2





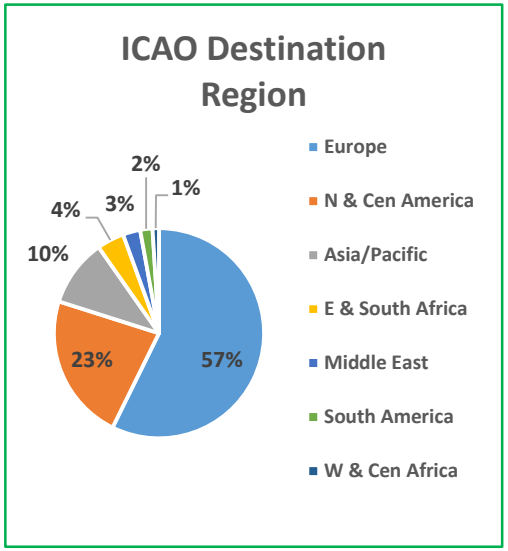
Origin Airports	CO_2 (kt)
Dubai	8,214
Sydney	398
London (Heathrow)	314
Singapore	299
Bangkok	292
Melbourne	262
New York (JFK)	253
Kuala Lumpur	230
Los Angeles	199
Brisbane	191
Johannesburg	181
Perth	173
Manchester	172
London (Gatwick)	149
Paris (CDG)	137
Other Airports	5,870
Total	**17,333**

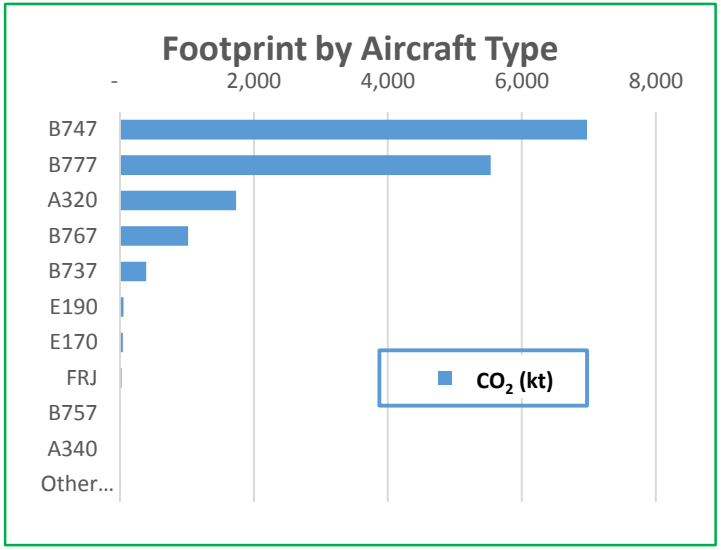


City-Pair Hierarchy	CO_2 (kt)
London (Heathrow)-Dubai	314
Dubai-London (Heathrow)	314
Dubai-Sydney	277
Sydney-Dubai	277
New York (JFK)-Dubai	253
Dubai-New York (JFK)	253
Los Angeles-Dubai	199
Dubai-Los Angeles	199
Dubai-Bangkok	198
Bangkok-Dubai	198
Dubai-Johannesburg	181
Johannesburg-Dubai	181
Dubai-Perth	173
Perth-Dubai	173
Dubai-Kuala Lumpur	173
Kuala Lumpur-Dubai	173
Manchester-Dubai	172
Dubai-Manchester	172
Singapore-Dubai	161
Dubai-Singapore	161
Dubai-London (Gatwick)	149
London (Gatwick)-Dubai	149
Dubai-Paris (CDG)	137
Paris (CDG)-Dubai	137
Houston-Dubai	134
Dubai-Houston	134
Dubai-Frankfurt	128
Frankfurt-Dubai	128
Dubai-Shanghai	127
Shanghai-Dubai	127
Other Routes	11,781
Total	**17,333**

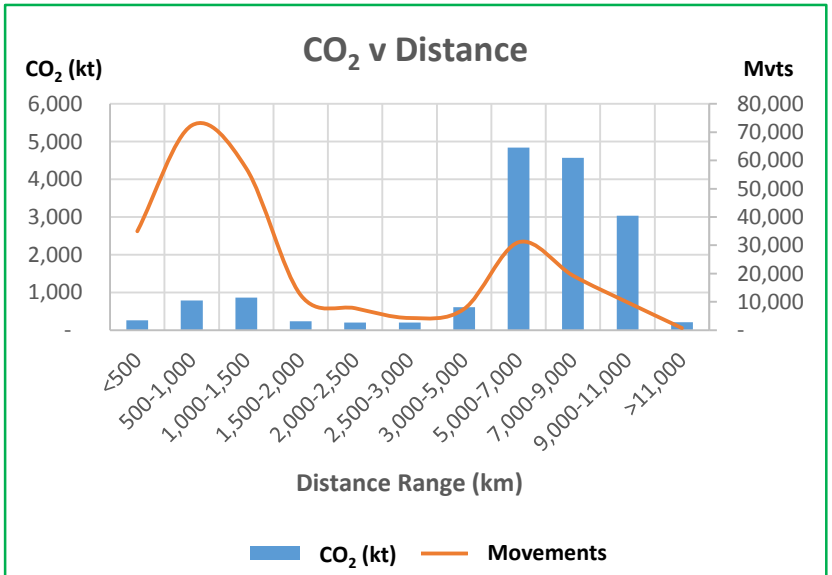
British Airways

Total Footprint = 15,808 kt CO_2





Origin Airports	CO_2 (kt)
London (Heathrow)	6,960
London (Gatwick)	716
New York (JFK)	503
Singapore	350
Johannesburg	273
Los Angeles	272
Hong Kong	232
Miami	231
San Francisco	216
Cape Town	177
Boston	168
Washington	155
Houston	153
Delhi	148
Bangkok	142
Other Airports	5,112
Total	**15,808**



City-Pair Hierarchy	CO_2 (kt)
New York (JFK)-London (Heathrow)	475
London (Heathrow)-New York (JFK)	475
London (Heathrow)-Singapore	277
Singapore-London (Heathrow)	276
Los Angeles-London (Heathrow)	272
London (Heathrow)-Los Angeles	272
Johannesburg-London (Heathrow)	251
London (Heathrow)-Johannesburg	251
London (Heathrow)-Hong Kong	232
Hong Kong-London (Heathrow)	232
Miami-London (Heathrow)	231
London (Heathrow)-Miami	231
San Francisco-London (Heathrow)	216
London (Heathrow)-San Francisco	216
London (Heathrow)-Cape Town	177
Cape Town-London (Heathrow)	177
London (Heathrow)-Boston	168
Boston-London (Heathrow)	168
London (Heathrow)-Washington	155
Washington-London (Heathrow)	155
Houston-London (Heathrow)	153
London (Heathrow)-Houston	153
Delhi-London (Heathrow)	148
London (Heathrow)-Delhi	148
Mumbai-London (Heathrow)	140
London (Heathrow)-Mumbai	140
London (Heathrow)-Dubai	133
Dubai-London (Heathrow)	133
London (Heathrow)-Chicago	129
Chicago-London (Heathrow)	129
Other Routes	9,494
Total	**15,808**

- the origin airports and the city-pair hierarchy elements demonstrate British Airways' focus on Heathrow – all flights in the city pair hierarchy involve Heathrow; the cross comparison between the origin airport and city-pair hierarchy indicates that most, but not all, of the routes are flights directly to/from Heathrow.

Lufthansa

The Lufthansa carbon footprint profile shows:

- a destination mix which is significantly different to British Airways, the other European airline in the top 5; there is a significant footprint contribution from intra Europe traffic; the contribution from N America traffic is slightly more than for Asia/Pacific
- the airline has a big focus on four engined aircraft – these generate about 60% of the footprint; it is the only airline in the top 5 that has no contribution from the B777; narrow bodied aircraft make a significant contribution (almost 30%)
- Frankfurt and Munich are preeminent origin airports; there is a good spread of other origin airports in a number of ICAO regions which have carbon footprints of similar magnitude
- the CO_2 v Departures element shows high movements numbers and a significant footprint contribution from short haul operations up to 2,000 km (just over 20% of the CO_2 footprint) – this is distinctly different to the other top 5 airlines; the other area of contribution is from flights in the 5,000 km to 11,000 km range
- all of the routes in the city-pair hierarchy involve flights into or out of Frankfurt; the relationship between the origin airport and city-pair hierarchy shows much more diversity than that shown in both the Emirates and British Airways profiles.

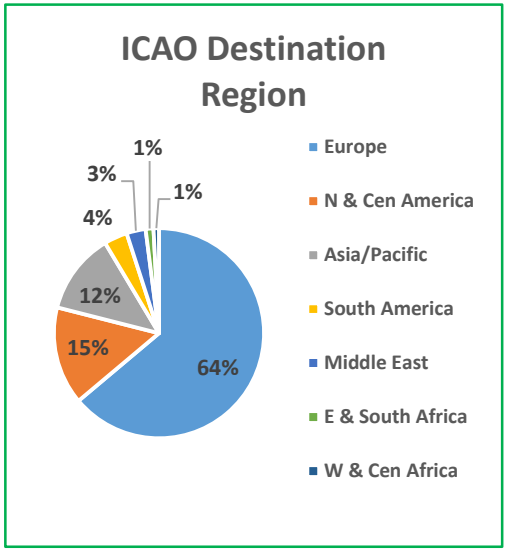
United Airlines

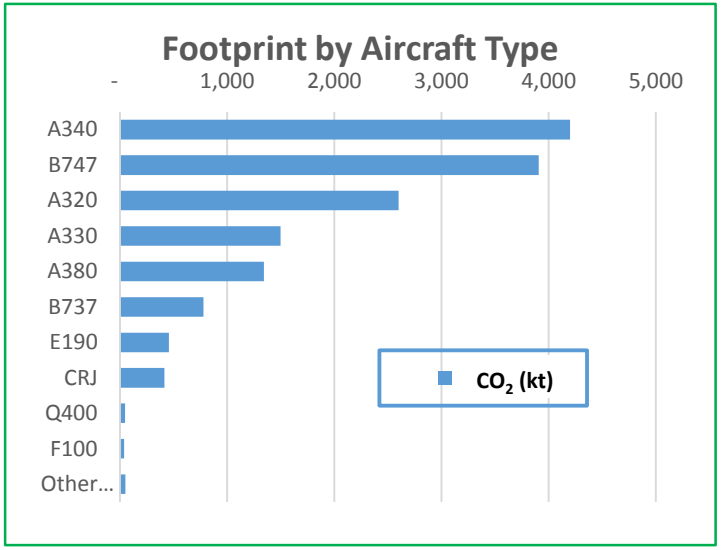
The United Airlines carbon footprint profile shows:

- the Asia/Pacific region makes a slighty greater footprint contribution than Europe (the opposite situation to Delta); there is a noticeable level of contribution from intra region flights
- the B777 is the top CO_2 contributor (about 40% of the footprint); the B747 also makes a significant contribution presence; narrow bodied aircraft contribute about 15% of the footprint
- Newark is the major contributor to the footprint; compared to the non US airlines United has a wide spread of important origin airports in its own country (5 origin airports in the US with a footprint of >900,000 kt);
- the CO_2 v Distance element shows that almost all the footprint derives from flights longer than 5,000 km (80% in the > 5,000 km range) despite a large spike in movement numbers in the 1,000 km to 1,500 km range
- the airline does not have a dominant city-pair route; in the top 15 there is a diversity of routes involving the Europe and Asia/Pacific regions which have footprints of similar magnitude.

Lufthansa

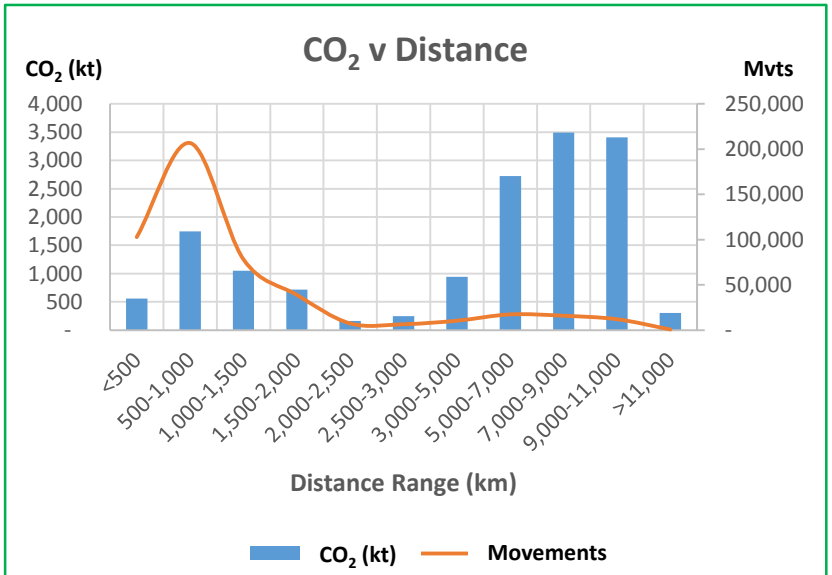
Total Footprint = 15,344 kt CO_2





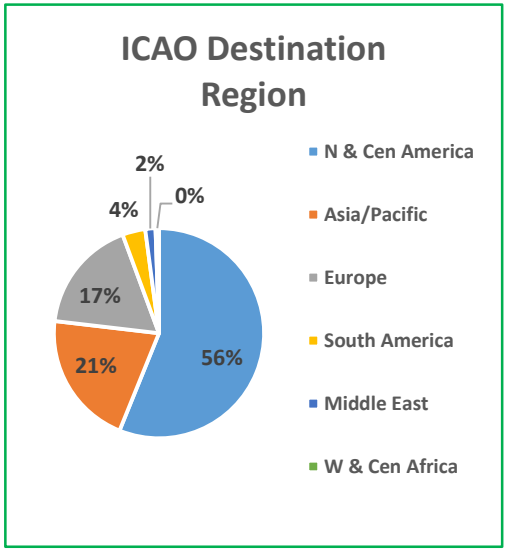
City-Pair Hierarchy	CO_2 (kt)
Los Angeles-Frankfurt	166
Frankfurt-Los Angeles	166
Buenos Aires-Frankfurt	152
Frankfurt-Buenos Aires	152
Shanghai-Frankfurt	149
Frankfurt-Shanghai	149
Frankfurt-Singapore	136
Singapore-Frankfurt	136
New York (JFK)-Frankfurt	132
Frankfurt-New York (JFK)	132
Sao Paulo-Frankfurt	127
Frankfurt-Sao Paulo	127
Frankfurt-Tokyo (Narita)	124
Tokyo (Narita)-Frankfurt	124
Mexico City-Frankfurt	123
Frankfurt-Mexico City	123
Osaka-Frankfurt	120
Frankfurt-Osaka	119
Chicago-Frankfurt	117
Frankfurt-Chicago	117
Hong Kong-Frankfurt	116
Frankfurt-San Francisco	116
San Francisco-Frankfurt	116
Frankfurt-Hong Kong	116
Frankfurt-Johannesburg	113
Johannesburg-Frankfurt	113
Bangkok-Frankfurt	109
Frankfurt-Bangkok	109
Frankfurt-Houston	107
Houston-Frankfurt	107
Other Routes	11,535
Total	**15,344**

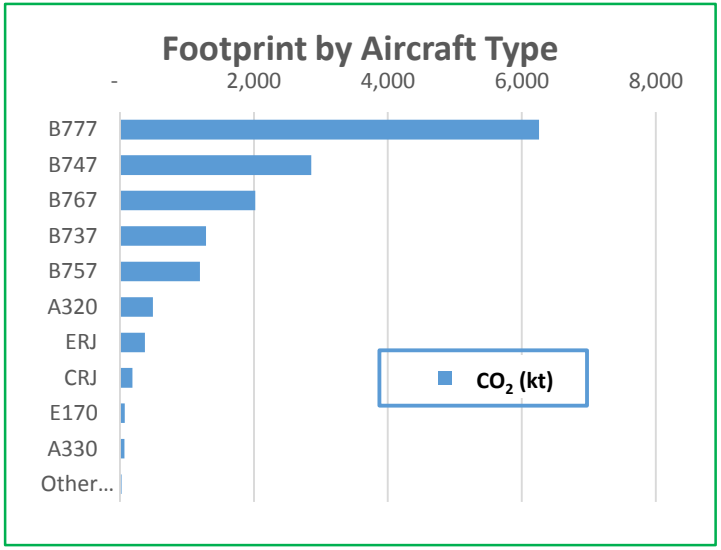
Origin Airports	CO_2 (kt)
Frankfurt	5,284
Munich	1,821
Dusseldorf	329
Los Angeles	234
Shanghai	220
Chicago	215
Sao Paulo	209
Tokyo (Narita)	199
Singapore	195
San Francisco	194
Hong Kong	190
Newark	182
New York (JFK)	180
Beijing	154
Buenos Aires	152
Other Airports	5,589
Total	**15,344**



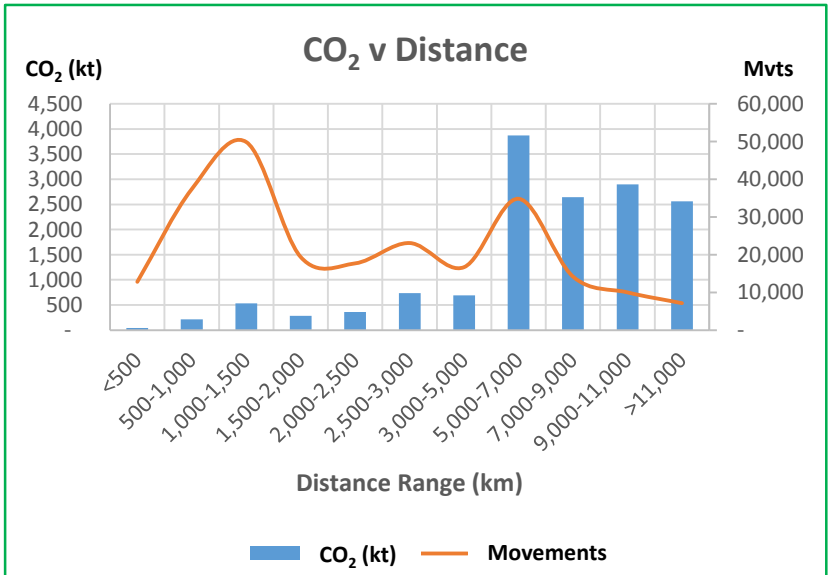
United Airlines

Total Footprint = 14,828 kt CO_2





Origin Airports	CO_2 (kt)
Newark	1,722
San Francisco	1,299
Washington	1,255
Chicago	1,165
Tokyo (Narita)	943
Houston	923
London (Heathrow)	708
Frankfurt	549
Los Angeles	458
Hong Kong	429
Beijing	396
Shanghai	392
Sydney	322
Sao Paulo	223
Agana	193
Other Airports	3,853
Total	**14,828**



City-Pair Hierarchy	CO_2 (kt)
San Francisco-Frankfurt	166
Frankfurt-San Francisco	166
Chicago-Hong Kong	162
Hong Kong-Chicago	162
Sydney-Los Angeles	162
Los Angeles-Sydney	162
San Francisco-Sydney	160
Sydney-San Francisco	160
Washington-London (Heathrow)	158
London (Heathrow)-Washington	158
Frankfurt-Washington	152
Washington-Frankfurt	152
Tokyo (Narita)-San Francisco	150
San Francisco-Tokyo (Narita)	150
San Francisco-Hong Kong	149
Hong Kong-San Francisco	149
London (Heathrow)-San Francisco	135
San Francisco-London (Heathrow)	135
Chicago-Tokyo (Narita)	132
Tokyo (Narita)-Chicago	132
Frankfurt-Chicago	128
Chicago-Frankfurt	128
Tel Aviv-Newark	124
Newark-Tel Aviv	124
Beijing-San Francisco	124
San Francisco-Beijing	124
London (Heathrow)-Chicago	118
Chicago-London (Heathrow)	118
Seoul-San Francisco	116
San Francisco-Seoul	116
Other Routes	10,556
Total	**14,828**

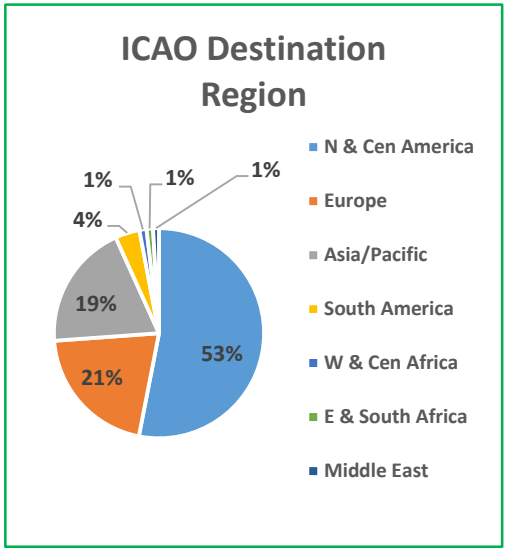
Delta Air Lines

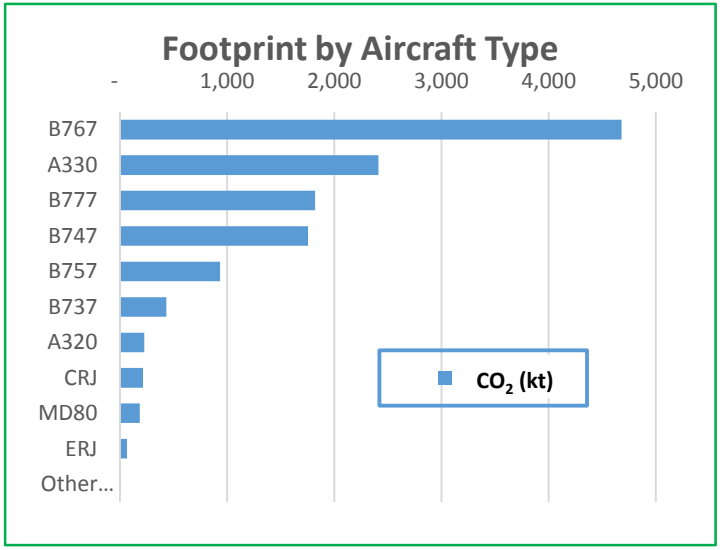
The Delta Air Lines carbon footprint profile shows:

- a slightly smaller proportion of its footprint in the N and Central America + Carribean region than United; it has a marginally larger presence in Europe than in the Asia/Pacific region;
- Delta is unusual in that the B767 is the dominant contributor to its carbon footprint (more than 35%); the contribution by the B777 is well under half that of the B767; narrow bodied aircraft make up a minor part of the footprint (about 9%)
- the origin airport hierarchy has a similar make up to that for United – four predominant airports then a number of geographically spread airports with similar magnitude footprints; Tokyo (Narita) is the highest non US origin airport for both airlines
- the CO_2 v Distance element is similar to that for United with almost all the footprint generated by flights travelling more than 5,00km (more than 80%); Delta has significantly less CO_2 in the >11,000 km range than United
- the airline does not have a clearly leading city-pair route; in the top 15 there Is a diversity of routes involving the Europe, Asia/Pacific, Middle East and South and East Africa regions which have footprints of broadly similar magnitude.

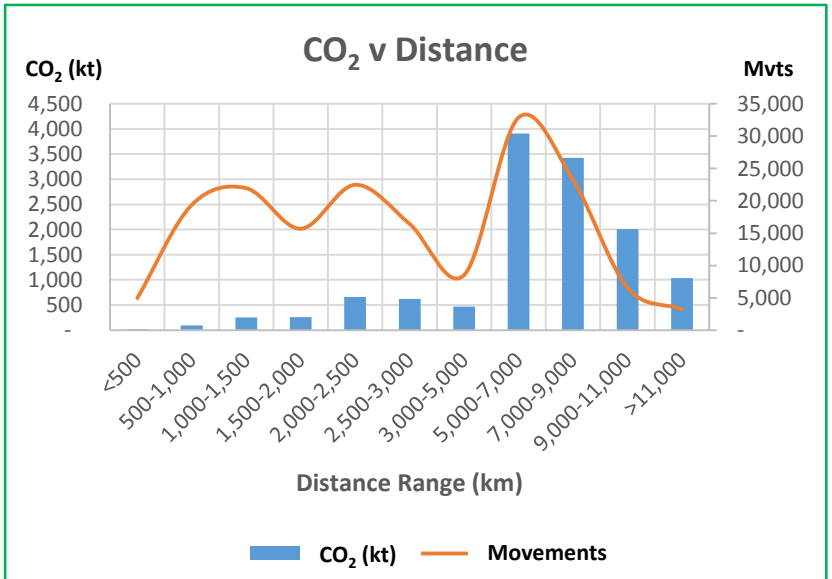
Delta Air Lines

Total Footprint = 12,743 kt CO_2





Origin Airports	CO_2 (kt)
Atlanta	1,983
New York (JFK)	1,229
Tokyo (Narita)	1,198
Detroit	1,007
Amsterdam	743
Minneapolis	402
Paris (CDG)	329
London (Heathrow)	321
Honolulu	305
Los Angeles	291
Seattle	262
Nagoya	199
Sao Paulo	150
Osaka	130
Shanghai	129
Other Airports	4,064
Total	**12,743**



City-Pair Hierarchy	CO_2 (kt)
Detroit-Amsterdam	177
Amsterdam-Detroit	177
Honolulu-Tokyo (Narita)	165
Tokyo (Narita)-Honolulu	165
New York (JFK)-Tokyo (Narita)	144
Tokyo (Narita)-New York (JFK)	144
Detroit-Tokyo (Narita)	136
Tokyo (Narita)-Detroit	136
Minneapolis-Amsterdam	129
Amsterdam-Minneapolis	129
Atlanta-Tokyo (Narita)	128
Tokyo (Narita)-Atlanta	128
Johannesburg-Atlanta	127
Atlanta-Johannesburg	127
New York (JFK)-Tel Aviv	118
Tel Aviv-New York (JFK)	118
Detroit-Nagoya	115
Nagoya-Detroit	115
Atlanta-Dubai	115
Dubai-Atlanta	115
Sydney-Los Angeles	113
Los Angeles-Sydney	113
Detroit-Shanghai	111
Shanghai-Detroit	110
London (Heathrow)-New York (JFK)	105
New York (JFK)-London (Heathrow)	105
Atlanta-Amsterdam	103
Amsterdam-Atlanta	103
Tokyo (Narita)-Minneapolis	89
Minneapolis-Tokyo (Narita)	89
Other Routes	8,996
Total	**12,743**

Chapter 7

Monetising Carbon

7.1 Introduction

To this point in the document the focus has been on computing and reporting the quantum of CO_2 that is generated by aircraft engaged in scheduled international passenger operations. This chapter converts the earlier carbon footprint information into monetary terms.

Much of the debate surrounding climate change and its management revolves around putting some form of monetary value on carbon. This debate has been particularly difficult in many countries and 'market based measures' (MBM) are currently the focus of the climate change debate within ICAO.

The basic building block for examination of any potential MBM is knowledge of the quantum of CO_2, and the equivalent monetary value, associated with the options being considered. For example, when considering the introduction of a partial MBM the policy developer will need to know, say, the carbon costs associated with particular regions or on one or a small number of routes. What will be the costs for the industry? What will be the costs for the travellers? An understanding of potential carbon revenues from the individual subsectors of aviation is likewise essential if decision makers are to be aware of the magnitude of funds that could be available for climate change expenditure.

The issue of introducing market based measures is clearly complex and will be a matter of ongoing debate. In keeping with the thrust of this document, this chapter is not intended to present arguments either for or against the introduction of these measures but is rather aimed at providing information that will assist the debate.

In broad terms this chapter has been structured in a way that takes selected figures from earlier in the document and simply converts CO_2 values to $ values. A carbon price of $20/tonne has been used for the computations as this is a value that is commonly used when considering generic carbon price scenarios. It is recognised that this price significantly exceeds the carbon price in Europe (at time of writing less than $5/tonne) but it is less than the carbon price in Australia of $23/tonne which is currently being paid by domestic aviation operators. If desired the reader can readily factor an alternative carbon price into the computations by simple multiplication.

The $ values shown in this chapter show the costs/revenues if some form of carbon charge were imposed on all the CO_2 emitted by all aircraft captured under an MBM regime. This situation currently applies in Australia for all domestic aviation under the Australian Government's carbon pricing regime. However, under other MBM regimes, either mooted or in place, measures such as grandfathered allocations or carbon neutral growth (based on a particular year) result in the carbon charge only being imposed on a portion of the total CO_2 emissions.

In order to present a balanced picture, carbon values are shown both in terms of total revenue/costs and per person costs. Quoting total carbon costs typically gives an impression of large financial imposts or revenues while reporting carbon costs on a per passenger basis often suggests relatively small impacts. While this chapter highlights particular aspects of the carbon footprint, any CO_2 value in the report can of course be converted into $ terms through simple multiplication.

7.2 Intra Regions

Figure 7.1 shows the monetary implications of introducing an MBM on a regional level at a carbon price of $20/tonne of CO_2.

The figure monetises the intra region carbon values in *Figure 3.4* and also shows the values in the form of $/passenger. This indicates the likely costs and revenues if consideration were being given to introducing an MBM at the regional level. It can be seen that revenues in excess of one billion dollars per year would be generated if a regional scheme were set up in either Europe or the Asia/Pacific region. The costs per passenger would be somewhat higher in the Asia/Pacific region.

ICAO Region	CO_2 Value ($x10^6$)	Cost/PAX ($)
Europe	1,233	2.75
Asia/Pacific	1,130	4.82
N & Central America + Caribbean	328	3.58
Middle East	140	2.64
South America	89	3.77
East & South Africa	35	2.72
W & Central Africa	12	2.09
Total	2,966	3.41

Figure 7.1: Monetised CO_2 footprint for intra region operations

There is of course an intra region MBM (an emissions trading scheme) for aviation currently in place within countries of the European Union.

7.3 Countries

Figure 7.2 takes *Figure 2.2* and converts the CO_2 values into monetary values. It shows the total monetary value of the CO_2 generated by international departures from each of the top 30 countries. It also shows the carbon costs per passenger.

It can be seen that if a carbon charge of $20/tonne had been in place for all global scheduled international passenger aircraft departures in 2012 approximately $7 billion would have been raised. On average this would have equated to a carbon charge of around $6 per passenger. Australia would have had the highest cost/passenger ($13) while Italy the lowest ($4) – these values are consistent with the contrasting geographical siting of these two countries.

Country	CO_2 Value ($x10^6$)	CO_2 Cost/PAX ($)
United States	999	9.9
United Kingdom	496	6.0
Germany	375	5.2
United Arab Emirates	291	7.5
Japan	279	8.5
China	277	6.8
France	276	5.7
Spain	213	4.5
Hong Kong	207	7.4
Singapore	196	7.6
Australia	190	12.5
Canada	167	7.1
South Korea	166	6.7
Thailand	164	7.3
Netherlands	151	6.4
Italy	150	3.9
India	144	7.2
Brazil	119	12.1
Russia	115	5.3
Turkey	101	4.7
Malaysia	90	5.6
Switzerland	88	4.0
Taiwan	86	4.7
Mexico	79	5.6
Qatar	78	6.6
Saudi Arabia	77	5.1
South Africa	72	11.4
Indonesia	61	5.4
Philippines	53	6.5
Portugal	50	4.6
Other countries	1,407	4.3
Total	**7,217**	**6.0**

Figure 7.2: Monetised CO_2 footprint by country

7.4 Airports

One option that is not frequently canvassed is to introduce climate change action at the airport level.

Figure 7.3, which monetises the carbon footprint associated with the top 30 airports from *Figure 5.2*, shows the revenue that would have been generated if a carbon charge of $20/tonne had been imposed by airports on departing international passengers in 2012.

Consistent with *Figure 7.2* the average cost per passenger would have been $6; the highest charges would have been of the order of $17/passenger for Los Angeles and San Francisco. Thirteen airports would have generated carbon revenues exceeding $100 million.

Origin Airports	CO_2 Value ($ x 10^6)	CO_2 Cost/PAX ($)
London (Heathrow)	328	9.2
Dubai	219	7.9
Hong Kong	207	7.4
Frankfurt	204	7.7
Paris (CDG)	203	7.7
Singapore	196	7.6
Tokyo (Narita)	178	11.1
New York (JFK)	164	11.8
Seoul	158	7.2
Bangkok	151	7.6
Amsterdam	146	6.7
Los Angeles	141	16.8
Beijing	102	10.1
Shanghai	99	7.8
Madrid	96	6.6
Sydney	93	14.2
Moscow	90	5.6
Kuala Lumpur	85	6.1
Istanbul	83	5.0
Taipei	82	4.9
San Francisco	79	17.1
Doha	78	6.6
Sao Paulo	75	12.6
Toronto	74	7.1
Chicago	73	12.4
Newark	69	10.4
Miami	69	6.5
Munich	68	4.8
Roma	67	5.1
Zurich	62	4.9
Other Airports	3,479	4.8
Total	**7,217**	**6.0**

Figure 7.3: Monetised CO_2 footprint by airport

7.5 Routes

Figure 7.4 converts *Figure 2.5* into monetary terms. It can be seen that in 2012 in excess of $10 million dollars would have been raised for each of the major routes if route based MBMs had been in place. The greatest cost/passenger would have been $27.80 (Sydney-Los Angeles route) and the lowest $2.70 (Taipei – Hong Kong).

An alphabetic listing of the footprints of the world's top 1,000 routes is shown in *ProfileF5* in Part II.

Route	CO_2 Value ($\$x10^6$)	CO_2 Cost/PAX ($)
London (Heathrow)-Singapore	40.6	23.0
London (Heathrow)-New York (JFK)	40.0	11.1
London (Heathrow)-Hong Kong	33.7	20.7
Los Angeles-Sydney	28.2	26.7
London (Heathrow)-Los Angeles	26.6	18.0
Los Angeles-Tokyo (Narita)	25.1	18.8
London (Heathrow)-Dubai	21.7	10.9
Los Angeles-Seoul	21.6	20.9
Singapore-Sydney	21.2	12.6
San Francisco-Hong Kong	21.0	25.2
Los Angeles-Taipei	20.1	24.9
Frankfurt-Singapore	20.1	21.8
London (Heathrow)-Johannesburg	19.3	18.6
London (Heathrow)-San Francisco	19.0	18.8
Honolulu-Tokyo (Narita)	18.6	11.3
Hong Kong-Singapore	18.0	5.5
Taipei-Hong Kong	18.0	2.6
London (Heathrow)-Chicago	17.7	12.1
Hong Kong-Sydney	16.7	14.1
Chicago-Tokyo (Narita)	16.6	22.1
London (Heathrow)-Miami	16.4	14.9
New York (JFK)-Tokyo (Narita)	16.3	23.8
London (Heathrow)-Bangkok	16.1	18.6
London (Heathrow)-Newark	15.6	10.5
Paris (CDG)-Tokyo (Narita)	15.4	20.8
Singapore-Melbourne	15.0	12.3
New York (JFK)-Paris (CDG)	14.9	11.3
San Francisco-Seoul	14.7	20.3
New York (JFK)-Seoul	14.7	24.0
London (Heathrow)-Washington	14.4	11.7
London (Heathrow)-Mumbai	14.2	15.9
Other Routes	6,585.6	5.7
Total	**7,217.1**	**6.0**

Figure 7.4: Monetised CO_2 footprint by route

7.6 Airlines

Current MBMs which capture aviation do so through, in one way or another, imposing the liability on the airlines (eg Australia (carbon tax), Europe (ETS), New Zealand (ETS/fuel surcharge). Ultimately this carbon charge is passed on to the airlines' customers.

Figure 7.5 shows the revenue (or conversely the cost to the airlines) that would have resulted if an airline based MBM had been in place in 2012. The figure, which monetises *Figure 6.1,* also shows the average cost/passenger that would have been incurred by passengers of the separate airlines. Given the nature of the services provided, it is not surprising that, of airlines on the list, Qantas has the highest carbon cost/passenger and that Ryanair and Easyjet have the lowest.

Seventeen airlines would have generated carbon revenues exceeding $100 million.

Airline	CO_2 Value ($\$x10^6$)	CO_2 Cost/PAX ($)
Emirates Airline	347	9.8
British Airways	316	8.2
Lufthansa	307	5.5
United Airlines	297	10.1
Delta Air Lines	255	9.6
Air France	248	7.2
Singapore Airlines	210	10.6
Cathay Pacific	203	9.4
American Airlines	201	7.0
KLM Royal Dutch Airlines	182	7.7
Korean Air	160	8.4
Qatar Airways	147	7.4
Ryanair	136	2.6
Thai Airways International	126	8.6
Air Canada	124	7.5
Turkish Airlines	122	5.3
Qantas	104	15.4
Etihad Airways	96	8.8
Easyjet	93	3.0
Iberia Airlines	86	7.0
Air China	82	8.9
Virgin Atlantic Airways	81	13.0
Swiss European Air Lines	81	4.8
Japan Airlines	80	8.1
Malaysia Airlines	76	8.3
All Nippon Airways	74	9.1
China Airlines	73	6.3
Asiana Airlines	71	5.7
Air Berlin	64	3.9
Saudi Arabian Airlines	64	6.6
Other Airlines	2,715	4.7
Total	**7,217**	**6.0**

Figure 7.5: Monetised CO_2 footprint by airline

Chapter 8

Computation and Validation

8.1 Background

This chapter gives an overview of the methodology and tools used to generate the information contained in this report. In particular, it is directed at providing an indication of the robustness of the computed CO_2 values.

One of the key aims of the author in preparing the book *The Carbon Footprint of Aircraft Operations in Australia* – 2011[29] in 2012 was to test a methodology for carrying out simplified approaches to computing and reporting the carbon footprint of aircraft operations. This earlier book contains a chapter which discusses validation of the carbon footprinting methodology used in that book. Given the positive outcome of that validation exercise, the carbon footprinting approach used in this current document is based on the same methodology – hence much of the wording in Section 8.2 is similar to the wording in the earlier book. The reader is encouraged to look at the validation work on the Australian footprint in the 2012 document (Chapter 6) in conjunction with the material contained in this chapter.

All the information in this report has been generated using a standard home computer; publicly available data sets; and the application of free and/or reasonably priced commercially available non-expert software.

The carbon footprinting of aviation is very much aided by the fact that there is a great deal of publicly available data about aircraft operations. However, when examining the carbon footprint at the global level there are many gaps in the data and care needs to be taken in interpreting the applicability of the CO_2 data. In addition to testing the robustness of the CO_2 computations this chapter attempts to identify and broadly quantify the extent of data gaps (see Section 8.4).

8.2 Computation and Reporting

Input Data

All the information in the report has been derived from an operations dataset for **global scheduled international passenger aircraft operations** for the year 2012. This dataset was purchased from Innovata, a US based company that specialises in '…the aggregation, management and distribution of…travel data'.[30] The dataset file size is approximately 2.5MB and was provided as a Microsoft Excel spreadsheet containing 73,448 rows and six columns – an extract from the file is shown in *Figure 8.1*.

[29] *The carbon footprint of aircraft operations in Australia – 2011,* D Southgate, 2012: http://www.scribd.com/doc/110857161/The-Carbon-Footprint-of-Aircraft-Operations-in-Australia-2011
[30] Innovata: http://www.innovata-llc.com/

Origin	Destination	Equipment	SubEquipment	Airline	TotalFlts
AAE	CDG	32S	319	ZI	104
AAE	LYS	737	738	AH	116
AAE	MRS	32S	319	ZI	156
AAE	MRS	737	738	AH	181
AAE	ORY	32S	319	ZI	55
AAE	ORY	32S	320	ZI	8
AAE	ORY	737	738	AH	169
AAE	TOJ	SWM	SWM	YO	25
AAL	AGP	737	73H	DY!	53
AAL	AGP	737	73W	QI	16
AAL	AMS	F70	F70	KL	939
AAL	AYT	737	73W	QI	9
AAL	BCN	32S	320	VY	69
AAL	BER	737	73H	DY!	12
AAL	CHQ	737	73W	QI	9
AAL	FAE	ARJ	AR8	RC	17
AAL	LGW	737	73H	DY!	102

Figure 8.1: Extract from the Innovata operations dataset

In order to compute carbon using a great circle methodology latitude/longitude information is required for each airport. This information was obtained from a dataset purchased from *World Airport Database.*[31] Translations from IATA to ICAO airport codes were also carried out using this database.

Carbon Counting

The derivation of CO_2 information from the Innovata aircraft operations dataset was carried out using *TNIP Carbon Counter* – a great circle carbon counting application developed by the Australian Government Department of Infrastructure and Transport.[32] This software is available for free download from the Department's website.

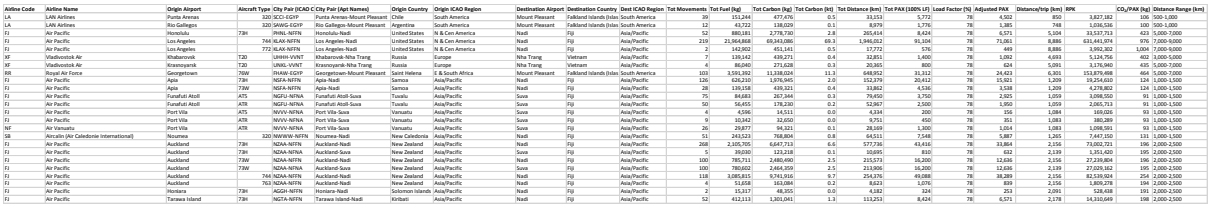
TNIP Carbon Counter contains all the information that is required to compute the weight of CO_2 generated by a flight between any city-pair. The program automatically computes the great circle distance between two airports based on an airport dataset which contains the geographic coordinates of the aerodrome reference points (ARPs) and applies this to fuel burn algorithms for different aircraft types to derive the amount of fuel used, and CO_2 generated, for each flight. The fuel burn algorithms are the same as those contained in the ICAO Carbon Calculator.[33] *TNIP Carbon Counter* also applies the great circle distance adjustment factors that are used in the ICAO Carbon Calculator – these add an increment to the great circle distance designed to reflect the actual distance flown.

TNIP Carbon Counter can directly read in files with the format shown in *Figure 8.1* and generate, amongst other things, an output table containing information on a wide range of user selected variables for each operation in the dataset (eg CO_2, distance, origin/destination airport, operator, destination State/Country, passenger numbers, etc). The actual computation is not lengthy – the carbon counting computation/archiving for the global dataset for the year 2012 takes about twenty minutes.

The *TNIP Carbon Counter* output was exported to Microsoft Excel to set up a number of master worksheets. An example of an extract from one of the master worksheets is shown in *Figure 8.2*.

[31] World Airports database: http://www.world-airport-database.co
[32] TNIP Carbon Counter: http://www.infrastructure.gov.au/aviation/environmental/transparent_noise/tnip_CC.aspx
[33] ICAO Carbon Calculator: http://www.icao.int/environmental-protection/CarbonOffset/Pages/default.aspx

[The figure has been included in this format for completeness – it is recognised that it is barely legible in a printed copy of the report but it can be readily magnified when the report is in its electronic form.]



Airline Code	Airline Name	Origin Airport	Aircraft Type	City Pair (ICAO C	City Pair (Apt Names)	Origin Country	Origin ICAO Region	Destination Airport	Destination Country	Dest ICAO Region	Tot Movements	Tot Fuel (kg)	Tot Carbon (kg)	Tot Carbon (kt)	Tot Distance (km)	Tot PAX (100% LF)	Load Factor (%)	Adjusted PAX	Distance/trip (km)	RPK	CO_2/PAX (kg)	Distance Range (km)
LA	LAN Airlines	Punta Arenas	320	SCCI-EGYP	Punta Arenas-Mount Pleasant	Chile	South America	Mount Pleasant	Falkland Islands (Islas	South America	39	151,244	477,476	0.5	33,153	5,772	78	4,502	850	3,827,182	106	500-1,000
LA	LAN Airlines	Rio Gallegos	320	SAWG-EGYP	Rio Gallegos-Mount Pleasant	Argentina	South America	Mount Pleasant	Falkland Islands (Islas	South America	12	43,722	138,029	0.1	8,979	1,776	78	1,385	748	1,036,536	100	500-1,000
FJ	Air Pacific	Honolulu	73H	PHNL-NFFN	Honolulu-Nadi	United States	N & Cen America	Nadi	Fiji	Asia/Pacific	52	880,183	2,778,730	2.8	265,414	8,424	78	6,571	5,104	33,537,713	423	5,000-7,000
FJ	Air Pacific	Los Angeles	744	KLAX-NFFN	Los Angeles-Nadi	United States	N & Cen America	Nadi	Fiji	Asia/Pacific	219	21,964,868	69,343,085	69.3	1,946,012	91,106	78	71,061	8,886	631,441,974	976	7,000-9,000
FJ	Air Pacific	Los Angeles	772	KLAX-NFFN	Los Angeles-Nadi	United States	N & Cen America	Nadi	Fiji	Asia/Pacific	2	142,902	451,141	0.5	17,772	576	78	449	8,886	3,992,302	1,004	7,000-9,000
XF	Vladivostok Air	Khabarovsk	T20	UHHH-VVNT	Khabarovsk-Nha Trang	Russia	Europe	Nha Trang	Vietnam	Asia/Pacific	7	139,142	439,271	0.4	32,851	1,400	78	1,092	4,693	5,124,756	402	3,000-5,000
XF	Vladivostok Air	Krasnoyarsk	T20	UNKL-VVNT	Krasnoyarsk-Nha Trang	Russia	Europe	Nha Trang	Vietnam	Asia/Pacific	4	86,040	271,628	0.3	20,365	800	78	624	5,091	3,176,940	435	5,000-7,000
RR	Royal Air Force	Georgetown	76W	FHAW-EGYP	Georgetown-Mount Pleasant	Saint Helena	E & South Africa	Mount Pleasant	Falkland Islands (Islas	South America	103	3,591,392	11,338,024	11.3	648,952	31,312	78	24,423	6,301	153,879,498	464	5,000-7,000
FJ	Air Pacific	Apia	73H	NSFA-NFFN	Apia-Nadi	Samoa	Asia/Pacific	Nadi	Fiji	Asia/Pacific	126	626,210	1,976,945	2.0	152,179	20,412	78	15,921	1,209	19,254,610	124	1,000-1,500
FJ	Air Pacific	Apia	73W	NSFA-NFFN	Apia-Nadi	Samoa	Asia/Pacific	Nadi	Fiji	Asia/Pacific	28	130,158	410,321	0.4	33,862	4,536	78	3,538	1,209	4,278,802	124	1,000-1,500
FJ	Air Pacific	Funafuti Atoll	ATS	NGFU-NFNA	Funafuti Atoll-Suva	Tuvalu	Asia/Pacific	Suva	Fiji	Asia/Pacific	75	84,283	267,344	0.3	79,450	3,750	78	2,925	1,059	1,098,550	91	1,000-1,500
FJ	Air Pacific	Funafuti Atoll	ATR	NGFU-NFNA	Funafuti Atoll-Suva	Tuvalu	Asia/Pacific	Suva	Fiji	Asia/Pacific	50	56,455	178,230	0.2	52,967	2,500	78	1,950	1,059	2,065,713	91	1,000-1,500
FJ	Air Pacific	Port Vila	ATS	NVVV-NFNA	Port Vila-Suva	Vanuatu	Asia/Pacific	Suva	Fiji	Asia/Pacific	4	4,596	14,511	0.0	4,334	200	78	156	1,084	169,026	93	1,000-1,500
FJ	Air Pacific	Port Vila	ATR	NVVV-NFNA	Port Vila-Suva	Vanuatu	Asia/Pacific	Suva	Fiji	Asia/Pacific	9	10,342	32,650	0.0	9,751	450	78	351	1,083	380,289	93	1,000-1,500
NF	Air Vanuatu	Port Vila	ATR	NVVV-NFNA	Port Vila-Suva	Vanuatu	Asia/Pacific	Suva	Fiji	Asia/Pacific	26	29,877	94,321	0.1	28,169	1,300	78	1,014	1,083	1,098,591	93	1,000-1,500
SB	Aircalin (Air Caledonie International)	Noumea	320	NWWW-NFFN	Noumea-Nadi	New Caledonia	Asia/Pacific	Nadi	Fiji	Asia/Pacific	51	243,523	768,804	0.8	64,511	7,548	78	5,887	1,265	7,447,150	131	1,000-1,500
FJ	Air Pacific	Auckland	73H	NZAA-NFFN	Auckland-Nadi	New Zealand	Asia/Pacific	Nadi	Fiji	Asia/Pacific	268	2,105,705	6,647,713	6.6	577,736	41,416	78	33,864	2,156	73,002,721	196	2,000-2,500
FJ	Air Pacific	Auckland	73H	NZAA-NFFN	Auckland-Suva	New Zealand	Asia/Pacific	Suva	Fiji	Asia/Pacific	5	39,030	123,218	0.1	10,695	810	78	632	2,139	1,351,420	195	2,000-2,500
FJ	Air Pacific	Auckland	73W	NZAA-NFFN	Auckland-Nadi	New Zealand	Asia/Pacific	Nadi	Fiji	Asia/Pacific	100	785,711	2,480,490	2.5	215,573	16,200	78	12,636	2,156	27,239,804	196	2,000-2,500
FJ	Air Pacific	Auckland	73W	NZAA-NFFN	Auckland-Suva	New Zealand	Asia/Pacific	Suva	Fiji	Asia/Pacific	100	780,602	2,464,359	2.5	213,906	16,200	78	12,636	2,139	27,029,162	195	2,000-2,500
FJ	Air Pacific	Auckland	744	NZAA-NFFN	Auckland-Nadi	New Zealand	Asia/Pacific	Nadi	Fiji	Asia/Pacific	118	3,085,815	9,741,916	9.7	254,376	49,088	78	38,289	2,156	82,539,924	254	2,000-2,500
FJ	Air Pacific	Auckland	763	NZAA-NFFN	Auckland-Nadi	New Zealand	Asia/Pacific	Nadi	Fiji	Asia/Pacific	4	51,658	163,084	0.2	8,623	1,076	78	839	2,156	1,809,278	194	2,000-2,500
FJ	Air Pacific	Honiara	73H	NGGH-NFFN	Honiara-Nadi	Solomon Islands	Asia/Pacific	Nadi	Fiji	Asia/Pacific	2	15,317	48,355	0.0	4,182	324	78	253	2,091	528,438	191	1,000-2,500
FJ	Air Pacific	Tarawa Island	73H	NGTA-NFFN	Tarawa Island-Nadi	Kiribati	Asia/Pacific	Nadi	Fiji	Asia/Pacific	52	412,113	1,301,041	1.3	113,253	8,424	78	6,571	2,178	14,310,649	198	2,000-2,500

Figure 8.2: Extract from an example master Excel worksheet

Data Interrogation

Almost all the data interrogation, the 'slicing and dicing', carried out to produce the tables/figures in the report was performed by applying Microsoft Excel pivot tables, and linked slicers, to the data in master worksheets like that shown in *Figure 8.2*.

Generation of Graphics

The graphics were predominantly produced using the standard chart functions contained in Microsoft Excel. The main quantity flow diagrams (eg *Figure 2.6*) were produced using a flow diagram software tool – *e!Sankey*.[34] The figures containing geographic coordinate information (eg *Figure 3.7*) were produced using a GIS application – *Maptitude*.[35]

Important Notes

A number of assumptions and/or allocation decisions were made in the generation of the information:

- When carbon counting, the default settings in *TNIP Carbon Counter* were used – for each operation in the Innovata dataset, for a given aircraft type, the CO_2 generated was computed using the default fuel burn profile and aircraft type substitution. Metrics involving 'per passenger' computations were based on the TNIP default seat configurations. By default TNIP Carbon Counter uses a factor of 3.157 to convert weight of jet fuel to weight of CO_2; the specific gravity of jet fuel is taken to be 0.8.

- A load factor of 78% was used for all flights in the database – this was the IATA published worlwide average load factor for international aviation for 2012.[36]

- IATA uses dynamic codes for airline operators – that is, if an airline operator code is no longer used it is allocated to another operator. Airline companies frequently go out of business and/or are acquired by other airlines and new entrants emerge. The non unique nature of the codes meant that in several instances the airline name in the standard databases was no longer correct. While the names were 'cleaned up' as far as possible, particularly for the major operators, it is highly likely that the Appendices may contain incorrectly named minor airlines.

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[34] e sankey: www.**e-sankey**.com/

[35] Maptitude: http://www.caliper.com/maptovu.htm

[36] IATA, *2012 Annual Review*, p12: http://www.iata.org/about/Documents/annual-review-2012.pdf

- The naming of airports also presented challenges. In many instances an airport is known by a local name (eg Heathrow) rather than the city (or cities) in which it is located. Generally, for ease of presentation, throughout the report the airports have been named with city, rather than local, airport names. This has the effect of grouping airports for those cities which have more than one international airport. Given the use of hierarchies to filter out smaller airports used in this document this grouping is useful as it can help cities with significant aviation traffic from 'falling under the radar' as the result of the splitting of significant traffic levels into small parts. The grouping of airports has been applied to all cities except London, New York, Paris and Tokyo where separate airports have been reported using IATA airport codes (placed in parentheses following the city name) or a local name in the case of Newark. In many cases the secondary international airports have small carbon footprints, but there are cities where the airports have been grouped and there is more than one significant airport (eg Moscow). There are issues about deciding whether an airport is, or is not associated, with a particular city and there are inconsistencies in the report in this area.

- There are grey areas in the classification of airports located in external territories. The Innovata database contains some external territories which are identified as being part of countries several thousand kilometres, and in a differenct ICAO region, from the location of the 'mother country'. It also contains some external territories which are in close geographic proximity to their mother countries. As every operation in the Innovata database is defined as being international these very close neighbouring territories become treated as separate countries. For example, the dataset contains flights from the Australian mainland to Norfolk Island (a small Australian island territory off the coast of the Australian State of New South Wales). By default the database defines these flights as international operations but they are considered domestic flights by the Australian authorities.

  In order to be consistent no changes were made to the dataset to adjust for domestic/international flight classification. In some instances airports (eg Guam) were treated (for carbon footprinting purposes) as being in the ICAO region where they are geographically located. In general the CO_2 associated with external territories is minimal and it is not considered that the adjustments made (or not made) induced any significant errors.

8.3 Validation

Overview

There are a number of published sources of information which can be used to assess the robustness of the CO_2 computations contained in this report. At the aggregated level the International Energy Agency (IEA) publishes information on jet fuel sales by country and the UNFCCC reports aviation bunkers as a 'memo item' in the reports on the CO_2 footprint of Annex 1 countries. A number of governments report energy use by the aviation sector as part of either aviation statistics, or energy/climate change, reporting regimes. Several major international airlines report fuel/CO_2 data as part of their annual corporate or sustainability reporting. The ICAO carbon calculator, and other similar on-line tools provided by airlines, can be used to compute CO_2 emissions on an individual flight basis.

Unfortunately there are anomalies between what, on the face of it, are authoritative validation points and hence there remain uncertainties in aviation carbon footprinting. Ultimately the 'real' data on the carbon footprint of aircraft operations at a disaggregated level (ie the flight by flight fuel use data), is owned by the airlines and given its commercial sensitivity it is unlikely to be made available for public scrutiny.

The validity of input into derived metrics such as CO_2/PAX can be examined by using data on passenger numbers published by national transport statistics agencies.

A key area of uncertainty is that generated by 'data gaps'. Ideally it would be desirable to present a complete picture of the carbon footprint of all international aircraft operations but much important data is not available to members of the public (see Section 8.4). This report solely computes the carbon footprint of scheduled international passenger operations since data is only readily available for this sector of the total footprint. To present a complete global carbon footprint picture, data would need to be available on other key areas of international aviation, in particular on the airfreight and non-scheduled aviation sectors.

Working with a database of scheduled, rather than actual, operations clearly will introduce errors. In practice scheduled services are cancelled; unscheduled services are introduced; new entrant airlines appear; existing airlines withdraw or are withdrawn. These are recognised weaknesses with the computational method adopted and may be an important source of error.

This section uses the known validation points to draw a picture of the likely robustness of the scheduled international passenger CO_2 computations contained in this report.

Robustness of the Core Operations Dataset

All the computations in this report rely on the accuracy and completeness of the operations database purchased from Innovata. At the top level it is important that the RPK values computed from the study database be consistent with independently reported activity levels. Converting this to passenger numbers and cross comparing with published data gives another level of validation.

The Innovata dataset does not contain information on passenger numbers and this was derived by assigning values for both the number of seats in each different aircraft type and for the load factors. As indicated in Section 8.2, the *TNIP Carbon Counter* default values were used to assign the number of seats and a load factor of 78% was used for all operations in the dataset. Applying these values to the dataset gave, for scheduled international passenger operations in 2012, the following values:

Total revenue passenger-kilometres = **3,483 x 10^9** Total passengers carried = **1.21 x 10^9**

IATA has published a figure of 1.1 billion for global international passengers carried in 2011.[37] Figure 8.3 shows ICAO's published values of both passenger numbers and revenue

			Revenue Passenger-Kilometres		Departures	Passengers carried	
	Period	Year	World* (billion)	International (billion)	World (million)	World (billion)	International (billion)
History		2000	3038	1790	21	1.7	0.5
	2000-2012		+4.8%	+5.4%	+3.3%	+4.5%	+6.3%
		2012	5349	3359	31	2.9	1.2
Forecasts	2012-2020		+4.5%	+4.8%	+3.9%	+4.5%	+5.2%
		2020	7631	4884	42	4.1	1.7
	2020-2030		+4.5%	+4.6%	+3.5%	+4.4%	+4.9%
		2030	11805	7672	59	6.3	2.8
	2012-2030		+4.5%	+4.7%	+3.6%	+4.5%	+5.1%

*international and domestic

Figure 8.3: ICAO data on global aviation activity 2012

[37] IATA, press release no 50; Dec 2012: http://www.iata.org/pressroom/pr/pages/2012-12-06-01.aspx

passenger-kilometres for 2012. It can be seen that the values computed from the Innovata dataset are in very close agreement with the reported values (recognising that the IATA figure is for 2011).[38]

As a further check, cross comparing the Airports Council International (ACI) published number of passenger numbers at the top five airports[39] (Chapter 5) with the number of passengers computed via *TNIP Carbon Counter* gives the values shown in *Figure 8.4*.

Airport	Computed No of PAX	ACI No of PAX	% Difference
London (Heathrow)	71,645,813	65,005,539	10.2
Dubai	55,442,763	56,011,254	-1.0
Hong Kong	56,361,618	55,306,963	1.9
Frankfurt	53,019,176	51,007,349	3.9
Paris (CDG)	52,642,791	56,211,730	-6.3

Figure 8.4: Comparison between computed and actual passenger numbers at key airports

The information in *Figures 8.3* and *8.4* gives a good level of confidence in the overall completeness of the Innovata dataset and gives an indication of the robustness of the CO_2/passenger data reported in this document.

Validation at the Global and Country Level

Published fuel and CO_2 data at the global level is almost always directed at presenting a complete picture of energy use (ie it is aimed at capturing all the jet fuel used for aircraft operations). This data is commonly sub-divided into domestic and international; jet fuel used for military purposes is typically identified separately.

The most commonly used dataset giving country by country information on global aviation fuel use is published by the International Energy Agency (IEA)[40]. The UNFCCC also publishes similar data for Annex 1 countries – this information is provided by treaty signatory members as a memo item in their annual reports[41]. *Figure 8.5* provides a country by country comparison between the UNFCCC data and the great circle computed footprint values shown in this report (see *Figure 2.2*). The data in the table relates solely to UNFCCC Annex 1 countries – note this data is for the latest year available 2010.

[38] ICAO, *Traffic Statistics for Revenue Scheduled Services*: http://www.icao.int/sustainability/Pages/FactsFigures-Data.aspx

[39] ACI, traffic data: http://www.aci.aero/Data-Centre/Monthly-Traffic-Data/International-Passenger-Rankings/12-months

[40] IEA, *Statistics and Balances*: http://www.iea.org/stats/index.asp

[41] UNFCCC, *Time series – Annex 1*: http://unfccc.int/ghg_data/ghg_data_unfccc/time_series_annex_i/items/3814.php

It can be seen from the figure that, as expected, the computed scheduled international passenger footprint values are, for most countries, lower than the reported total international aviation footprint. Putting aside uncertainties arising from the use of a great circle methodology, the differences are likely to be primarily due to unaccounted CO_2 emissions associated with dedicated freight and non-scheduled operations (see discussion in Section 8.4).

While across the whole dataset the level of 'undercounting' is about 25% when the UNFCCC CO_2 emissions are adjusted to a figure for 2012 (275,169 kt), for some countries the difference is less than 10%. It may be surmised that in these countries the level of freight and/or charter traffic is lower than the average. For example, the previously published carbon footprint report for Australia, which gives a figure consistent with that in *Figure 8.5,* made specific reference to the relatively low level of charter aircraft activity in that country.[42]

Another area of potential error is misallocation between the domestic and international sectors – this would appear to be the case, for example, with the wide disparity in the two values for Turkey in *Figure 8.5*.

The IEA data, which reports fuel use in many more countries (ie in both Annex 1 and non-Annex 1 countries) contains a number of apparently anomalous values. It does appear that some countries report fuel use/CO_2 based on fuel uplifted while others report based on country of aircraft registration. In some countries fuel use is likely to be influenced by tankering.

A good summary of both the IEA and UNFCCC datasets for 2008 can be found in a report published by the International Transport Forum.[43] The report points out issues with interpreting the data and states that it

Country	UNFCCC 2010 CO_2 (kt)	Scheduled Passenger 2012 CO_2 (kt)	% Difference
United States	73,327	49,949	32
United Kingdom	31,834	24,811	22
Germany	24,792	18,757	24
Japan	16,434	13,960	15
France	16,356	13,821	15
Spain	13,182	10,648	19
Australia	10,335	9,497	8
Netherlands	10,205	7,539	26
Italy	9,513	7,488	21
Canada	9,058	8,366	8
Russia	7,860	5,736	27
Switzerland	4,297	4,397	-2
Belgium	4,234	2,479	41
Portugal	2,633	2,496	5
Denmark	2,448	1,905	22
Ireland	2,339	1,584	32
New Zealand	2,326	2,200	5
Greece	2,113	1,392	34
Sweden	2,093	1,548	26
Austria	2,072	1,849	11
Finland	1,676	1,413	16
Poland	1,586	1,127	29
Norway	1,314	1,276	3
Luxembourg	1,297	125	90
Czech Republic	1,040	771	26
Ukraine	905	876	3
Hungary	684	489	29
Bulgaria	506	292	42
Romania	497	657	-32
Turkey	435	5,026	-1,056
Iceland	381	339	11
Latvia	362	317	12
Malta	321	243	24
Croatia	247	251	-2
Belarus	232	135	42
Lithuania	147	178	-21
Estonia	115	108	6
Slovakia	105	60	43
Slovenia	74	62	15
Monaco	3	5	-84
Total	**259,374**	**204,171**	**21**

Figure 8.5: CO_2 footprint comparison – UNFCCC v values reported in Chapter 2

[42] *The carbon footprint of aircraft operations in Australia – 2011,* D Southgate, 2012, p76: http://www.scribd.com/doc/110857161/The-Carbon-Footprint-of-Aircraft-Operations-in-Australia-2011

[43] ITF, *Transport Greenhouse Gas Emissions,* 2010: http://www.internationaltransportforum.org/Pub/pdf/10GHGCountry.pdf

"…includes emissions from international aviation and international maritime bunkers - there is no internationally agreed allocation mechanism for these and totals here are indicative of the scale of these emissions, not of their national "ownership"".

When examining country carbon footprints for aviation it is important to be aware of tankering. For some smaller countries, whose connections into the international network are through short haul international flights, the actual fuel uplifted (and therefore the IEA/UNFCCC fuel/CO_2 reported) may be less than the actual fuel used due to airlines not uplifting fuel in the country concerned. Tankering takes place for a number of reasons such as a higher price for fuel in some specific countries (eg separate taxation regime), turnaround time constraints, lack of ground support, etc. This a factor which will tend to increase or decrease the computed CO_2 value relative to fuel uplifted data depending on whether the country is, or is not, a favoured place for re-fuelling.

ICAO provides figures on the size of the global carbon footprint for aviation in its *2010 Environmental Report.*[44] This report (p32) indicates that in 2006 the global international aviation sector consumed 116 Mt of fuel. This is equivalent to the generation of 366 Mt of CO_2. If this is adjusted to a 2012 value assuming 3% growth in emissions per year, 366 becomes 437 Mt of CO_2 for the global footprint of international aircraft operations in 2012. This therefore gives a difference of about 20% between the ICAO figure for the carbon footprint of total international operations and the figure computed in this report of 361 Mt CO_2 for the carbon footprint of international scheduled passenger operations in 2012. Thus this comparison gives a similar difference to that given between the total and passenger footprints in the UNFCCC data in *Figure 8.5*.

The group coordinating the industry response to climate change – the Air Transport Action Group (ATAG), states that "Worldwide, flights produced 676 million tonnes of CO_2 in 2011".[45] If this is normalised to a 2012 figure by adding 3% growth this is equal to 696 Mt CO_2. ATAG also indicates that international operations comprise 62% of the total aviation carbon footprint – therefore the ATAG figure gives a value of 696 x .62 = 431 Mt CO_2. This figure is in close agreement with the ICAO figure.

The IEA reports that the global consumption of jet kerosene in 2009 was 2,227,804 kt.[46] This equates to 703 Mt of CO_2 for the total carbon footprint of aviation in 2009. If the ATAG figure of 62% for the proportion of the total footprint that applies to international aviation is used to convert this into the international aviation carbon footprint this equals 436 Mt of CO_2 (which equals 476 Mt of CO_2 in 2012 if there was growth of 3%/year between 2009 and 2012). Hence the IEA figure for the size of the international operations carbon footprint in 2012 is about 10% higher than for the other two sources.

India has produced a useful aviation carbon footprint report for activities within its jurisdiction.[47] This report provides a figure of 3,623 kt of CO_2 emitted by non-Indian registered aircraft departing to international destinations in 2011. It also indicates that Indian registered aircraft emitted 5,949 kt of CO_2 for all operations to/from India. If it is assumed that about half of this figure is for Indian registered aircraft departing India then the total CO_2 footprint for the country in 2011 = 2,975 + 3,623 = 6,598 kt CO_2 (this converts to a 2012 figure of 6,994 kt CO_2). This compares with a figure of 7,182 kt CO_2 for India contained in Figure 2.2. While this shows a good level of agreement, when the comparison is broken down into the constituent Indian and non-Indian airlines the difference is

[44] ICAO, *Environmental Report 2010*: http://www.icao.int/environmental-protection/Documents/Publications/ENV_Report_2010.pdf
[45] ATAG, Facts and Figures: http://www.atag.org/facts-and-figures.html
[46] IEA, *Oil in World 2009*: http://www.iea.org/stats/oildata.asp?COUNTRY_CODE=29
[47] *The Carbon Footprint of Indian Aviation 2011*: http://dgca.nic.in/env/Carbon%20Footprint%20Report%202011.pdf

about 15%. Examination of the master worksheet indicates a figure of 5,138 kt, rather than 5,949 kt, for CO_2 emitted by Indian airlines departing on international passenger operations.

Summary

In broad terms the estimates for the carbon footprint of global international aviation in 2012 (all figures adjusted to 2012 using an annual growth figure of 3%) discussed in this section are:

ICAO 437 Mt CO_2 (approx. 20% greater than the computed vale of 361 Mt)

ATAG 431 Mt CO_2 (approx. 20% greater than the computed value of 361 Mt)

IEA 476 Mt CO_2 (approx. 30% greater than the computed value of 361 Mt)

It is not possible to provide a UNFCCC global figure for the carbon footprint of international aviation as its published data only relates to Annex 1 countries. On average the year adjusted UNFCCC values for country CO_2 are about 25% greater than the computed values reported in this document.

These values need to be examined in the context of the data gaps discussed in Section 8.4 (primarily dedicated freight and non-scheduled aircraft movements – see *Figure 8.9)*.

Validation at the Airline Level

Having identified the differences between total reported and computed fuel use at both the global and country level the question then becomes to what extent are the differences due to the data gaps (see Section 8.4) as opposed to errors in the computational methodology**.**

Data published by the airlines (or reported by aviation authorities based on statutory energy/fuel use reports provided by airlines) would appear to provide the best way to test the robustness of the computational methodology. The 'true' data, that is the fuel use data on a flight by flight basis, is owned by the airlines and is generally treated as the *gold standard* for validation purposes.

A number of sources are available for comparing the computed CO_2 values with those reported by airlines. *Figure 8.6* provides comparisons between the computed and reported values for the top 5 airlines (see Chapter 6). The numbers in the table need to be read in conjunction with the associated notes as none of the numbers is strictly comparable – all the sources have different bases for the reporting.

Airline	Calculated CO_2 (kt) 2012	Reported CO_2 (kt)	Year
Emirates Airline	17,333	16,205	2010-11
British Airways	15,808	15,255	2010-11
Lufthansa Group	21,881	21,349	2011
United Airlines	16,656	17,777	2012
Delta Air Lines	12,743	15,078	2012
Cathay Pacific	11,369	12,598	2011

Figure 8.6: CO_2 footprint comparison – computed v reported values for the top 5 airlines (+ Cathay Pacific)

Notes

1) It is worth noting the year of the reported data. A figure of 3% annual growth in CO_2 emissions is used throughout the report as a global average footprint growth figure – this may not be particularly accurate for individual companies and hence some care needs to be taken in trying to convert the values to a common base year.

2) The Emirates CO_2 value has been derived from information in its 2010-11 Sustainability report.[48] The value has been computed from the information on total passenger-kilometres (PK) flown and the published fuel efficeiency expressed as litres/100PK.

3) The values reported by British Airways include fuel used by dedicated freighters.[49]

4) Lufthansa breaks down the footprint into passenger and freight components but not into domestic and international.[50] There was no apparent simple route to determining the domestic/international split; in the cited reference (p64) the company reports that 16% of its fuel is used on flights of less than 800km; the Innovata database shows that a substantial number of international flights carried out by Lufthansa Group aircraft have a range of less than 800 km therefore the domestic proportion of the Group's footprint is likely to be significantly less than 16%. Lufthansa also reports that approximately 25% of the its carbon footprint is related to the carriage of freight – it is not clear whether this figure relates solely to the footprint of cargo carried in dedicated freighters or also covers freight carried in the belly of passenger aircraft. The carbon footprint figure is for the Lufthansa Group and also includes carbon contributions from Austrian Air, Germanwings and SWISS.

5) The United Airlines reported CO_2 figure[51] includes fuel used by dedicated freighters and non-scheduled operations. The CO_2 figures, both calculated and reported, include contributions from Continental Airlines – United and Continental merged in early March 2012.

6) The Delta Airlines reported CO_2 figure[52] includes fuel used by dedicated freighters and non-scheduled operations.

7) The values for Cathay Pacific have been included as Cathay has published very useful transparent carbon footprint data which breaks down fuel use into passenger and freight. [53] Approximately 80% of the Cathay carbon footprint is related to passenger flights. The carbon footprint figure is for the Cathay Pacific Group and also includes carbon contributions from Dragonair.

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[48] Emirates Airline, *Environmental Report 2010-2011*: http://www.emirates.com/english/images/The%20Emirates%20Group%20Environment%20Report_tcm233-701728.pdf

[49] British Airways, *Corporate Responsibility Report 2010/2011*: http://d2zax00nj39hb2.cloudfront.net/wp-content/uploads/CR-Report-2010-11.pdf

[50] Lufthansa Group, *Balance*, Issue 2012, p66: http://www.lufthansagroup.com/fileadmin/downloads/en/LH-sustainability-report-2012.pdf

[51] United Airlines, *Annual Fuel Costs and Consumption*: http://www.transtats.bts.gov/fuel.asp

[52] Delta Airlines, *Annual Fuel Costs and Consumption*: http://www.transtats.bts.gov/fuel.asp

[53] Cathy Pacific, *Sustainable Development Report* 2011, Environmental Indicators Table: http://downloads.cathaypacific.com/cx/aboutus/sd/2011/pdf/CX_SDR11_Full.pdf

Under the European Union ETS, airlines are required to report on their CO_2 emissions on an annual basis – the total emissions for each airline are published by the European Commission.[54] *Figure 8.7* shows a comparison between the computed and reported CO_2 emissions for 2012 for a number of example airlines.

Airline	Computed CO_2 (kt)	EU ETS CO_2 (kt)	% Difference
British Airways	1,989	2,544	28
Cathay Pacific	32	38	19
Emirates Airline	33	40	21
Easyjet	4,559	4,611	1
Ryanair	6,801	7,457	10
SWISS	576	599	4

Figure 8.7: Comparison between computed and EU ETS reported CO_2 footprints for airlines

The reported EU ETS emissions cover both domestic and intra Europe international operations. The computed footprint only relates to flights in the Innovata database between the 30 countries covered by the EU ETS (ie intra Europe international operations). The footprint for British Airways and Easyjet can be adjusted to figures which solely relate to international flights by reference to a database published by the UK CAA (assuming these airlines only operate domestic services within the UK)[55]. This data set provides Available Seat Kilometre (ASK) information for both intra Europe international and UK domestic services – this can be used to derive a reasonably robust relationship between domestic and international carbon footprints for UK airlines. When these ratios are applied to the carbon footprints shown in the figure:

- for British Airways the difference between the computed and actual carbon footprint drops to about 9%
- for Easyjet the difference drops to around -4%.

Overall there is broad agreement between the computed and reported carbon footprints when assessed at the airline level. All things being equal, it would be expected that the reported footprint would be larger than the computed footprint as a range of operations such as ad hoc charters, maintenance, training, repositioning, etc flights will not be caught by the "scheduled" definition. As indicated by the notes, there are issues with each of the comparisons but it would seem that the Emirates and Cathay Pacific comparisons are the most robust. There is no need for a domestic/international footprint split in the data for these two airlines as they do not carry out domestic operations (China is treated as an international destination for flights to/from Hong Kong in the Innovata database) and both companies have provided information which appears to give a relatively clean value for fuel used by scheduled international passenger (as opposed to freight) operations.

[54] European Commission, *Union Registry, Reports*: http://ec.europa.eu/clima/policies/ets/registry/documentation_en.htm
[55] UK CAA, *Aviation statistics*: http://www.caa.co.uk/default.aspx?catid=80

Validation at the Route Level

Carbon footprinting comparisons can be made at the route level by reference to recognised city-pair carbon calculators. *Figure 8.8* shows the comparison between the results of the output of the ICAO, Qantas and Cathay carbon calculators[56, 57, 58] for the top 10 routes (see *Figure 2.5)*.

The values for the Qantas calculator shown in the figure have been arrived at by averaging the values for the outward and return legs of the city-pair (the Qantas calculator produces a different value for each leg).

An important point in this comparison is that both the ICAO and Cathay calculators provide the user with the option to select a class of travel – the values in the figure report economy class data. On the other hand the computations in this report, and the Qantas calculator, apportion the total CO_2 load equally across all passengers. This means that a lower footprint value would be expected to be reported by the ICAO and Cathay calculators when reporting the economy class footprint. The CO_2 allocation to passengers is further reduced in the ICAO carbon calculator by the application of a freight factor which ascribes a proportion of the fuel burned on each flight to the belly freight carbon footprint.

Route	Computed CO_2/PAX (kg)	ICAO Carbon Calculator CO_2/PAX (kg) (economy class)	Qantas CO_2/PAX (kg)	Cathay CO_2/PAX (kg) (economy class)
London (Heathrow)-Singapore	1,149	765	1,376	
London (Heathrow)-JFK	556	363		
London (Heathrow)-Hong Kong	1,034	685	1,292	830
Sydney-Los Angeles	1,336	983	1,681	
London (Heathrow)-Los Angeles	902	594		
Los Angeles-Tokyo (Narita)	939	620		
London (Heathrow)-Dubai	543	393		
Los Angeles-Seoul	1,046	678		
Sydney-Singapore	629	454	728	
San Francisco-Hong Kong	1,262	797		960

Figure 8.8: CO_2 footprint comparison – computed v reported values for the top 10 routes (units CO_2 kg)/PAX)

Given the above it would appear that a comparison between the computed values and the Qantas carbon calculator offers the best comparison. This is possible on four of the top 10 routes – it can be seen that the great circle computed values are all within about 15% of the Qantas values. It should be noted that the Qantas calculator applies to the Qantas footprint on the selected routes while the computed values relates to the footprint of all the operators on the routes. In addition, it is important to bear in mind that the values in the table are expressed in terms of CO_2/PAX; the accuracy of these computations depends on assumptions about both aircraft seat configurations and load factors. In this study generic values have been used across all countries and airlines for these two variables – clearly an unrefined approach which only provides an indirect indicator of the

[56] Qantas carbon calculator: https://www.qantas.com.au/travel/airlines/offset-my-flight/global/en
[57] ICAO Carbon Calculator: http://www.icao.int/environmental-protection/CarbonOffset/Pages/default.aspx
[58] Cathay Pacific calculator http://www.cathaypacific.com/cpa/en_AU/aboutus/carbonoffset

robustness of the total footprint. Nevertheless, the numbers are broadly consistent and do not suggest any gross errors in the computations.

Profile F5 in Part II contains CO_2 footprint information for 1,000 international city-pair combinations. The reader can use this listing to make further comparisons between the computed CO_2 values shown in this report and the output of published carbon calculators.

8.4 The Data Gaps

As discussed earlier in this chapter, if a transparent picture is to be presented of the carbon footprint of international aircraft operations it would be useful to understand the quantum of the contribution made by the identifiable individual components to the total footprint.

Data on international scheduled passenger movements is widely available and the ease of access to data in this particular area results in it being the core component of most aviation statistical regimes (this is also driven by the fact these movements constitute the overwhelming majority of activity in the international aviation sector).

There are other components, notably dedicated freight aircraft and non-scheduled passenger operations, which make significant contributions to the total footprint. However, robust data on these components is not readily accessible to members of the public – hence there are 'data gaps' which weaken our picture of the total carbon footprint for international aviation.

Operations by dedicated freighters

As indicated earlier, both Lufthansa and Cathay have published separate carbon footprint data for the freight part of their businesses. Unfortunately, it is not clear whether the published data relates solely to cargo carried in dedicated freighters or whether additional CO_2 has been ascribed to the freight footprint (or removed from the 'passenger footprint') to take account of cargo carried in the bellies of passenger aircraft. Putting definitional issues aside, both of these companies indicate that about 20-25% of their carbon footprint derives from the carriage of freight. These two companies are major freight operators and the quantum of the freight components of these companies' carbon footprints does not provide an across the sector footprint picture.

Despite concerted efforts it was not possible to find many sources of information in this area. Putting aside differentiation between scheduled and non-scheduled freight operations, it appears that complete operations datasets are not available for scheduled freight operators. Some dedicated freight operators have significant carbon footprints. For example, based on US Government fuel use data, Federal Express (Fedex) had a jet fuel carbon footprint of about 4,400 kt CO_2 and United Parcel Service (UPS) had a footprint of about 3,500 kt CO_2 for international operations in 2011.[59] This would place both of these operators in the top 30 airlines shown in *Figure 6.1*. The same source indicates that the proportion of the total operations defined as 'non-scheduled' is less than 5% for both operators.

The only credible study that the author was able to locate in this area was an examination of the carbon footprint of the airfreight industry carried out by Morrell in 2007 for the air cargo industry.[60] Morrell split the cargo CO_2 contribution into the freighter aircraft impact, and the impact of cargo carried on passenger flights. He indicates "…it can be seen that freighters represented only 6.4% of

[59] US Bureau of Transportation Statistics, *Airline Fuel Cost and Consumption*: http://www.transtats.bts.gov/fuel.asp
[60] *The Environmental Impact of Air Cargo, P Morrell, 2007*: http://www.tiaca.org/images/TIACA/PDF/The%20Environmental%20Impact%20of%20Air%20Cargo.pdf p11

the total global consumption (and of course a similar CO_2 emissions impact)" [61] The report does not distinguish between domestic and international freighter operations but does refer, in a number of places, to jet freighters being predominantly used on long-haul operations. In the absence of any other information it is assumed, as a crude approximation, that all of the freighter carbon footprint comes from international operations. [It can be seen from the CO_2 v Distance profiles throughout this report that short-haul operations make a very small contribution to the carbon footprint of a sub-sector that involves long-haul operations.]

If it is assumed that all freighter operations are international and make up 6.4% of the world's carbon footprint, the freighter contribution will be about 10% of the total international aviation carbon footprint (since international aviation generates about 60% of the total global footprint for aviation).

Non-scheduled Operations

Ascertaining the footprint contribution made by charter, or non-scheduled, traffic presents similar challenges to computing airfreight footprint contributions. The data that is available indicates a very uneven picture.

The United Kingdom Civil Aviation Authority (CAA) publishes comprehensive aviation statistical data.[62] Information in the CAA database indicates that in 2011 about 20% of the international Available Seat Kilometres (ASK) provided by UK operators was carried out through non-scheduled services (ASK is directly related to the quantum of CO_2 generated). In the United States data published by the Bureau of Transportation Statistics indicates that in 2012 about 15% of the fuel used in international aviation by US carriers could be ascribed to non-scheduled services.[63]

A 2007 ICAO report provides useful insights. The ICAO report '*Outlook for Air Transport to the Year 2025*'[64] states that *"…Non-scheduled air transport is primarily devoted to international passenger traffic, with freight traffic and domestic traffic being relatively small by comparison. The share of non-scheduled passenger traffic in the total international passenger traffic declined from about 15 per cent during the latter part of the 1990s to around 10 per cent in 2005….Non-scheduled traffic is very important on intra-European routes which account for the largest part of the world charter market in terms of passengers, followed by North Atlantic routes."* [In this context "passenger traffic" is being defined through passenger-km which is directly related to CO_2 emissions]

In the absence of other data the ICAO figure for 2005 cited above - 10% of total international passenger traffic - is taken as an indicative value for the carbon footprint contribution from non-scheduled traffic in 2012.

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[61] Footnote 51, p5
[62] UK CAA, *Aviation statistics*: http://www.caa.co.uk/default.aspx?catid=80
[63] US Bureau of Transportation Statistics, *Airline Fuel Cost and Consumption*: http://www.transtats.bts.gov/fuel.asp
[64] ICAO, *Outlook for Air Transport to the Year 2025,* p10: http://www.icao.int/sustainability/Documents/C313_Outlook_En.pdf

Business Aviation & Other Operations

There are many other sub-sectors of aviation; these include business aviation, military, training, commercial aerial work, private flying, etc. System wide carbon footprint information on these activities is difficult to find. In cases where this information is published it is generally not broken down into international and domestic components. While international operations in these sub-sectors do take place, the available information suggests that the international component is relatively minor and the vast majority of the activities should be categorised as 'domestic'. Given this, for the purposes of this document the contribution of these sub-sectors to the carbon footprint of international aircraft operations is taken to be zero.

Summary

The discussion in this section broadly indicates that the carbon footprint of the dedicated freight and non-scheduled sub-sectors of international aviation both make a contribution of about 10% of the total. It must be stressed that these numbers have little verifiable basis and should be considered as first order approximations. Nevertheless, taking these assumptions into account gives a breakdown of the carbon footprint for international aircraft operations for 2012 with the constituents shown in *Figure 8.9*.

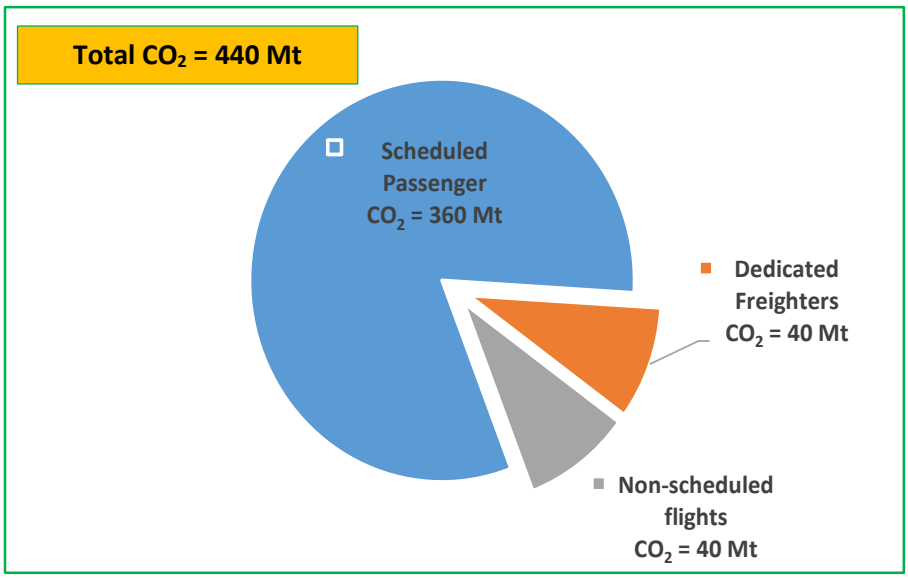


Figure 8.9: Indicative breakdown of the carbon footprint for international flights 2012

It can be seen that the figure shows the total carbon footprint for international aviation in 2012 equalled 440 Mt of CO_2. It was shown in the previous section that a value of 440 Mt of CO_2 for the total international carbon footprint for 2012 is broadly consistent with footprint data published by both ICAO and ATAG and is about 10% lower than the figure published by the IEA. Therefore the breakdown shown in this figure provides comfort that, at least at the aggregated level, the computed values for the carbon footprint of scheduled international passenger operations published in this report are generally sound.

If questions around the composition of the total footprint of international aviation are put to one side, it is estimated that computations relating solely to the scheduled passenger component of the footprint provide results that are within around 10% of the true answer. This estimate is primarily based on the published information on the Emirates and Cathay Pacific footprints where the freight component has been disaggregated from the passenger contribution (shown in *Figure 8.6*). In addition, the testing of the methodology in the previously mentioned carbon footprint study of

aircraft operations in Australia produced answers which were within 5% of CO_2 generation values published by Qantas and Virgin[65]. This level of error is also consistent with the foregoing discussion on the data gap and the total footprint estimates of ICAO, ATAG and the IEA.

8.5 Observations

- Validation of carbon footprinting of international aviation at the global level is difficult. There appears to be a dearth of consolidated reliable fuel/energy use data which covers the sector. The data that exists often conflicts, apparently due to differences in the bases of compilation that are not well explained.

- Data is readily available on activity levels within the international passenger movement sector - this has enabled the production of this report. However, while a number of bodies (primarily airlines and government) generate information which can be used to examine certain aspects of the aviation carbon footprint, unfortunately this is often reported in a way that is ambiguous. For example, it is often not clear whether:

  - CO_2 data relates to movements to/from a country or whether it relates to operations by aircraft registered in a particular country operating elsewhere in the world

  - data on the freight carbon footprint relates solely to fuel used in dedicated freighters or includes an allocation to capture the footprint of cargo in the belly of aircraft

  - particular operations have been ascribed to domestic or international activities

  - fuel used for military purposes has been included in carbon footprint computations

  - non-scheduled operations have been captured in published data on passenger/freight fuel use.

- Great circle techniques appear to provide robust carbon footprint results. The very limited number of aircraft types in use in international aviation today (five aircraft families generate more than 75% of the global scheduled international passenger footprint) is undoubtedly an important factor in this outcome. It would appear that, provided the fuel use algorithms for the key aircraft types are robust, great circle based carbon footprinting will provide a reliable picture at the aggregated level.

- Ultimately if a carbon management regime is to be established for international aviation it is unlikely to receive public support if it is not transparent. A fundamental design requirement for any new regime is that members of the public, or at the least independent specialists, are able to verify the carbon outcomes using publicly available data.

[65] *The carbon footprint of aircraft operations in Australia – 2011,* D Southgate, 2012, p74: http://www.scribd.com/doc/110857161/The-Carbon-Footprint-of-Aircraft-Operations-in-Australia-2011

PART II

FOOTPRINT PROFILES

FOOTPRINT PROFILES

This Part of the document contains sets of carbon footprint profiles for the four areas covered in Chapters 3 to 6 – Regions, Countries, Airports, and Airlines. There is also a carbon footprint listing for the top 1,000 routes used by scheduled international passenger flights in 2012.

Profile F1:	ICAO Regions carbon footprint profiles.	Four sheets – descending CO_2.
Profile F2:	Country carbon footprint profiles.	Forty six sheets - descending CO_2.
Profile F3:	Airports carbon footprint profiles.	Fifteen sheets - descending CO_2.
Profile F4:	Airlines carbon footprint profiles.	Fifteen sheets - descending CO_2.
Profile F5:	Route carbon footprint information.	Top 1,000 city-pairs - alphabetic.

This Part of the report is purely a data resource and is aimed at extending the information which has been presented in Part I. The broad intent is to capture, as far as possible, information on the vast majority of the carbon footprint for scheduled international passenger flights. The emphasis has been placed on presenting information at the country level since this is the level at which negotiations are carried out within the United Nations. The country footprint profiles contained in *Profile F2* and in Part I capture about 90% of the global footprint.

The carbon footprint profile concept is introduced in Section 2.2 and is used throughout the report. The profiles present a dashboard style picture of different aspects of the carbon footprint for the entity being examined (eg a specific country) using a number of different elements. Each element is independent and has a total footprint which equals the total footprint for the entity under consideration. Similarly, it is important to appreciate that each of the profiles presents a picture of the same data but from a different perspective. For example, the airport profiles are independent of the airline profiles; adding data between the two profile types will lead to double counting. The total footprint for any of the high level categories (eg airports, airlines) is equal to 360,857 Mt of CO_2.

The footprints contained in this Part of the report do not repeat the footprint profiles in Part I. The profiles for the top CO_2 emitters are contained in Chapters 3 to 6.

The level of disaggregation that is contained in the information in this Part inevitably leads to the generation of footprint components that are small. While these are likely to contain high relative errors (given the computation methodology) the absolute errors may not be significant. Due to the assumptions required, the 'CO_2/PAX' values have a greater level of uncertainty than the 'CO_2' values.

Profile F1

ICAO Region Footprint Profiles

Profile F1 contains carbon footprint profiles for the lowest four ICAO regions categorised by the size of the carbon footprint.

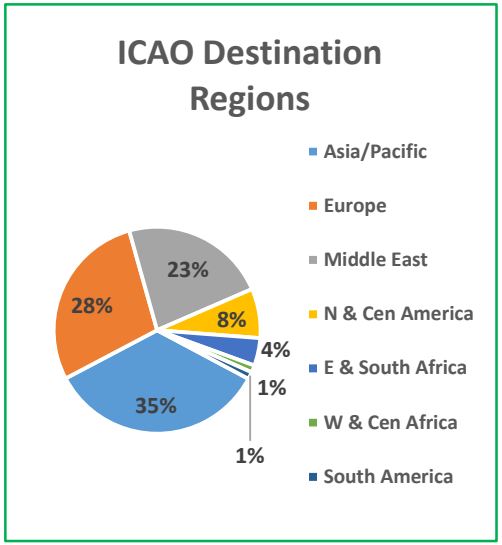
The profiles for the top three regions (dark orange colour in the figure), are contained in Chapter 3.

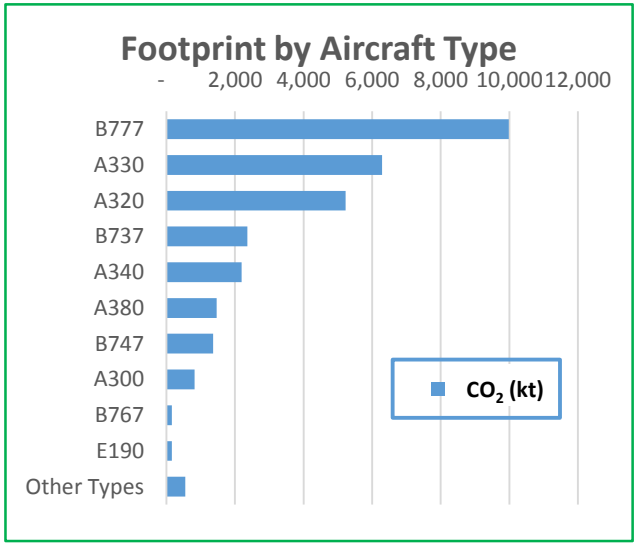
The profiles are ordered by descending weight of CO_2.

ICAO Region	CO_2 (kt)	Cumulative %
Europe	128,052	35
Asia/Pacific	105,608	65
N & Central America + Caribbean	68,049	84
Middle East	30,566	92
South America	16,390	97
East & South Africa	8,795	99
West & Central Africa	3,396	100
Total	**360,857**	

Middle East

Total Footprint = 30,566 kt CO_2



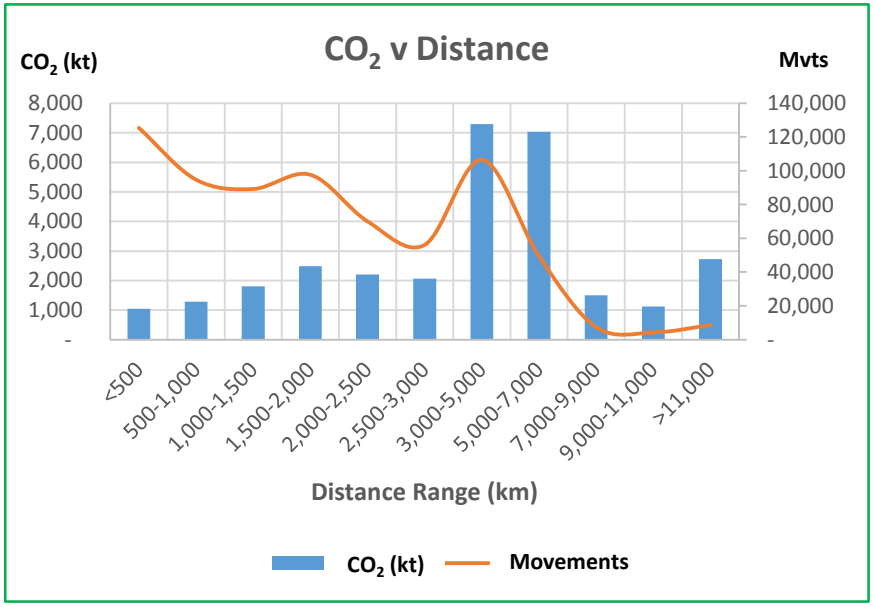


Origin Airports	CO_2 (kt)
Dubai	10,976
Doha	3,881
Abu Dhabi	2,970
Jeddah	2,014
Cairo	1,669
Riyadh	1,304
Kuwait City	1,085
Bahrain	982
Muscat	815
Amman	726
Beirut	616
Sharjah	559
Tehran	538
Dammam	351
Khartoum	339
Other Airports	1,741
Total	**30,566**

Destination Airports	CO_2 (kt)
London (Heathrow)	1,581
Dubai	1,141
Bangkok	814
Cairo	800
Frankfurt	792
New York (JFK)	688
Jakarta	672
Paris (CDG)	654
Jeddah	615
Manila	604
Kuala Lumpur	597
Istanbul	565
Sydney	489
Mumbai	482
Kuwait City	462
Other Airports	19,612
Total	**30,566**

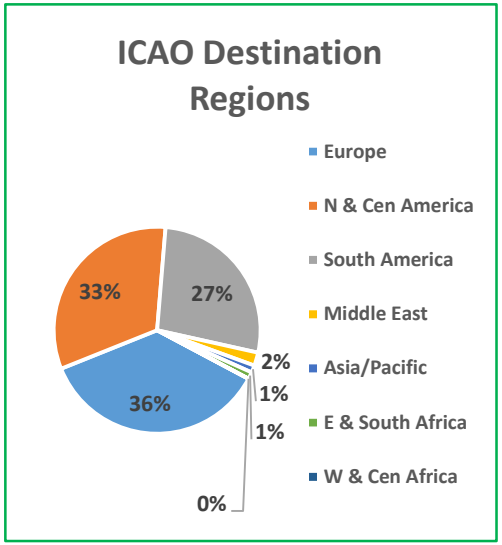
Airlines	CO_2 (kt)
Emirates Airline	8,705
Qatar Airways	3,847
Etihad Airways	2,570
Saudi Arabian Airlines	1,963
EgyptAir	1,487
Gulf Air Bahrain	855
Oman Air	653
Royal Jordanian	634
Flydubai	620
Air Arabia	582
Kuwait Airways	513
Lufthansa	451
British Airways	423
Middle East Airlines	362
Turkish Airlines	354
Other Airlines	6,548
Total	**30,566**

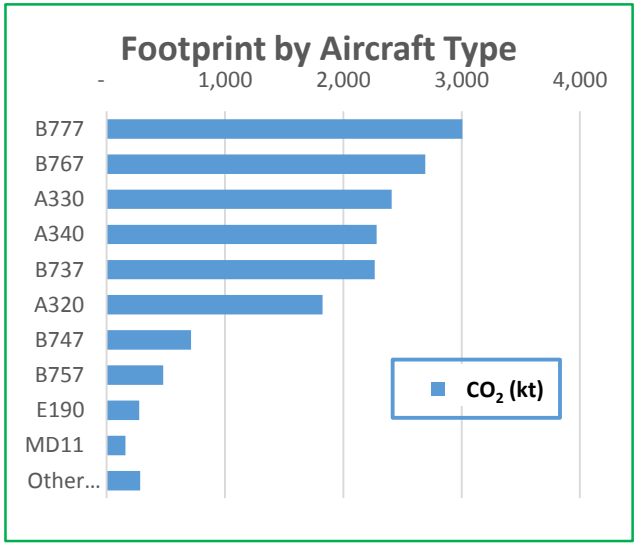
City-Pair Hierarchy	CO_2 (kt)
Dubai-London (Heathrow)	542
Jeddah-Jakarta	331
Dubai-Sydney	277
Dubai-New York (JFK)	253
Dubai-Bangkok	238
Dubai-Singapore	234
Abu Dhabi-Sydney	212
Doha-London (Heathrow)	212
Dubai-Hong Kong	203
Dubai-Los Angeles	199
Abu Dhabi-London (Heathrow)	189
Dubai-Paris (CDG)	188
Dubai-Beijing	183
Dubai-Johannesburg	181
Dubai-Kuala Lumpur	180
Other Routes	26,945
Total	**30,566**



South America

Total Footprint = 16,390 kt CO_2



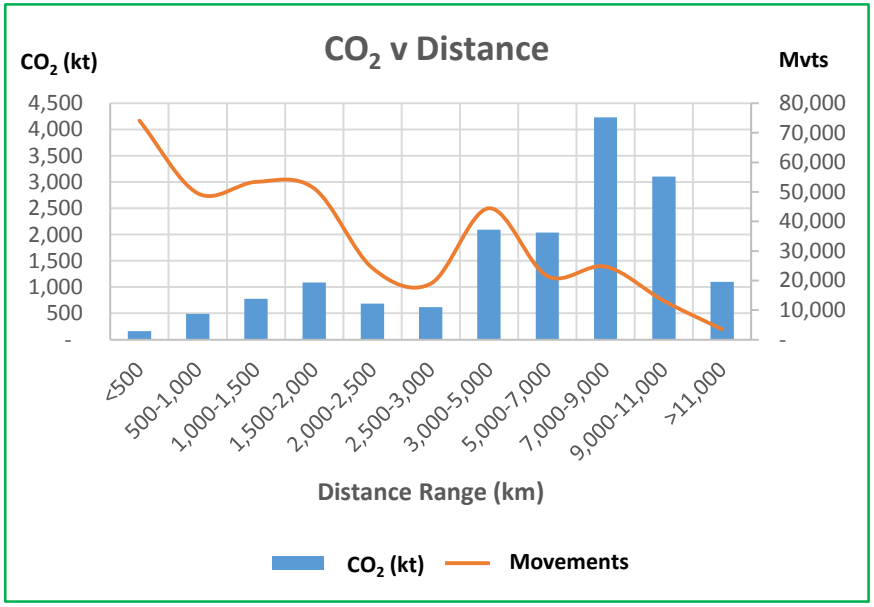


Origin Airports	CO_2 (kt)
Sao Paulo	3,783
Buenos Aires	2,417
Rio de Janeiro	1,429
Lima	1,408
Santiago de Chile	1,356
Panama City	1,227
Bogota	1,077
Caracas	729
Guayaquil	359
Curacao	232
Montevideo	218
Aruba	198
Philipsburg	179
Quito	164
Brasilia	156
Other Airports	1,460
Total	**16,390**

Destination Airports	CO_2 (kt)
Madrid	1,684
Miami	1,577
Paris (CDG)	923
New York (JFK)	756
Amsterdam	737
Buenos Aires	677
Frankfurt	627
Panama City	559
Sao Paulo	558
Lisboa	534
Lima	534
Santiago de Chile	507
Mexico City	450
London (Heathrow)	419
Bogota	374
Other Airports	5,474
Total	**16,390**

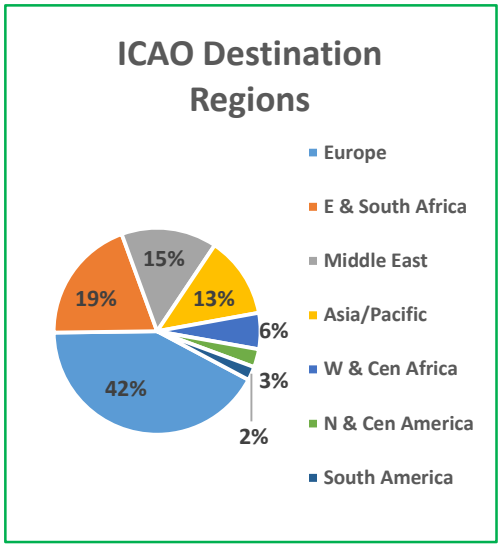
Airlines	CO_2 (kt)
LAN Airlines	1,801
Copa Airlines	1,506
TAM Airlines (TAM Linhas Aer	1,446
American Airlines	1,366
Iberia Airlines	907
Air France	859
Avianca - Aerovias Nacionales	816
KLM Royal Dutch Airlines	653
Aerolineas Argentinas	639
TAP Portugal	588
Lufthansa	551
United Airlines	523
Delta Air Lines	480
TACA Airlines	386
Alitalia	308
Other Airlines	3,562
Total	**16,390**

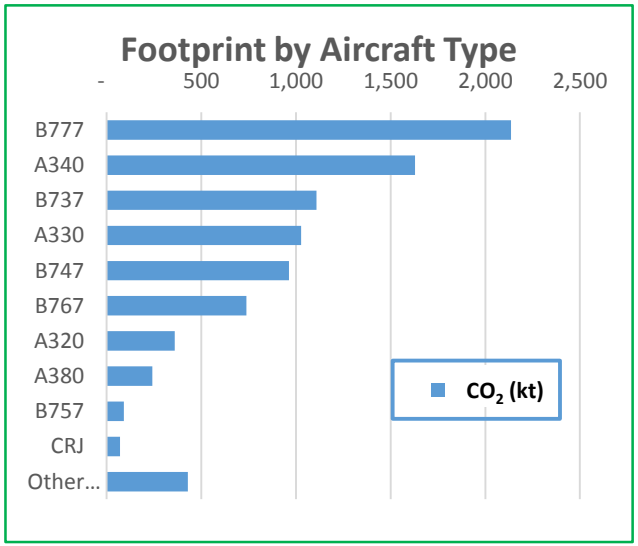
City-Pair Hierarchy	CO_2 (kt)
Buenos Aires-Madrid	340
Sao Paulo-Miami	286
Buenos Aires-Miami	265
Sao Paulo-New York (JFK)	260
Sao Paulo-Paris (CDG)	245
Rio de Janeiro-Paris (CDG)	227
Lima-Madrid	226
Sao Paulo-Frankfurt	218
Sao Paulo-London (Heathrow)	211
Sao Paulo-Madrid	209
Santiago de Chile-Madrid	185
Bogota-Madrid	172
Buenos Aires-Sao Paulo	164
Sao Paulo-Buenos Aires	163
Buenos Aires-Roma	160
Other Routes	13,060
Total	**16,390**



E & South Africa

Total Footprint = 8,795 kt CO_2



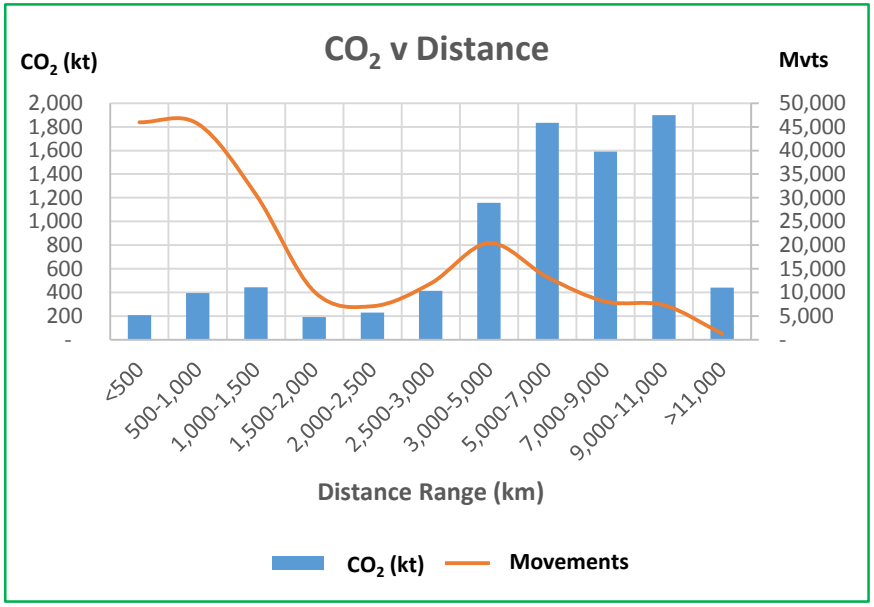


Origin Airports	CO_2 (kt)
Johannesburg	2,990
Nairobi	1,030
Addis Ababa	938
Mauritius	606
Cape Town	563
St-Denis de la Reunic	484
Luanda	450
Dar es Salaam	245
Entebbe/Kampala	199
Antananarivo	162
Windhoek	151
Lusaka	141
Mahe	109
Mombasa	89
Kigali	80
Other Airports	559
Total	**8,795**

Destination Airports	CO_2 (kt)
London (Heathrow)	1,076
Dubai	814
Paris (CDG)	561
Amsterdam	430
Johannesburg	396
Frankfurt	396
Paris (Orly)	300
Hong Kong	226
Nairobi	210
Bangkok	170
Sydney	166
Lisboa	156
Addis Ababa	150
Mumbai	145
Zurich	132
Other Airports	3,469
Total	**8,795**

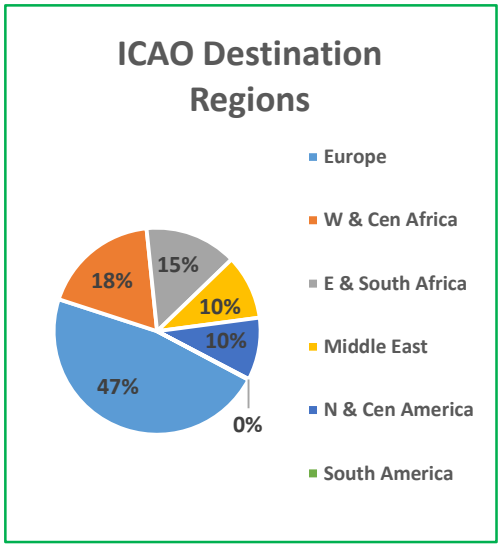
Airlines	CO_2 (kt)
South African Airways	1,364
Ethiopian Airlines	997
Emirates Airline	699
Kenya Airways	684
British Airways	660
Air France	397
KLM Royal Dutch Airlines	389
Air Mauritius	352
Air Austral	279
TAAG Angola Airlines (Linhas A	234
Lufthansa	185
Corsairfly	178
Air Namibia	164
Virgin Atlantic Airways	157
Qantas	147
Other Airlines	1,908
Total	**8,795**

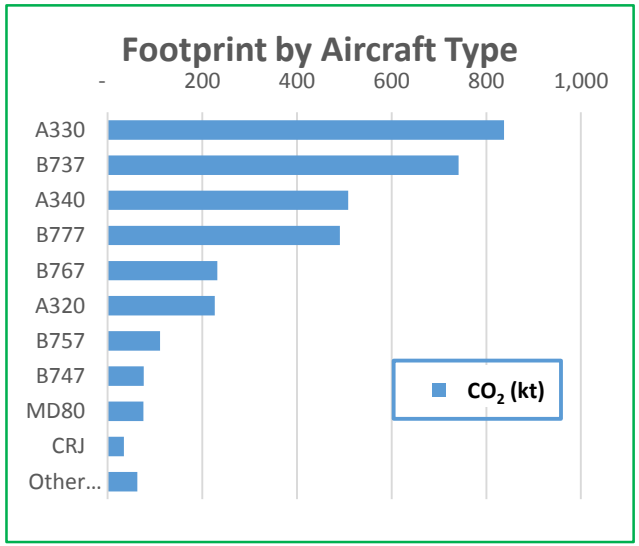
City-Pair Hierarchy	CO_2 (kt)
Johannesburg-London (Heathrow)	484
Cape Town-London (Heathrow)	259
St-Denis de la Reunion-Paris (Orly)	249
Johannesburg-Hong Kong	208
Johannesburg-Frankfurt	186
Johannesburg-Dubai	181
Mauritius-Paris (CDG)	171
Nairobi-London (Heathrow)	167
Johannesburg-Sydney	147
Nairobi-Amsterdam	135
Johannesburg-Atlanta	127
Luanda-Lisboa	123
Cape Town-Dubai	118
Johannesburg-Paris (CDG)	111
Johannesburg-New York (JFK)	109
Other Routes	6,020
Total	**8,795**



W & Cen Africa

Total Footprint = 3,396 kt CO_2



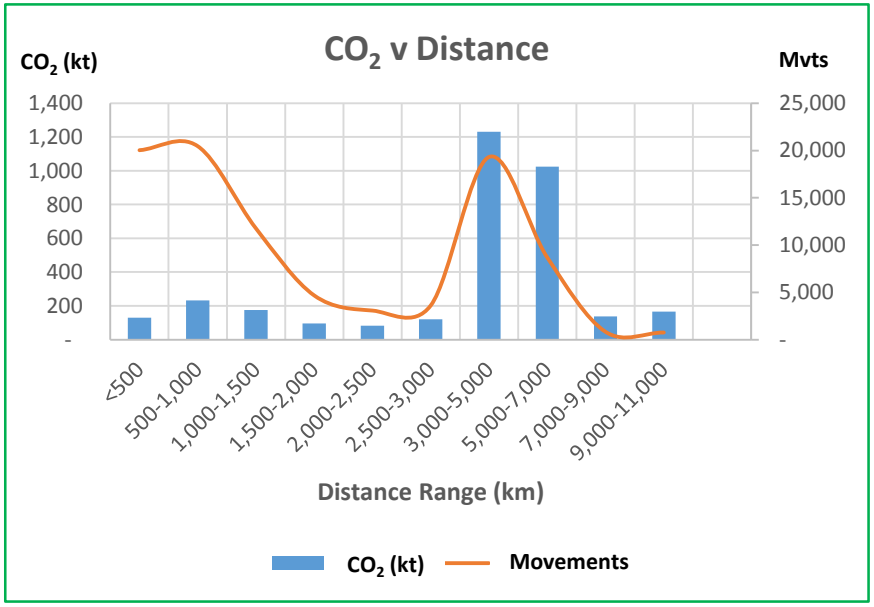


Origin Airports	CO_2 (kt)
Lagos	838
Accra	438
Dakar	353
Abuja	161
Abidjan	152
Douala	145
Kinshasa	122
Bamako	119
Cotonou	112
Libreville	111
Ouagadougou	79
Lome	75
Pointe Noire	62
Brazzaville	60
Conakry	53
Other Airports	516
Total	**3,396**

Destination Airports	CO_2 (kt)
Paris (CDG)	528
London (Heathrow)	292
Dubai	197
Addis Ababa	191
Johannesburg	168
Brussels	163
Casablanca	145
Frankfurt	110
Nairobi	102
Amsterdam	97
New York (JFK)	85
Atlanta	85
Houston	82
Washington	71
Lisboa	67
Other Airports	1,013
Total	**3,396**

Airlines	CO_2 (kt)
Air France	529
Ethiopian Airlines	219
Emirates Airline	211
South African Airways	204
Brussels Airlines	183
Arik Air	162
British Airways	155
Royal Air Maroc	152
Kenya Airways	139
Delta Air Lines	138
Lufthansa	128
KLM Royal Dutch Airlines	93
United Airlines	78
Asky Airlines	74
Kingfisher Red	72
Other Airlines	859
Total	**3,396**

City-Pair Hierarchy	CO_2 (kt)
Lagos-London (Heathrow)	144
Lagos-Dubai	100
Lagos-Houston	82
Accra-London (Heathrow)	74
Lagos-Atlanta	68
Abuja-London (Heathrow)	59
Lagos-Johannesburg	57
Dakar-Johannesburg	56
Douala-Paris (CDG)	53
Dakar-Washington	53
Accra-Dubai	52
Dakar-Dubai	45
Accra-Amsterdam	45
Abidjan-Paris (CDG)	44
Lagos-New York (JFK)	43
Other Routes	2,422
Total	**3,396**



Profile F2

Country Footprint Profiles

Profile F2 contains carbon footprint profiles for the 46 countries listed at the bottom of the figure to the right. The number of countries chosen is based on capturing 90% of the global carbon footprint for scheduled international passenger flights in 2012.

The profiles for the top five countries (dark orange colour in the figure), are contained in Chapter 4.

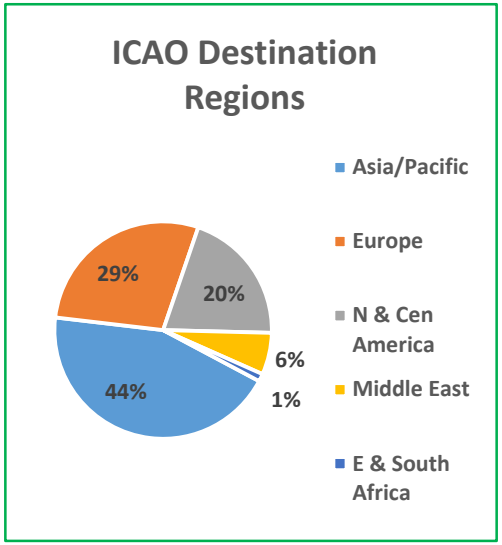
The Innovata database contains entries for 221 countries. A number of these are external territories of larger countries and are not normally identified as separate countries.

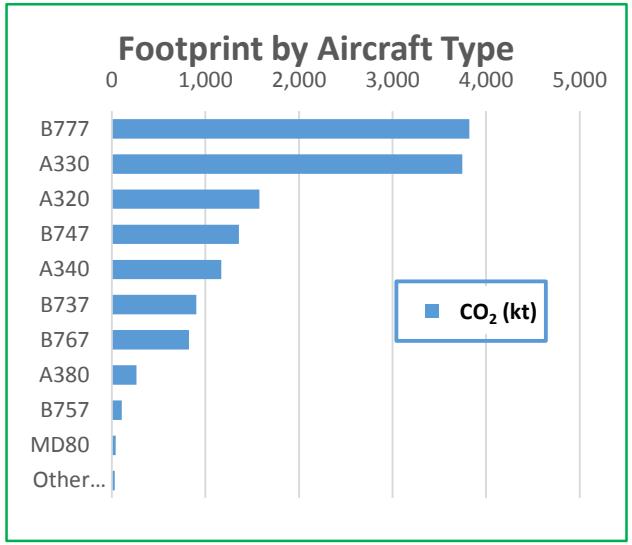
The profiles in the following pages are ordered by descending weight of CO_2.

Country	CO_2 (kt)	Cumulative %
United States	49,949	14
United Kingdom	24,811	21
Germany	18,757	26
United Arab Emirates	14,547	30
Japan	13,960	34
China	13,872	38
France	13,821	41
Spain	10,648	44
Hong Kong	10,363	47
Singapore	9,816	50
Australia	9,497	53
Canada	8,366	55
South Korea	8,292	57
Thailand	8,209	60
Netherlands	7,539	62
Italy	7,488	64
India	7,182	66
Brazil	5,932	67
Russia	5,736	69
Turkey	5,026	70
Malaysia	4,494	72
Switzerland	4,397	73
Taiwan	4,292	74
Mexico	3,950	75
Qatar	3,881	76
Saudi Arabia	3,857	77
South Africa	3,616	78
Indonesia	3,065	79
Philippines	2,633	80
Portugal	2,496	81
Argentina	2,480	81
Belgium	2,479	82
Egypt	2,310	83
New Zealand	2,200	83
Israel	1,952	84
Denmark	1,905	84
Austria	1,849	85
Vietnam	1,707	85
Ireland	1,584	86
Sweden	1,548	86
Finland	1,413	86
Peru	1,410	87
Greece	1,392	87
Chile	1,375	88
Morocco	1,327	88
Pakistan	1,282	88
Norway	1,276	89
Colombia	1,275	89
Dominican Republic	1,231	89
Panama	1,227	90
Poland	1,127	90
Other Countries	36,017	100
Total	**360,857**	

China

Total Footprint = 13,872 kt CO_2



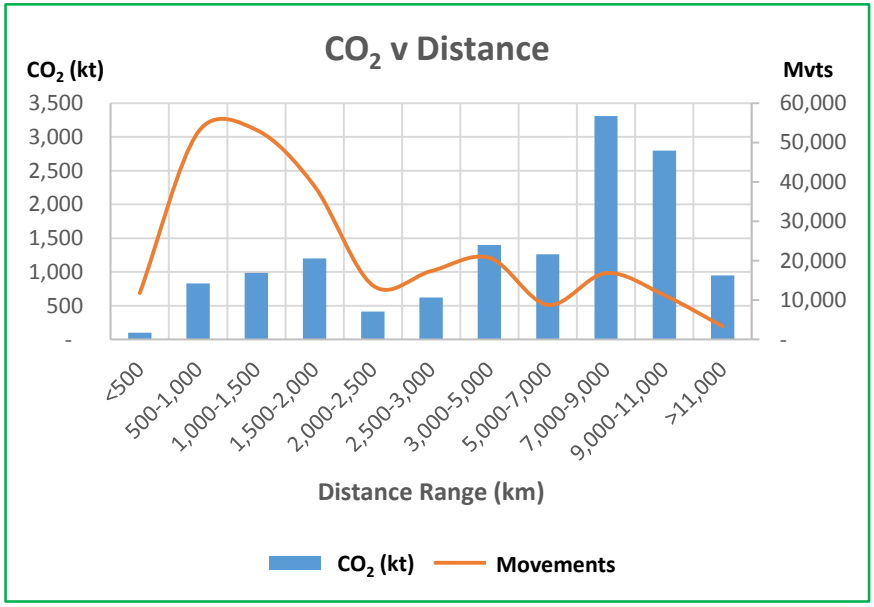


Origin Airports	CO_2 (kt)
Beijing	5,074
Shanghai	4,965
Guangzhou	1,647
Hangzhou	227
Chengdu	226
Xiamen	193
Kunming	124
Qingdao	118
Nanjing	107
Zhenzhen	106
Dalian	106
Shenyang	98
Chongqing	97
Urumqi	82
Tianjin	76
Other Airports	626
Total	**13,872**

Destination Airports	CO_2 (kt)
Hong Kong	931
Singapore	787
Paris (CDG)	638
Frankfurt	605
Los Angeles	569
Seoul	551
Amsterdam	527
Taipei	517
Tokyo (Narita)	436
Bangkok	426
Dubai	424
Chicago	401
London (Heathrow)	376
San Francisco	362
Kuala Lumpur	360
Other Airports	5,963
Total	**13,872**

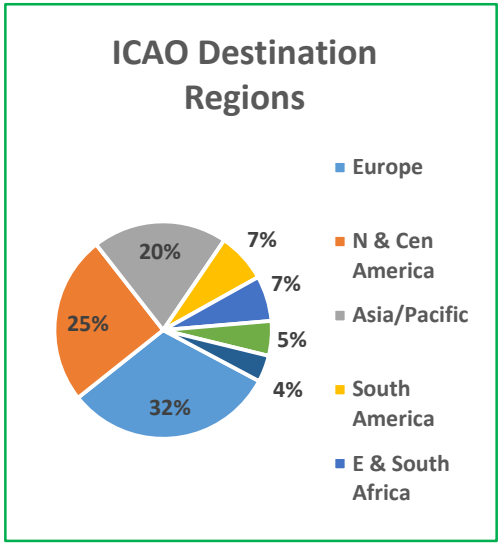
Airlines	CO_2 (kt)
Air China	2,029
China Eastern Airlines	1,394
China Southern Airlines	1,340
United Airlines	788
Lufthansa	434
Dragonair, Hong Kong Dragon	420
KLM Royal Dutch Airlines	407
Singapore Airlines	363
Air France	356
Air Canada	314
Emirates Airline	307
American Airlines	299
Hainan Airlines	278
Delta Air Lines	249
All Nippon Airways	245
Other Airlines	4,649
Total	**13,872**

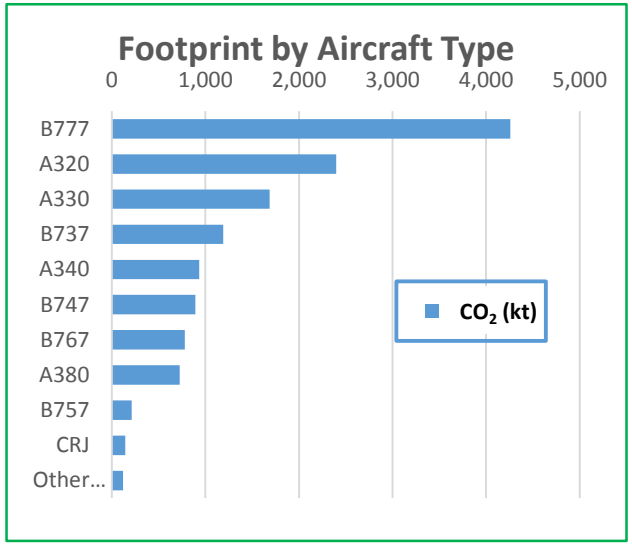
City-Pair Hierarchy	CO_2 (kt)
Beijing-Hong Kong	292
Shanghai-Frankfurt	289
Shanghai-Paris (CDG)	289
Shanghai-Hong Kong	285
Shanghai-Los Angeles	281
Beijing-Frankfurt	256
Beijing-Singapore	256
Shanghai-Singapore	253
Beijing-San Francisco	247
Shanghai-Chicago	207
Beijing-Paris (CDG)	196
Beijing-Chicago	193
Shanghai-London (Heathrow)	189
Shanghai-Amsterdam	188
Beijing-Dubai	182
Other Routes	10,269
Total	**13,872**



France

Total Footprint = 13,821 kt CO_2



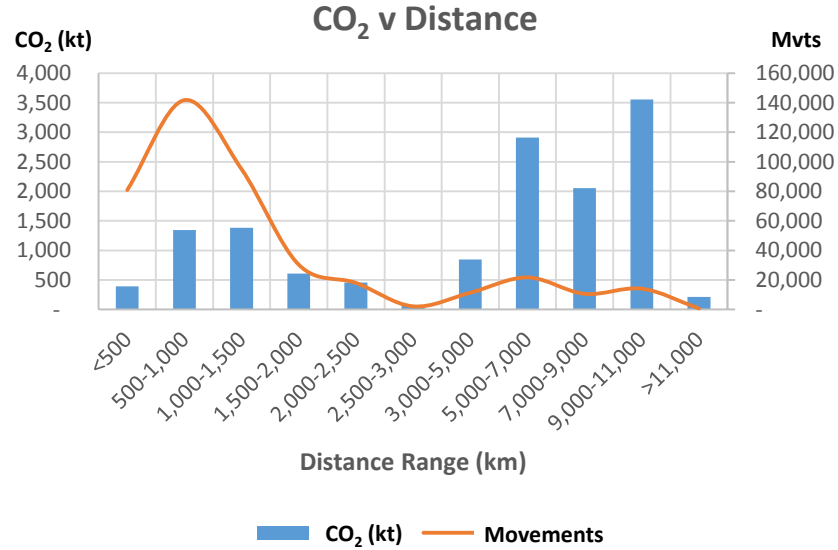


Origin Airports	CO_2 (kt)
Paris (CDG)	10,132
Paris (Orly)	1,805
Nice	466
Lyon	326
Marseille Provence	323
Beauvais	192
Toulouse	182
Bordeaux	91
Nantes	80
Montpellier	21
Strasbourg	20
Carcassonne	19
Lille	15
Biarritz	12
Bergerac	11
Other Airports	126
Total	**13,821**

Destination Airports	CO_2 (kt)
St-Denis de la Reunion	411
New York (JFK)	401
Tokyo (Narita)	386
Hong Kong	290
Shanghai	289
Montreal	287
Pointe-a-Pitre	262
Singapore	258
Sao Paulo	245
Fort de France	242
Los Angeles	238
Dubai	231
Seoul	230
Rio de Janeiro	227
Beijing	196
Other Airports	9,627
Total	**13,821**

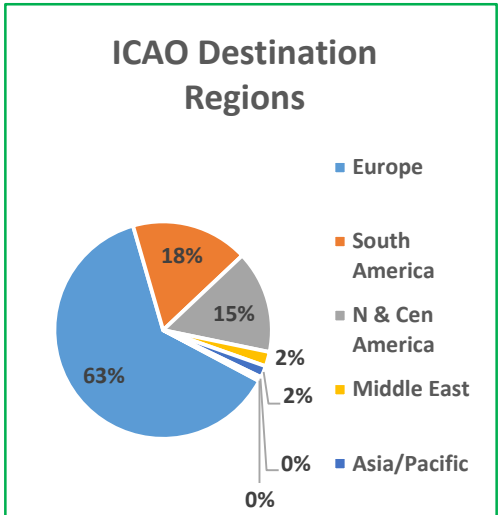
Airlines	CO_2 (kt)
Air France	6,090
Easyjet	439
Corsairfly	365
Delta Air Lines	358
Ryanair	340
American Airlines	213
Air Caraibes	203
Royal Air Maroc	195
Air Austral	186
Japan Airlines	181
Emirates Airline	179
Lufthansa	170
Cathay Pacific	154
Singapore Airlines	145
United Airlines	142
Other Airlines	4,462
Total	**13,821**

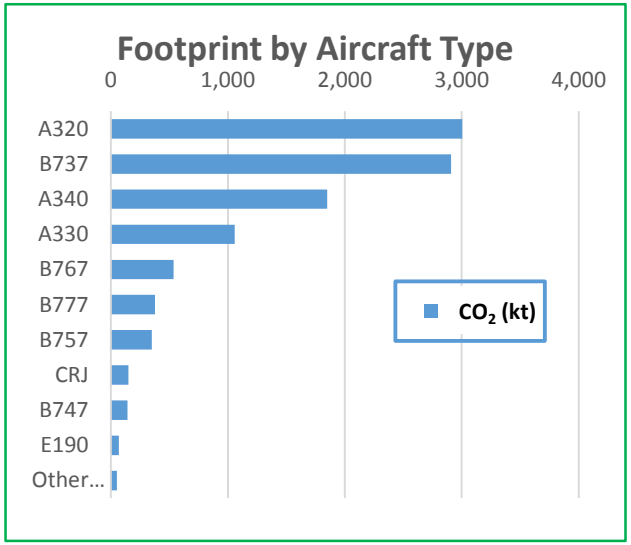
City-Pair Hierarchy	CO_2 (kt)
Paris (CDG)-Tokyo (Narita)	386
Paris (CDG)-New York (JFK)	373
Paris (CDG)-Hong Kong	290
Paris (CDG)-Shanghai	289
Paris (CDG)-Singapore	258
Paris (Orly)-St-Denis de la Reunion	249
Paris (Orly)-Pointe-a-Pitre	248
Paris (CDG)-Sao Paulo	245
Paris (CDG)-Los Angeles	238
Paris (Orly)-Fort de France	233
Paris (CDG)-Montreal	232
Paris (CDG)-Seoul	230
Paris (CDG)-Rio de Janeiro	227
Paris (CDG)-Beijing	196
Paris (CDG)-Mexico City	190
Other Routes	9,935
Total	**13,821**



Spain

Total Footprint = 10,648 kt CO_2



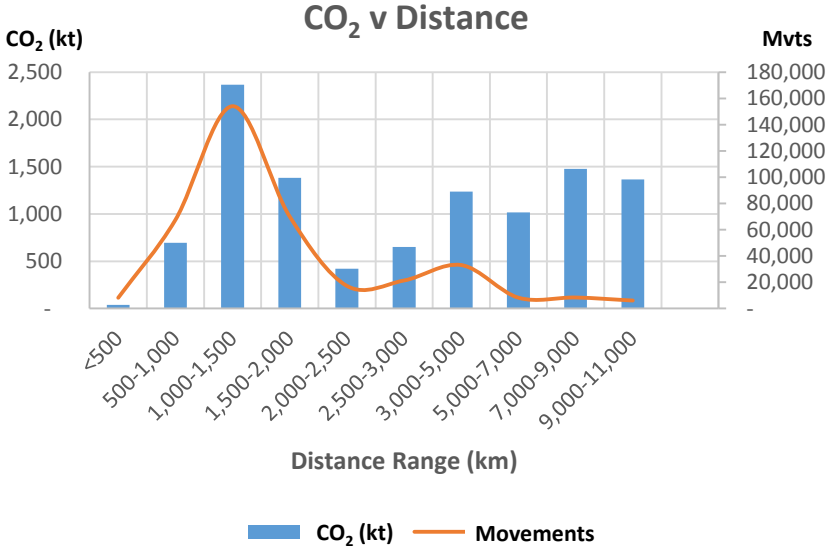


Origin Airports	CO_2 (kt)
Madrid	4,788
Barcelona	1,781
Palma de Mallorca	763
Malaga	682
Granadilla de Abone	512
Alicante	446
Las Palmas	352
Fuerteventura	214
Lanzarote	202
Valencia	178
Eivissa	138
Girona	133
Bilbao	86
Sevilla	84
Murcia	71
Other Airports	218
Total	**10,648**

Destination Airports	CO_2 (kt)
Buenos Aires	398
London (Gatwick)	289
New York (JFK)	263
Sao Paulo	260
Lima	236
Amsterdam	224
Mexico City	217
Bogota	211
Frankfurt	210
Dusseldorf	197
Manchester	189
Santiago de Chile	184
London (Stansted)	178
Miami	170
Roma	166
Other Airports	7,255
Total	**10,648**

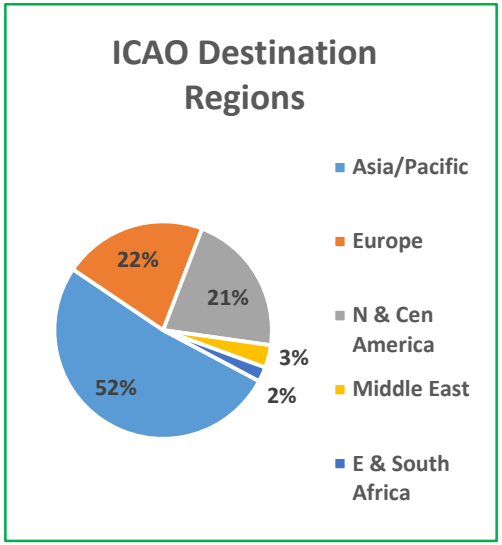
Airlines	CO_2 (kt)
Iberia Airlines	2,166
Ryanair	1,391
Easyjet	712
Air Europa	564
Air Berlin	512
Vueling Airlines	370
LAN Airlines	242
Condor Flugdienst	211
American Airlines	196
Norwegian Air Shuttle	189
Lufthansa	188
TUIfly	188
Avianca - Aerovias Nacionales	184
Monarch Airlines	183
Jet2.com	182
Other Airlines	3,171
Total	**10,648**

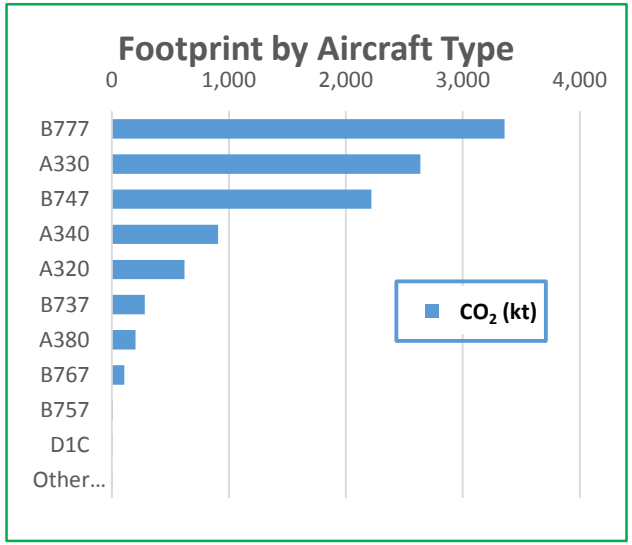
City-Pair Hierarchy	CO_2 (kt)
Madrid-Buenos Aires	340
Madrid-Lima	236
Madrid-Mexico City	214
Madrid-Sao Paulo	209
Madrid-Santiago de Chile	184
Madrid-New York (JFK)	175
Madrid-Bogota	172
Madrid-Miami	131
Madrid-Caracas	130
Madrid-La Habana	115
Madrid-Santo Domingo	104
Madrid-Cancun	89
Madrid-London (Heathrow)	81
Barcelona-New York (JFK)	78
Madrid-Dubai	77
Other Routes	8,313
Total	**10,648**



Hong Kong

Total Footprint = 10,363 kt CO_2



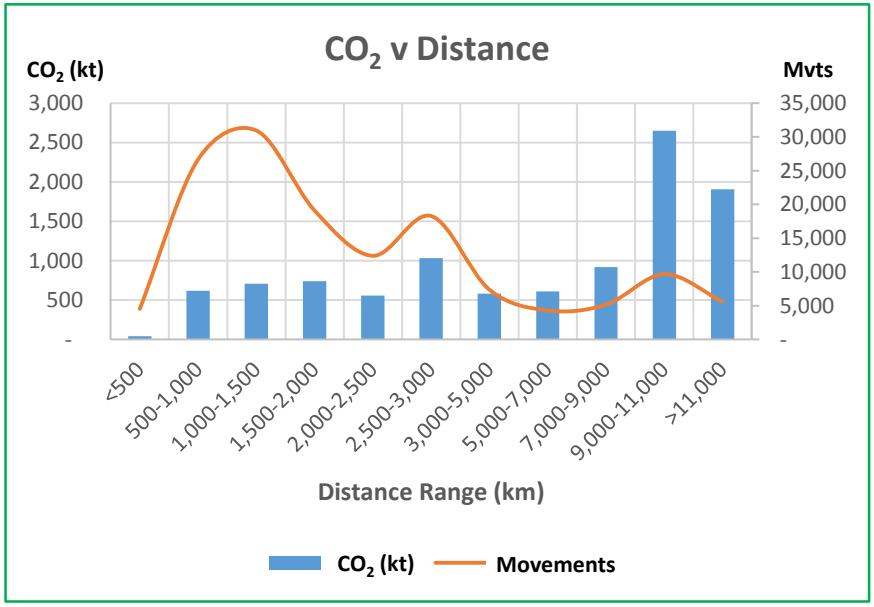


Origin Airports	CO_2 (kt)
Hong Kong	10,363
Other Airports	0
Total	**10,363**

Destination Airports	CO_2 (kt)
London (Heathrow)	843
San Francisco	524
Singapore	451
Taipei	450
Sydney	419
New York (JFK)	348
Bangkok	323
Vancouver	305
Los Angeles	297
Beijing	292
Paris (CDG)	290
Toronto	290
Shanghai	285
Seoul	280
Chicago	280
Other Airports	4,688
Total	**10,363**

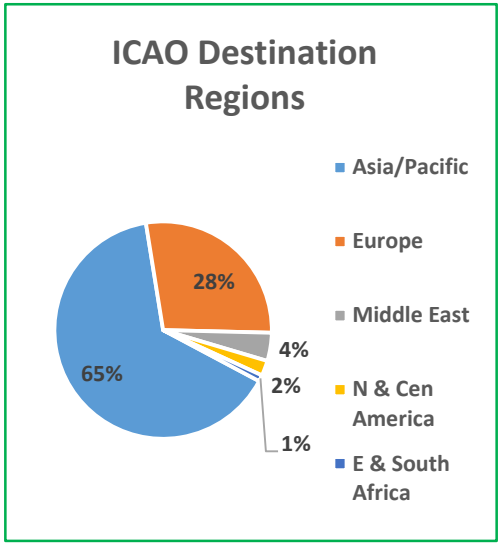
Airlines	CO_2 (kt)
Cathay Pacific	4,824
Dragonair, Hong Kong Dragon	609
United Airlines	429
Singapore Airlines	288
Hong Kong Airlines	286
Qantas	270
British Airways	232
Air Canada	207
Lufthansa	190
China Airlines	174
Air New Zealand	160
Virgin Atlantic Airways	144
Thai Airways International	143
Air France	142
Emirates Airline	133
Other Airlines	2,133
Total	**10,363**

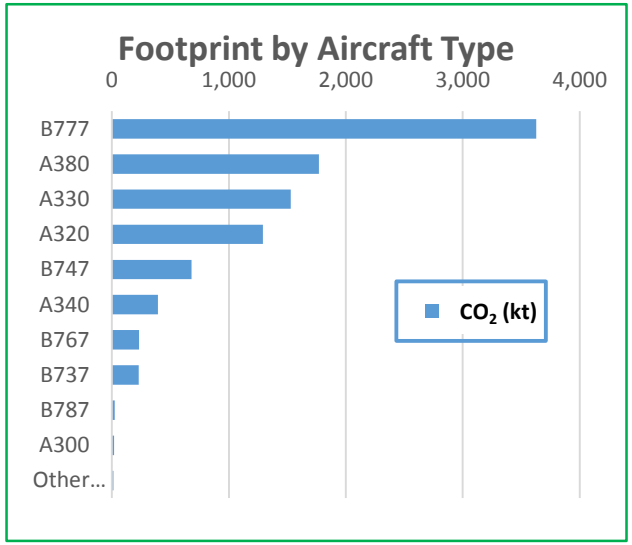
City-Pair Hierarchy	CO_2 (kt)
Hong Kong-London (Heathrow)	843
Hong Kong-San Francisco	524
Hong Kong-Singapore	451
Hong Kong-Taipei	450
Hong Kong-Sydney	419
Hong Kong-New York (JFK)	348
Hong Kong-Bangkok	323
Hong Kong-Vancouver	305
Hong Kong-Los Angeles	297
Hong Kong-Beijing	292
Hong Kong-Paris (CDG)	290
Hong Kong-Toronto	290
Hong Kong-Shanghai	285
Hong Kong-Seoul	280
Hong Kong-Chicago	280
Other Routes	4,688
Total	**10,363**



Singapore

Total Footprint = 9,816 kt CO_2



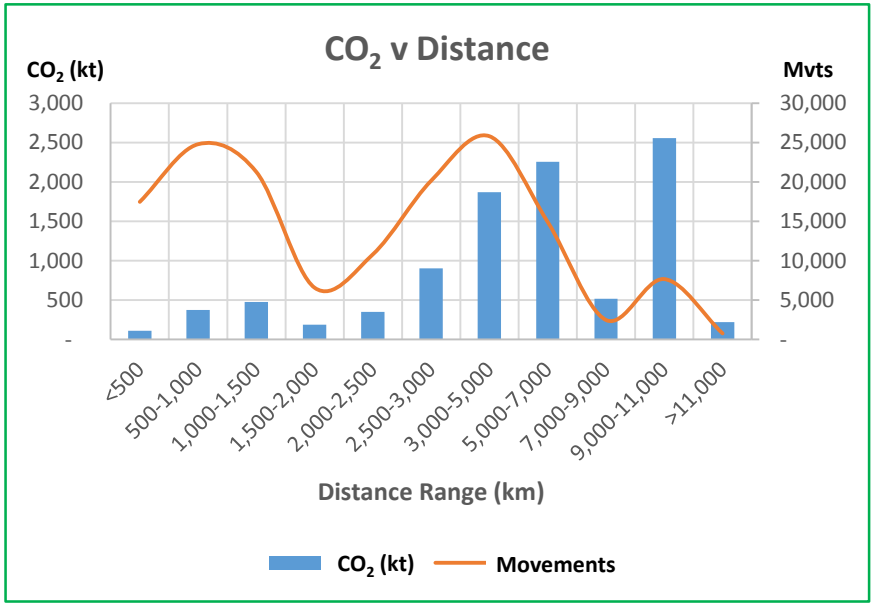


Origin Airports	CO_2 (kt)
Singapore	9,816
Other Airports	0
Total	**9,816**

Destination Airports	CO_2 (kt)
London (Heathrow)	1,015
Sydney	529
Frankfurt	502
Hong Kong	451
Melbourne	376
Tokyo (Narita)	334
Brisbane	295
Seoul	274
Bangkok	263
Paris (CDG)	258
Beijing	256
Shanghai	253
Jakarta	242
Dubai	234
Manila	222
Other Airports	4,313
Total	**9,816**

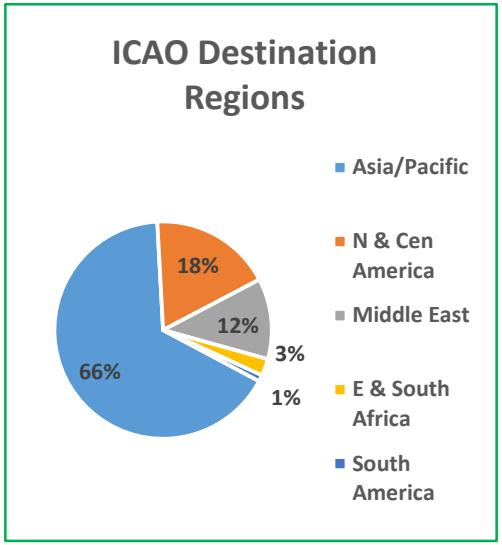
Airlines	CO_2 (kt)
Singapore Airlines	4,726
Qantas	818
British Airways	350
Emirates Airline	299
SilkAir	279
Tiger Airways	271
Cathay Pacific	223
Jetstar Asia Airways	208
Lufthansa	195
Qatar Airways	131
KLM Royal Dutch Airlines	115
Jetstar Airways	113
Air France	113
China Eastern Airlines	112
All Nippon Airways	101
Other Airlines	1,761
Total	**9,816**

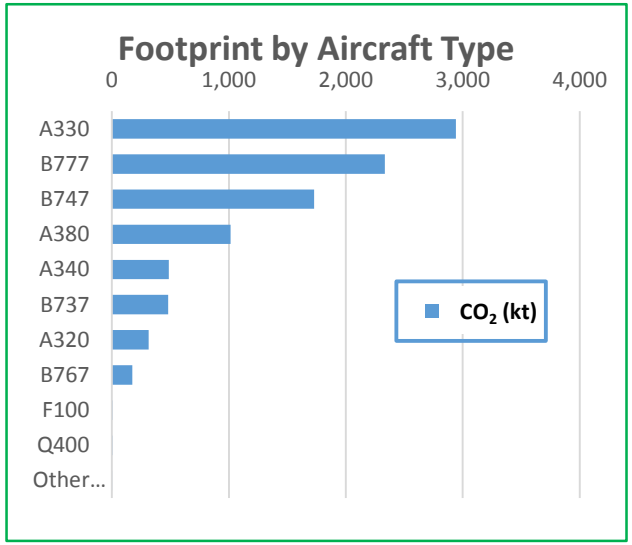
City-Pair Hierarchy	CO_2 (kt)
Singapore-London (Heathrow)	1,015
Singapore-Sydney	529
Singapore-Frankfurt	502
Singapore-Hong Kong	451
Singapore-Melbourne	376
Singapore-Tokyo (Narita)	334
Singapore-Brisbane	295
Singapore-Seoul	274
Singapore-Bangkok	263
Singapore-Paris (CDG)	258
Singapore-Beijing	256
Singapore-Shanghai	253
Singapore-Jakarta	242
Singapore-Dubai	234
Singapore-Manila	222
Other Routes	4,313
Total	**9,816**



Australia

Total Footprint = 9,497 kt CO_2



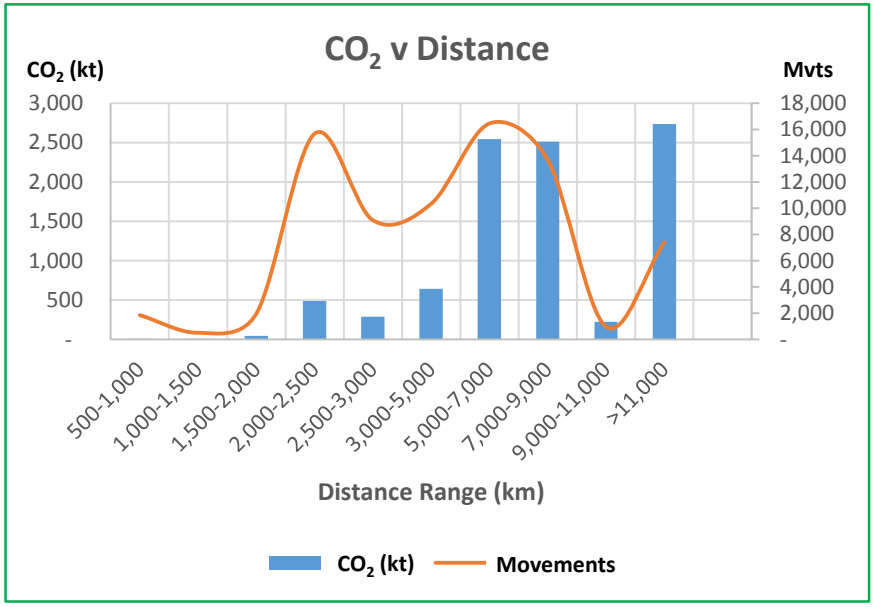


Origin Airports	CO_2 (kt)
Sydney	4,817
Melbourne	2,175
Brisbane	1,160
Perth	853
Coolangatta/Gold C	173
Adelaide	148
Cairns	129
Darwin	40
Port Hedland	1
Maroochydore	<1
Newcastle	<1
Other Airports	0
Total	**9,496**

Destination Airports	CO_2 (kt)
Singapore	1,510
Los Angeles	1,124
Hong Kong	868
Dubai	694
Kuala Lumpur	598
Bangkok	550
Auckland	471
Abu Dhabi	312
Denpasar	284
Tokyo (Narita)	266
Guangzhou	261
Shanghai	256
Seoul	229
Johannesburg	211
San Francisco	160
Other Airports	1,702
Total	**9,497**

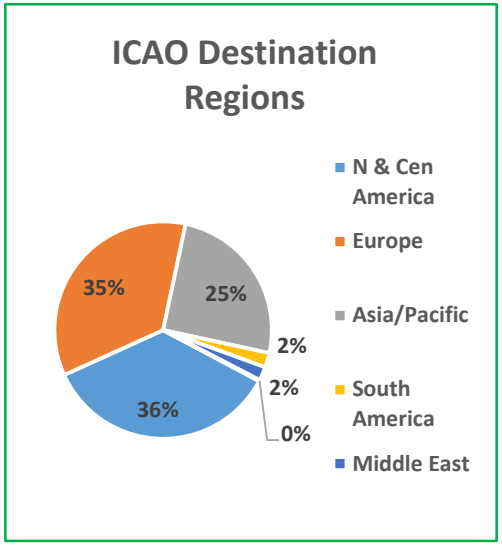
Airlines	CO_2 (kt)
Qantas	2,079
Emirates Airline	1,035
Singapore Airlines	775
Cathay Pacific	564
Virgin Australia	521
Jetstar Airways	488
Thai Airways International	373
Malaysia Airlines	370
United Airlines	325
Etihad Airways	294
Air New Zealand	266
China Southern Airlines	261
AirAsia X	171
Korean Air	159
Garuda Indonesia	153
Other Airlines	1,663
Total	**9,497**

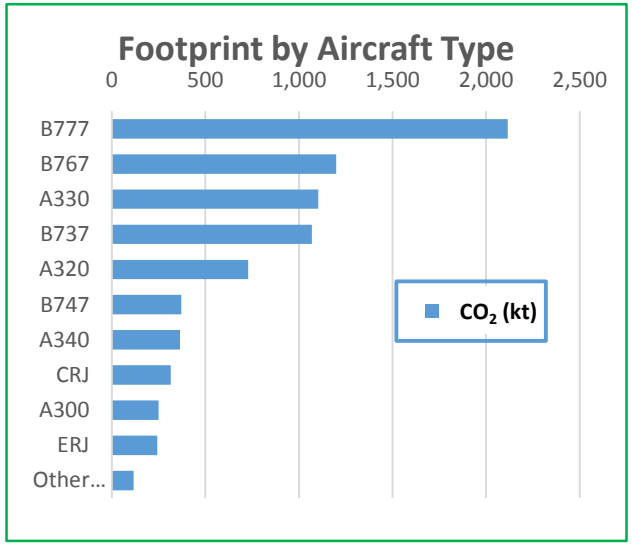
City-Pair Hierarchy	CO_2 (kt)
Sydney-Los Angeles	707
Sydney-Singapore	530
Sydney-Hong Kong	418
Melbourne-Singapore	376
Sydney-Bangkok	314
Brisbane-Singapore	295
Sydney-Dubai	277
Melbourne-Hong Kong	244
Melbourne-Los Angeles	225
Melbourne-Kuala Lumpur	215
Sydney-Abu Dhabi	212
Perth-Singapore	198
Brisbane-Los Angeles	192
Sydney-Kuala Lumpur	181
Perth-Dubai	173
Other Routes	4,940
Total	**9,497**



Canada

Total Footprint = 8,366 kt CO_2



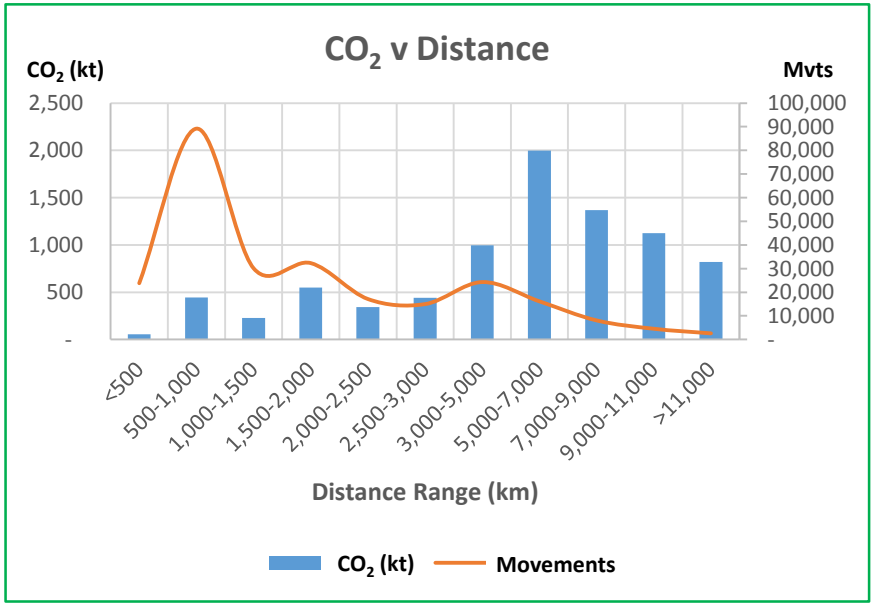


Origin Airports	CO_2 (kt)
Toronto	3,698
Vancouver	2,155
Montreal	1,261
Calgary	620
Edmonton	179
Ottawa	157
Halifax	78
Winnipeg	57
Quebec	53
Regina	24
Saskatoon	24
St. Johns	13
Victoria	12
Kelowna	8
London	6
Other Airports	20
Total	**8,366**

Destination Airports	CO_2 (kt)
London (Heathrow)	758
Hong Kong	595
Frankfurt	418
Paris (CDG)	357
Amsterdam	287
Beijing	254
Shanghai	243
Tokyo (Narita)	226
Chicago	202
Los Angeles	196
Seoul	183
Taipei	173
Cancun	172
Las Vegas	153
San Francisco	127
Other Airports	4,022
Total	**8,366**

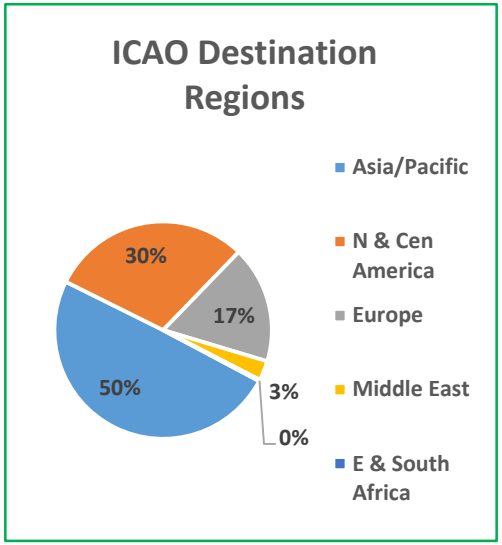
Airlines	CO_2 (kt)
Air Canada	3,080
WestJet	588
Air Transat	558
Cathay Pacific	425
United Airlines	392
British Airways	312
KLM Royal Dutch Airlines	261
American Airlines	219
Sunwing Airlines	209
Lufthansa	183
Air France	174
Delta Air Lines	148
Korean Air	131
EVA Air	104
US Airways	104
Other Airlines	1,477
Total	**8,366**

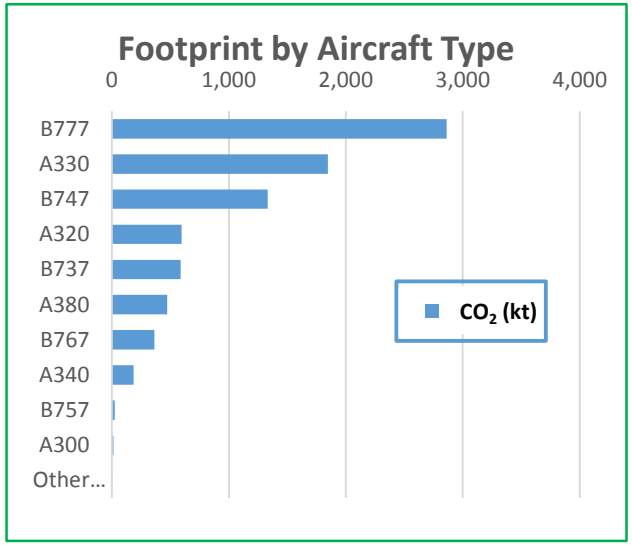
City-Pair Hierarchy	CO_2 (kt)
Vancouver-Hong Kong	305
Toronto-Hong Kong	290
Toronto-London (Heathrow)	277
Montreal-Paris (CDG)	230
Vancouver-London (Heathrow)	206
Toronto-Frankfurt	170
Vancouver-Shanghai	136
Toronto-Beijing	130
Vancouver-Taipei	124
Vancouver-Beijing	124
Vancouver-Sydney	120
Vancouver-Seoul	114
Toronto-Amsterdam	109
Toronto-Shanghai	107
Toronto-Paris (CDG)	107
Other Routes	5,817
Total	**8,366**



South Korea

Total Footprint = 8,292 kt CO_2



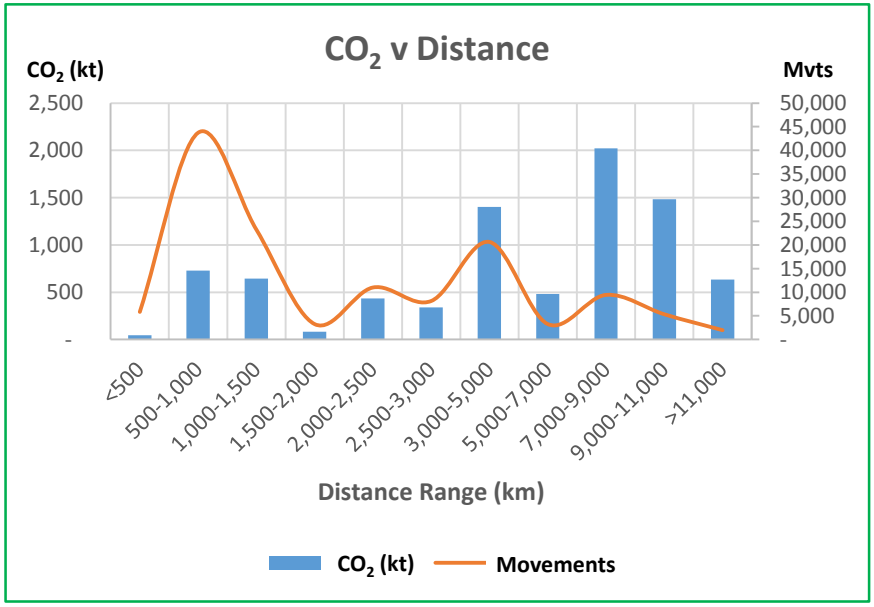


Origin Airports	CO_2 (kt)
Seoul	7,919
Busan	316
Keku	45
Daegu	6
Cheong Ju	6
Yangyang	<1
Yeosu	<1
Other Airports	0
Total	**8,292**

Destination Airports	CO_2 (kt)
Los Angeles	541
Bangkok	374
San Francisco	368
New York (JFK)	367
Hong Kong	307
Singapore	275
Frankfurt	270
Paris (CDG)	230
Honolulu	224
Tokyo (Narita)	216
London (Heathrow)	193
Manila	187
Tokyo (Haneda)	183
Atlanta	163
Chicago	163
Other Airports	4,231
Total	**8,292**

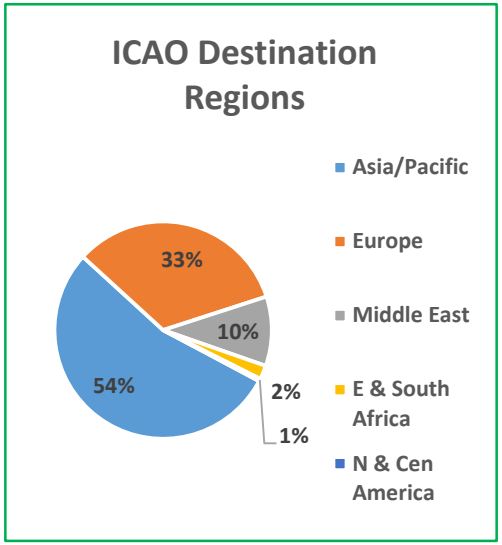
Airlines	CO_2 (kt)
Korean Air	3,859
Asiana Airlines	1,757
Singapore Airlines	230
Thai Airways International	184
United Airlines	131
Lufthansa	125
KLM Royal Dutch Airlines	106
Cathay Pacific	105
Delta Air Lines	100
Jeju Air	89
Vietnam Airlines	87
Emirates Airline	81
Air France	81
China Eastern Airlines	78
Philippine Airlines	74
Other Airlines	1,204
Total	**8,292**

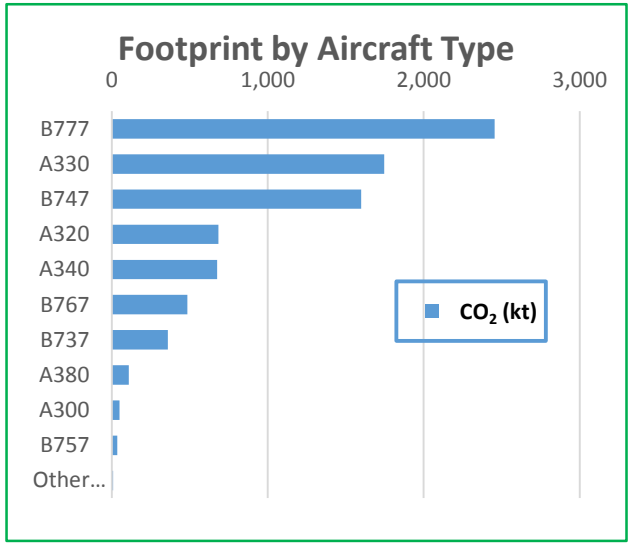
City-Pair Hierarchy	CO_2 (kt)
Seoul-Los Angeles	541
Seoul-San Francisco	368
Seoul-New York (JFK)	367
Seoul-Bangkok	315
Seoul-Hong Kong	280
Seoul-Singapore	274
Seoul-Frankfurt	270
Seoul-Paris (CDG)	230
Seoul-Honolulu	224
Seoul-London (Heathrow)	193
Seoul-Tokyo (Haneda)	183
Seoul-Tokyo (Narita)	177
Seoul-Manila	164
Seoul-Atlanta	163
Seoul-Chicago	163
Other Routes	4,380
Total	**8,292**



Thailand

Total Footprint = 8,209 kt CO_2



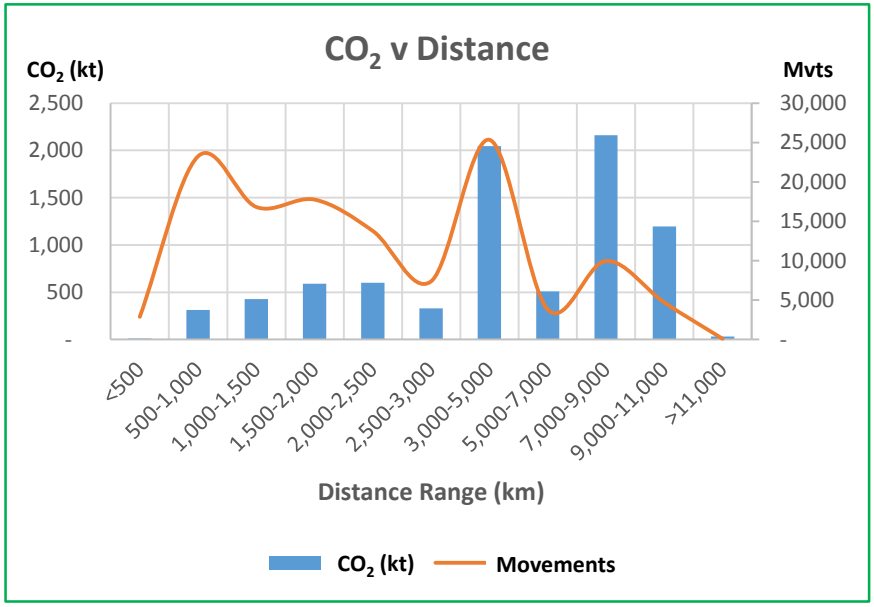


Origin Airports	CO_2 (kt)
Bangkok	7,583
Phuket	533
Chiang Mai	49
Koh Samui	25
Krabi	9
Hatyai	8
Surat Thani	2
Chiang Rai	<1
Hua Hin	<1
Other Airports	0
Total	**8,208**

Destination Airports	CO_2 (kt)
Seoul	433
London (Heathrow)	402
Hong Kong	388
Tokyo (Narita)	350
Sydney	342
Singapore	334
Frankfurt	311
Moscow	246
Dubai	240
Amsterdam	228
Kuala Lumpur	194
Copenhagen	190
Paris (CDG)	177
Taipei	175
Zurich	166
Other Airports	4,032
Total	**8,209**

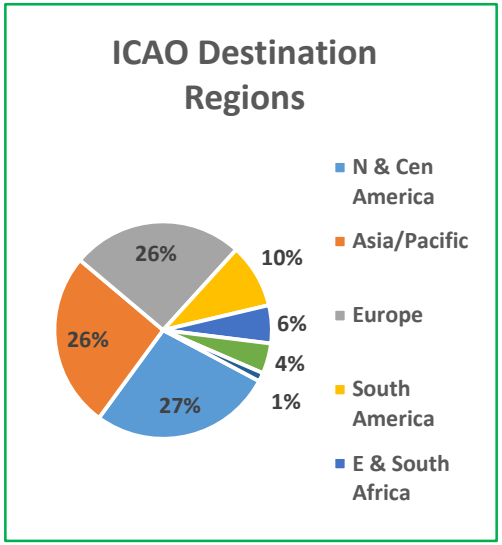
Airlines	CO_2 (kt)
Thai Airways International	3,078
Emirates Airline	294
Thai AirAsia	201
Transaero Airlines	197
China Airlines	188
Korean Air	185
EVA Air	180
Qatar Airways	178
Cathay Pacific	178
British Airways	142
Japan Airlines	127
Lufthansa	126
Etihad Airways	123
Turkish Airlines	117
KLM Royal Dutch Airlines	101
Other Airlines	2,795
Total	**8,209**

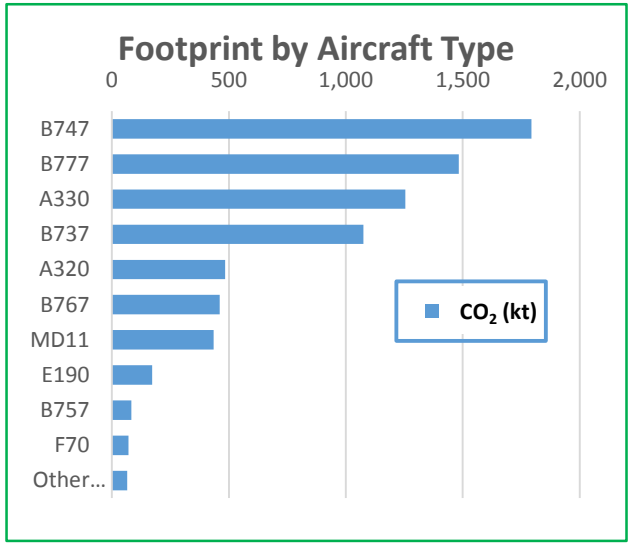
City-Pair Hierarchy	CO_2 (kt)
Bangkok-London (Heathrow)	402
Bangkok-Tokyo (Narita)	350
Bangkok-Hong Kong	322
Bangkok-Seoul	315
Bangkok-Sydney	314
Bangkok-Frankfurt	306
Bangkok-Singapore	264
Bangkok-Dubai	237
Bangkok-Amsterdam	228
Bangkok-Copenhagen	190
Bangkok-Paris (CDG)	174
Bangkok-Taipei	169
Bangkok-Zurich	155
Bangkok-Moscow	154
Bangkok-Melbourne	146
Other Routes	4,483
Total	**8,209**



Netherlands

Total Footprint = 7,539 kt CO_2



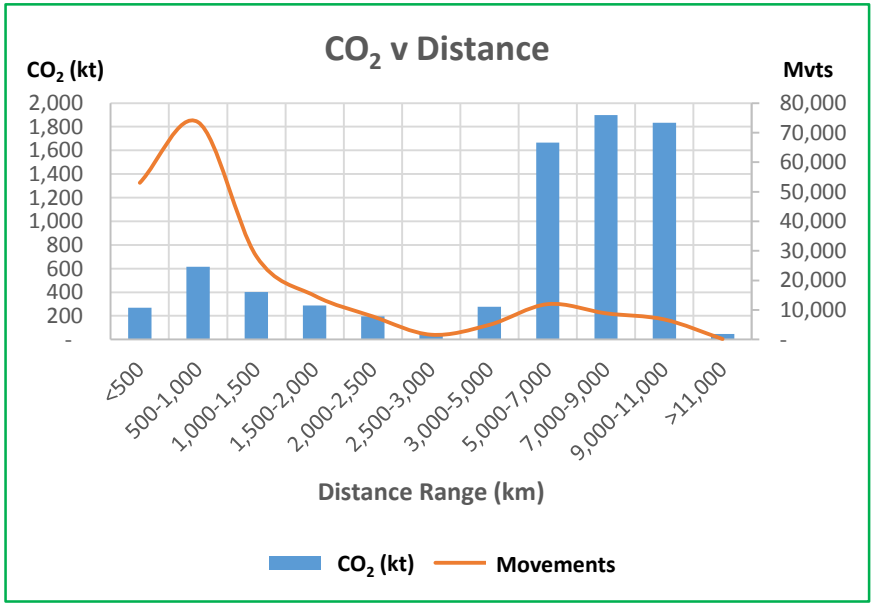


Origin Airports	CO_2 (kt)
Amsterdam	7,300
Eindhoven	153
Rotterdam	60
Maastricht	21
Groningen	5
Other Airports	0
Total	**7,539**

Destination Airports	CO_2 (kt)
Bangkok	228
Hong Kong	228
Kuala Lumpur	207
Singapore	197
Shanghai	188
Detroit	177
Atlanta	173
New York (JFK)	165
Beijing	159
Houston	155
Tokyo (Narita)	150
Dubai	145
Seoul	137
Nairobi	135
Minneapolis	129
Other Airports	4,969
Total	**7,539**

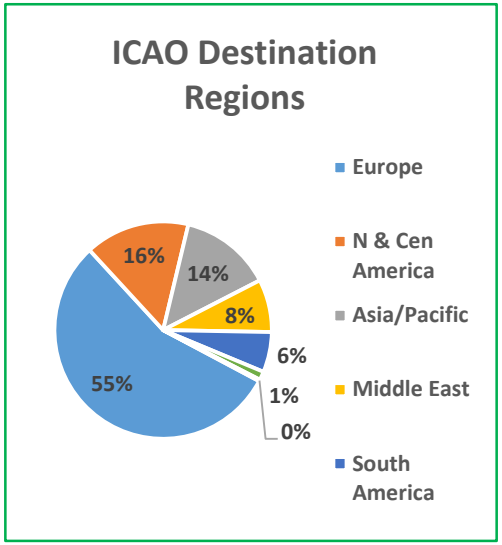
Airlines	CO_2 (kt)
KLM Royal Dutch Airlines	4,458
Delta Air Lines	743
Transavia	306
Easyjet	124
Arkefly	121
United Airlines	120
China Southern Airlines	119
Cathay Pacific	113
China Airlines	103
Malaysia Airlines	101
Ryanair	99
Singapore Airlines	98
Air France	57
Emirates Airline	55
Kenya Airways	51
Other Airlines	870
Total	**7,539**

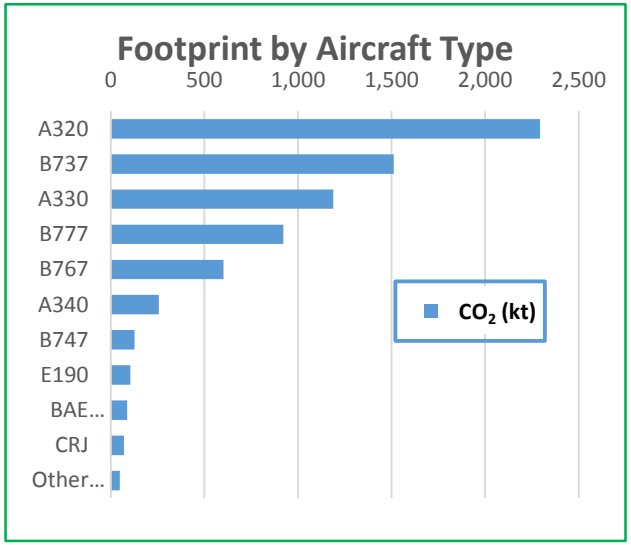
City-Pair Hierarchy	CO_2 (kt)
Amsterdam-Bangkok	228
Amsterdam-Hong Kong	228
Amsterdam-Kuala Lumpur	207
Amsterdam-Singapore	197
Amsterdam-Shanghai	188
Amsterdam-Detroit	177
Amsterdam-Atlanta	173
Amsterdam-New York (JFK)	165
Amsterdam-Beijing	159
Amsterdam-Houston	155
Amsterdam-Tokyo (Narita)	150
Amsterdam-Dubai	145
Amsterdam-Seoul	137
Amsterdam-Nairobi	135
Amsterdam-Minneapolis	129
Other Routes	4,969
Total	**7,539**



Italy

Total Footprint = 7,488 kt CO_2



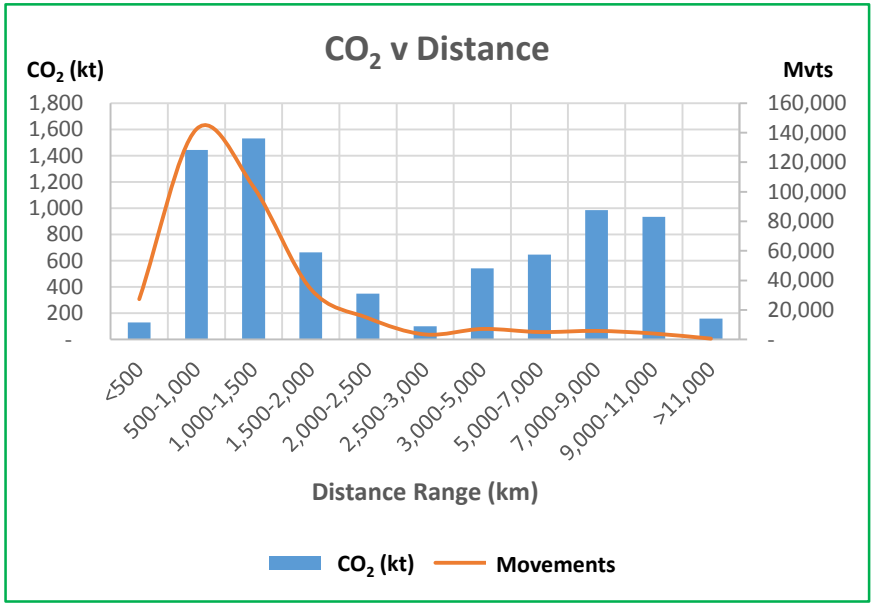


Origin Airports	CO_2 (kt)
Roma	3,422
Milano	1,944
Venezia	463
Bergamo	302
Bologna	240
Pisa	168
Napoli	144
Treviso	95
Firenze	91
Verona	85
Torino	75
Catania	68
Palermo	54
Bari	53
Cagliari	34
Other Airports	252
Total	**7,488**

Destination Airports	CO_2 (kt)
New York (JFK)	346
Dubai	266
Paris (CDG)	257
Madrid	218
London (Gatwick)	195
Sao Paulo	173
Tokyo (Narita)	173
Buenos Aires	159
Hong Kong	153
London (Heathrow)	147
Amsterdam	140
Barcelona	140
London (Stansted)	139
Frankfurt	138
Beijing	133
Other Airports	4,709
Total	**7,488**

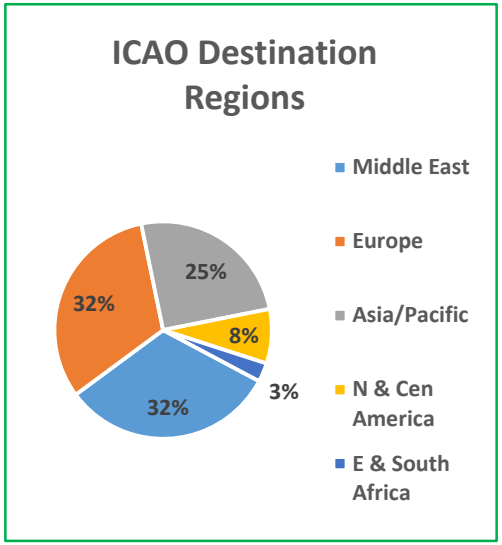
Airlines	CO_2 (kt)
Alitalia	1,399
Ryanair	858
Easyjet	455
Emirates Airline	266
Lufthansa	249
Delta Air Lines	244
Air France	194
British Airways	179
Air China	154
Cathay Pacific	153
Singapore Airlines	133
Wizz Air	115
Qatar Airways	112
Air Berlin	110
Thai Airways International	105
Other Airlines	2,764
Total	**7,488**

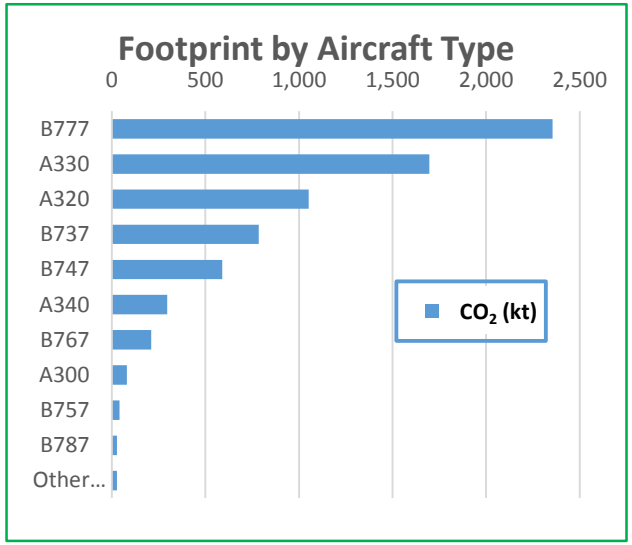
City-Pair Hierarchy	CO_2 (kt)
Roma-New York (JFK)	180
Roma-Buenos Aires	159
Roma-Tokyo (Narita)	122
Milano-New York (JFK)	115
Milano-Dubai	108
Roma-Beijing	107
Roma-Washington	104
Roma-Sao Paulo	98
Roma-Toronto	97
Roma-Dubai	93
Milano-Singapore	92
Milano-Hong Kong	87
Milano-Sao Paulo	76
Roma-Madrid	74
Roma-London (Heathrow)	69
Other Routes	5,908
Total	**7,488**



India

Total Footprint = 7,182 kt CO_2



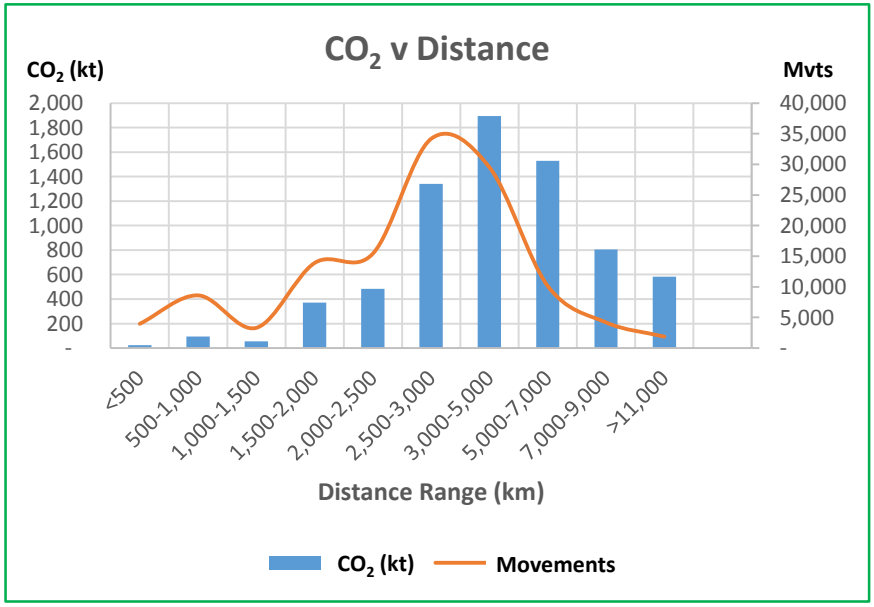


Origin Airports	CO_2 (kt)
Delhi	2,503
Mumbai	2,083
Chennai/Madras	617
Bangalore	499
Cochin	300
Hyderabad	256
Calicut	234
Trivandrum	203
Kolkata	143
Ahmedabad	59
Goa	59
Tiruchirapally	57
Lucknow	40
Amritsar	36
Mangalore	28
Other Airports	66
Total	**7,182**

Destination Airports	CO_2 (kt)
London (Heathrow)	887
Dubai	843
Singapore	540
Frankfurt	370
Bangkok	344
Newark	326
Hong Kong	251
Doha	239
Paris (CDG)	227
Kuala Lumpur	203
Sharjah	203
Riyadh	196
Muscat	171
Brussels	161
Abu Dhabi	143
Other Airports	2,077
Total	**7,182**

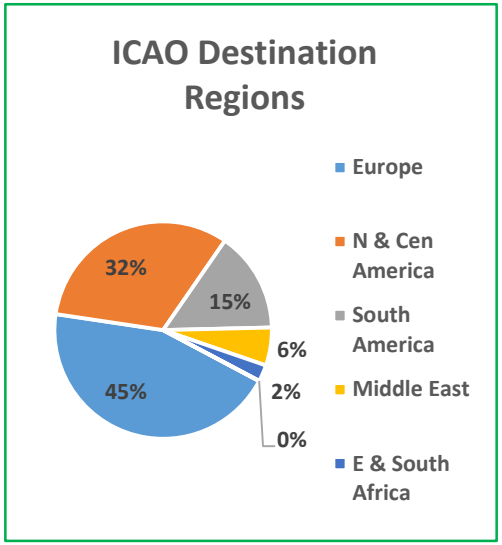
Airlines	CO_2 (kt)
Air India	1,099
Jet Airways	900
Emirates Airline	607
British Airways	469
Lufthansa	424
Singapore Airlines	253
Qatar Airways	201
Air India Express	189
Saudi Arabian Airlines	175
Thai Airways International	167
United Airlines	166
Air France	164
Air Arabia	136
Cathay Pacific	135
Malaysia Airlines	133
Other Airlines	1,962
Total	**7,182**

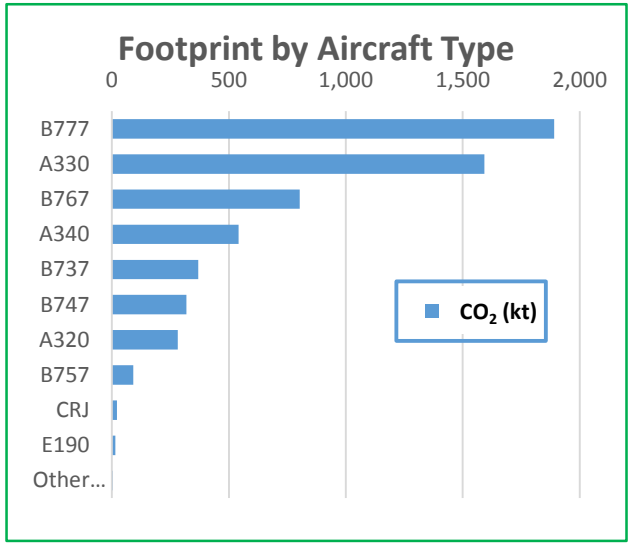
City-Pair Hierarchy	CO_2 (kt)
Mumbai-London (Heathrow)	354
Delhi-London (Heathrow)	352
Mumbai-Newark	217
Mumbai-Singapore	166
Mumbai-Dubai	155
Delhi-Singapore	140
Delhi-Dubai	130
Delhi-Frankfurt	128
Delhi-Bangkok	121
Delhi-Paris (CDG)	119
Mumbai-Bangkok	114
Delhi-Chicago	112
Delhi-Newark	109
Delhi-Hong Kong	104
Chennai/Madras-Dubai	100
Other Routes	4,761
Total	**7,182**



Brazil

Total Footprint = 5,932 kt CO_2



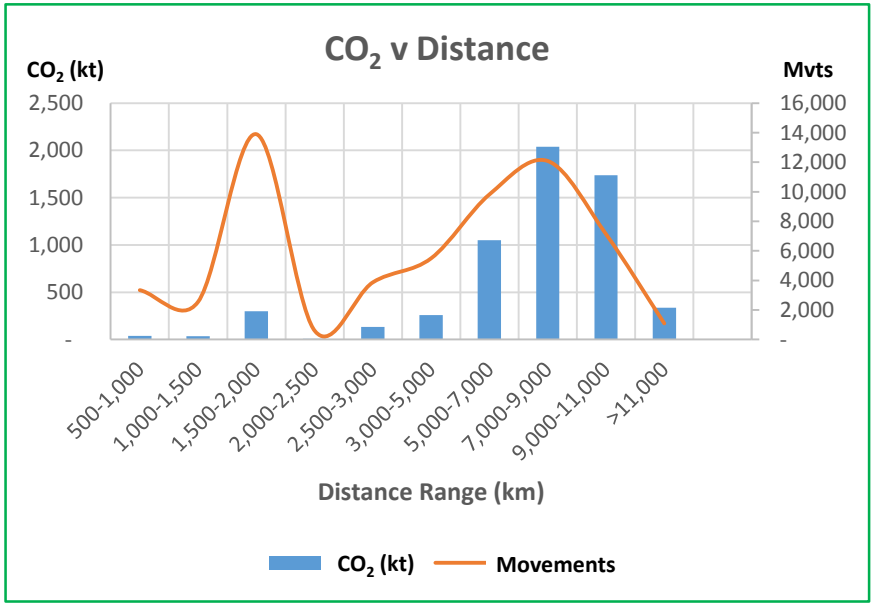


Origin Airports	CO_2 (kt)
Sao Paulo	3,783
Rio de Janeiro	1,429
Brasilia	156
Belo Horizonte	120
Porto Alegre	95
Salvador	92
Recife	86
Fortaleza	45
Manaus	39
Natal	29
Campinas	26
Florianopolis	8
Iguassu Falls	8
Curitiba	7
Belem	3
Other Airports	5
Total	**5,932**

Destination Airports	CO_2 (kt)
Miami	545
Lisboa	522
Paris (CDG)	472
New York (JFK)	368
Frankfurt	353
London (Heathrow)	315
Madrid	295
Buenos Aires	278
Dubai	225
Panama City	178
Roma	156
Amsterdam	131
Atlanta	130
Mexico City	129
Orlando	120
Other Airports	1,716
Total	**5,932**

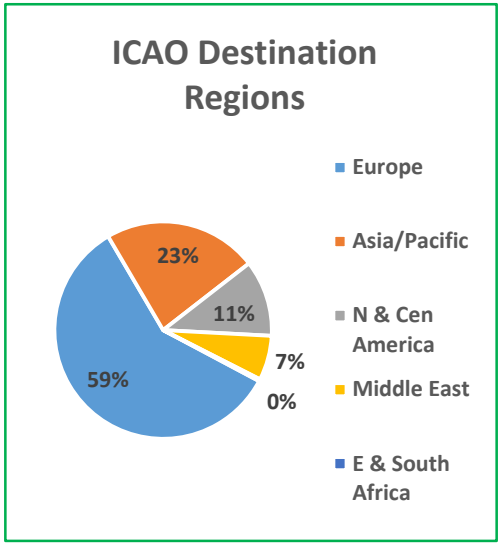
Airlines	CO_2 (kt)
TAM Airlines (TAM Linhas Aer	1,275
American Airlines	582
TAP Portugal	561
Air France	345
Lufthansa	277
United Airlines	263
Emirates Airline	246
Delta Air Lines	232
Iberia Airlines	202
British Airways	195
Copa Airlines	165
Alitalia	152
LAN Airlines	143
Gol Transportes Aéreos	136
KLM Royal Dutch Airlines	131
Other Airlines	1,028
Total	**5,932**

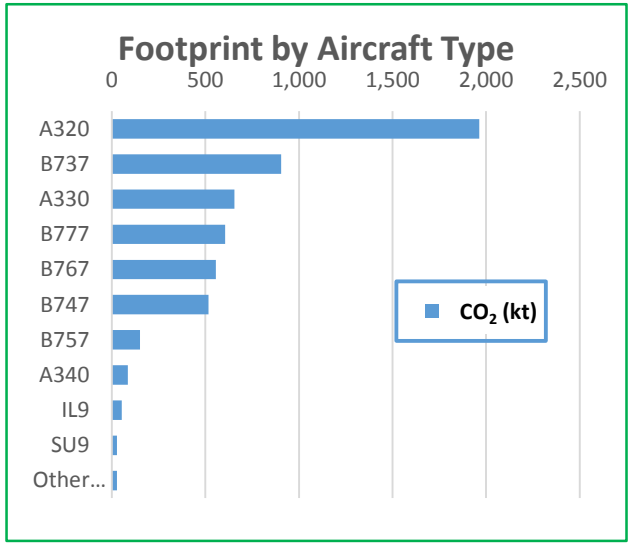
City-Pair Hierarchy	CO_2 (kt)
Sao Paulo-Miami	286
Sao Paulo-New York (JFK)	260
Sao Paulo-Paris (CDG)	245
Rio de Janeiro-Paris (CDG)	227
Sao Paulo-Frankfurt	218
Sao Paulo-London (Heathrow)	211
Sao Paulo-Madrid	209
Sao Paulo-Buenos Aires	163
Sao Paulo-Mexico City	129
Sao Paulo-Dubai	115
Rio de Janeiro-Frankfurt	114
Sao Paulo-Doha	111
Rio de Janeiro-Dubai	110
Sao Paulo-Orlando	110
Rio de Janeiro-New York (JFK)	108
Other Routes	3,317
Total	**5,932**



Russia

Total Footprint = 5,736 kt CO_2



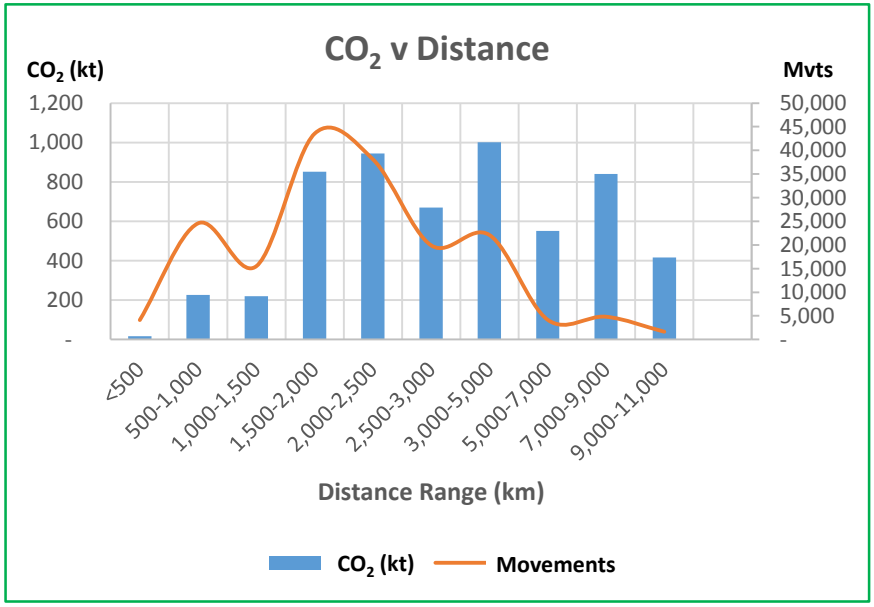


Origin Airports	CO_2 (kt)
Moscow	4,512
St. Petersburg	539
Yekaterinburg	157
Novosibirsk	97
Rostov Na Donu	39
Kazan	39
Krasnodar	38
Samara	38
Krasnoyarsk	31
Vladivostok	29
Irkutsk	21
Khabarovsk	21
Ufa	20
Sochi	19
Surgut	17
Other Airports	119
Total	**5,736**

Destination Airports	CO_2 (kt)
Beijing	231
Bangkok	198
New York (JFK)	193
Dubai	156
Frankfurt	133
London (Heathrow)	133
Tashkent	129
Yerevan	116
Higuey	114
Shanghai	111
Paris (CDG)	111
Dushanbe	111
Tel Aviv	111
Seoul	106
Phuket	102
Other Airports	3,681
Total	**5,736**

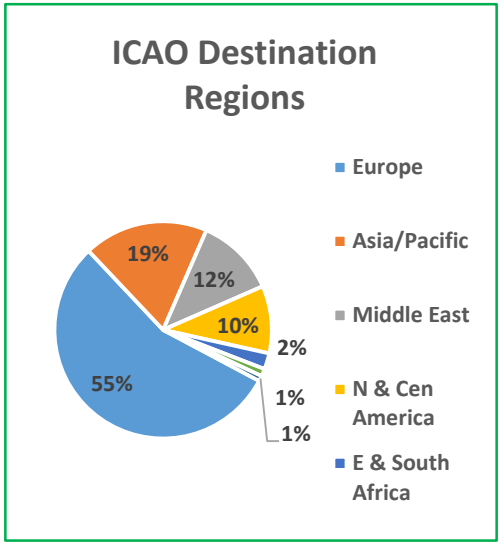
Airlines	CO_2 (kt)
Aeroflot Russian Airlines	1,583
Transaero Airlines	1,088
S7 Airlines (Siberia Airlines)	243
Rossiya - Russian Airlines	210
Lufthansa	151
Uzbekistan Airways	127
Singapore Airlines	122
UTair Aviation	114
Emirates Airline	102
Ural Airlines	98
Turkish Airlines	71
British Airways	71
Air France	62
Czech Airlines	60
Aerosvit Airlines	59
Other Airlines	1,576
Total	**5,736**

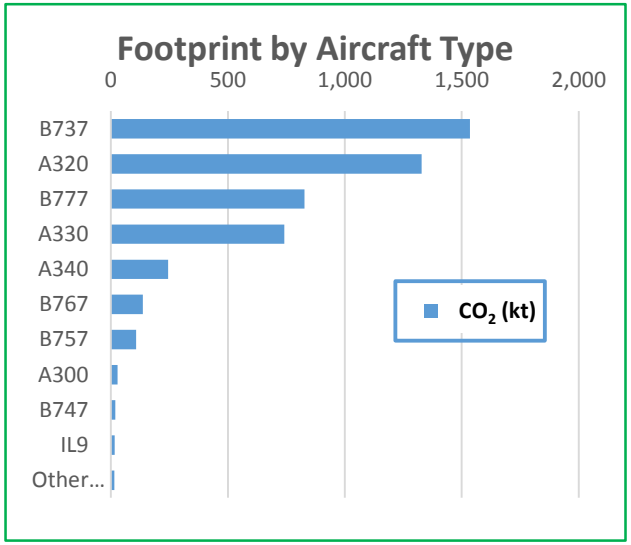
City-Pair Hierarchy	CO_2 (kt)
Moscow-New York (JFK)	193
Moscow-Beijing	166
Moscow-Bangkok	155
Moscow-London (Heathrow)	125
Moscow-Shanghai	111
Moscow-Higuey	107
Moscow-Dubai	93
Moscow-Phuket	92
Moscow-Paris (CDG)	90
Moscow-Tokyo (Narita)	89
Moscow-Tel Aviv	85
Moscow-Frankfurt	84
Moscow-Hong Kong	82
Moscow-Yerevan	80
Moscow-Hurghada	78
Other Routes	4,106
Total	**5,736**



Turkey

Total Footprint = 5,026 kt CO_2



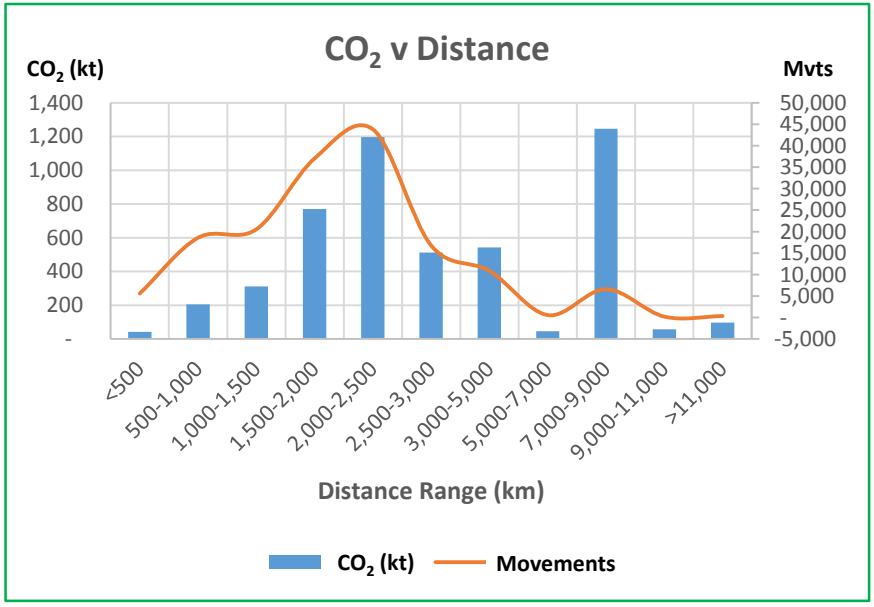


Origin Airports	CO_2 (kt)
Istanbul	4,146
Antalya	434
Ankara	117
Izmir	112
Dalaman	99
Bodrum	40
Adana	27
Kayseri	15
Gaziantep	9
Hatay	7
Trabzon	5
Anadolu	4
Samsun	4
Konya	2
Zonguldak	1
Other Airports	5
Total	**5,026**

Destination Airports	CO_2 (kt)
New York (JFK)	201
Dusseldorf	137
Seoul	134
Frankfurt	130
Singapore	126
Munich	116
Bangkok	107
Amsterdam	100
London (Heathrow)	100
Moscow	97
Los Angeles	97
Dubai	95
Ercan	94
Stuttgart	89
Tokyo (Narita)	80
Other Airports	3,323
Total	**5,026**

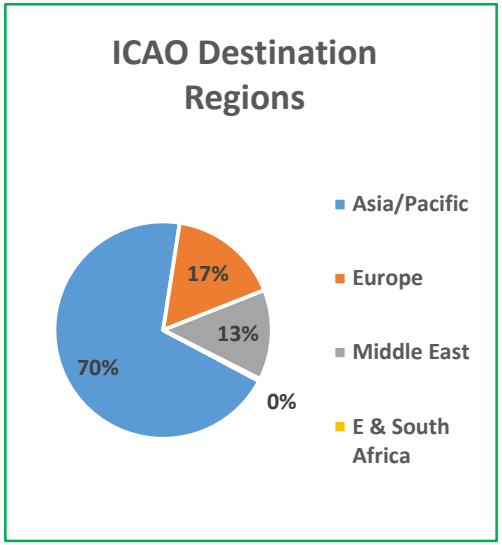
Airlines	CO_2 (kt)
Turkish Airlines	3,023
Pegasus Airlines	288
SunExpress	175
Air Berlin	80
Condor Flugdienst	78
Lufthansa	75
Air Mali International	71
Singapore Airlines	58
TUIfly	56
Aeroflot Russian Airlines	48
Emirates Airline	45
Easyjet	44
Delta Air Lines	42
Saudi Arabian Airlines	41
Atlasjet	41
Other Airlines	860
Total	**5,026**

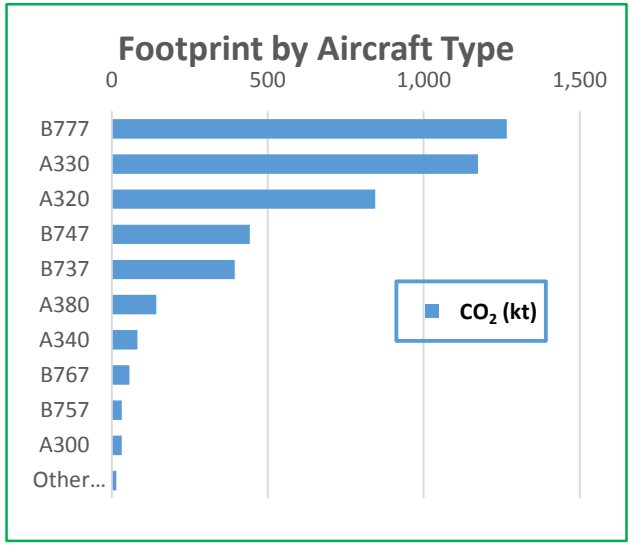
City-Pair Hierarchy	CO_2 (kt)
Istanbul-New York (JFK)	201
Istanbul-Seoul	134
Istanbul-Singapore	126
Istanbul-Bangkok	107
Istanbul-London (Heathrow)	100
Istanbul-Los Angeles	97
Istanbul-Dubai	95
Istanbul-Tokyo (Narita)	80
Istanbul-Paris (CDG)	79
Istanbul-Shanghai	73
Istanbul-Amsterdam	73
Istanbul-Chicago	71
Istanbul-Washington	68
Istanbul-Tehran	68
Istanbul-Hong Kong	64
Other Routes	3,591
Total	**5,026**



Malaysia

Total Footprint = 4,494 kt CO_2



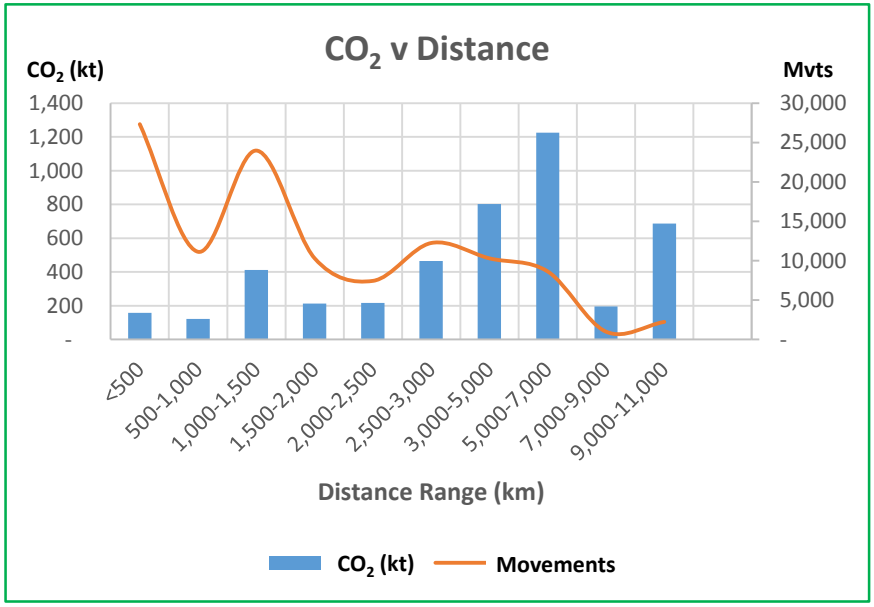


Origin Airports	CO_2 (kt)
Kuala Lumpur	4,237
George Town	127
Kota-Kinabalu	97
Kuching	20
Langkawi	6
Miri	3
Ipoh	2
Johor Bahru	<1
Kuantan	<1
Pulau Tioman	<1
Batu Berendam	<1
Kuala Terengganu	<1
Kota Bharu	<1
Tawau	<1
Other Airports	0
Total	**4,492**

Destination Airports	CO_2 (kt)
London (Heathrow)	282
Hong Kong	230
Melbourne	215
Amsterdam	206
Singapore	185
Sydney	181
Dubai	180
Bangkok	145
Seoul	140
Jakarta	136
Taipei	130
Doha	119
Tokyo (Narita)	111
Paris (CDG)	96
Beijing	94
Other Airports	2,043
Total	**4,494**

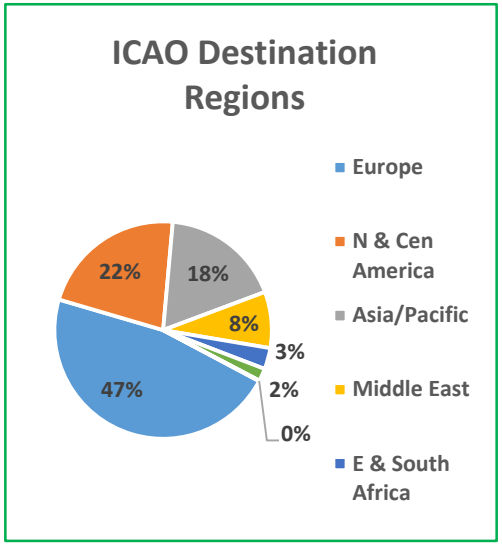
Airlines	CO_2 (kt)
Malaysia Airlines	1,844
AirAsia	526
AirAsia X	457
Emirates Airline	230
Qatar Airways	129
KLM Royal Dutch Airlines	119
Cathay Pacific	118
Indonesia AirAsia	97
Saudi Arabian Airlines	72
Iran Air	57
Korean Air	50
Etihad Airways	49
China Airlines	49
SilkAir	42
Oman Air	42
Other Airlines	613
Total	**4,494**

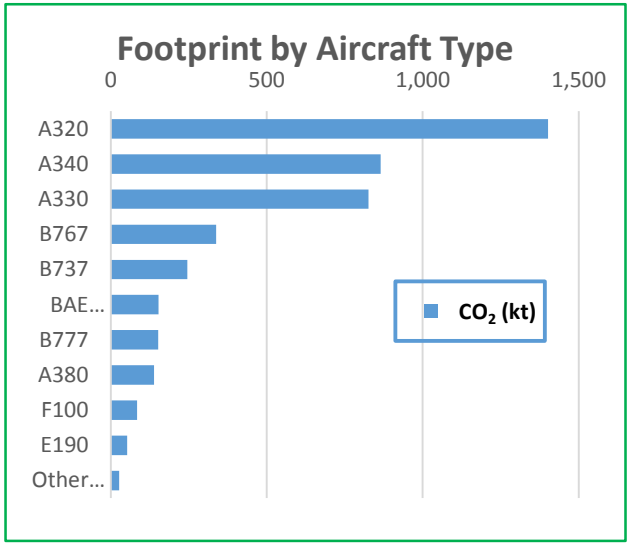
City-Pair Hierarchy	CO_2 (kt)
Kuala Lumpur-London (Heathrow)	282
Kuala Lumpur-Melbourne	215
Kuala Lumpur-Amsterdam	206
Kuala Lumpur-Sydney	181
Kuala Lumpur-Dubai	180
Kuala Lumpur-Hong Kong	166
Kuala Lumpur-Bangkok	136
Kuala Lumpur-Jakarta	124
Kuala Lumpur-Seoul	121
Kuala Lumpur-Doha	119
Kuala Lumpur-Tokyo (Narita)	111
Kuala Lumpur-Taipei	108
Kuala Lumpur-Singapore	106
Kuala Lumpur-Paris (CDG)	96
Kuala Lumpur-Beijing	94
Other Routes	2,247
Total	**4,494**



Switzerland

Total Footprint = 4,397 kt CO_2



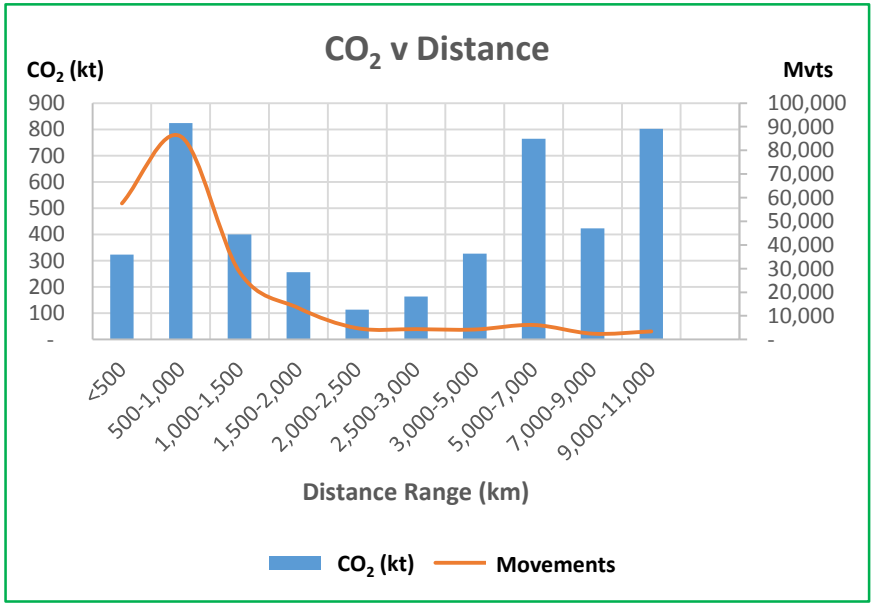


Origin Airports	CO_2 (kt)
Zurich	3,120
Geneva	993
Basel	259
Bern	15
St. Gallen - Altenrhei	7
Lugano	2
Sion	<1
Other Airports	0
Total	**4,397**

Destination Airports	CO_2 (kt)
New York (JFK)	202
Dubai	170
Bangkok	155
Singapore	138
London (Heathrow)	134
Newark	121
Tokyo (Narita)	88
Tel Aviv	85
Sao Paulo	82
Istanbul	81
Madrid	80
Hong Kong	79
Los Angeles	78
Beijing	77
Montreal	77
Other Airports	2,749
Total	**4,397**

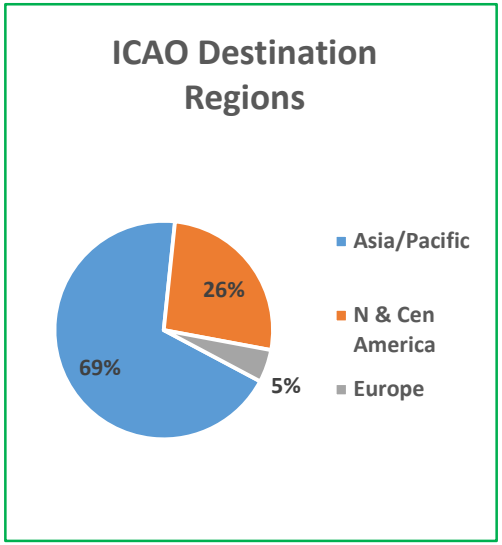
Airlines	CO_2 (kt)
Swiss European Air Lines	2,001
Easyjet	320
United Airlines	143
Singapore Airlines	138
Edelweiss Air	138
Emirates Airline	132
Lufthansa	97
Air Berlin	86
British Airways	85
Thai Airways International	78
Air Canada	67
Easyjet Switzerland	61
Qatar Airways	60
Delta Air Lines	52
TAP Portugal	51
Other Airlines	887
Total	**4,397**

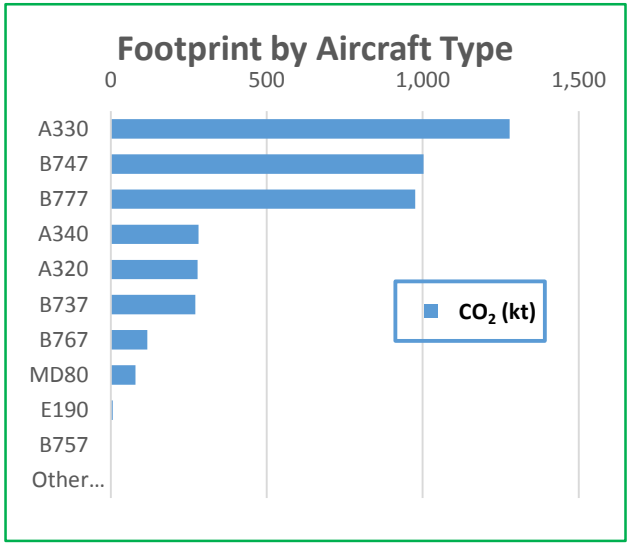
City-Pair Hierarchy	CO_2 (kt)
Zurich-Bangkok	155
Zurich-New York (JFK)	152
Zurich-Singapore	138
Zurich-Dubai	125
Zurich-Tokyo (Narita)	88
Zurich-Newark	83
Zurich-Sao Paulo	82
Zurich-Hong Kong	79
Zurich-Los Angeles	78
Zurich-Beijing	77
Zurich-San Francisco	76
Zurich-Shanghai	76
Zurich-Johannesburg	71
Zurich-Chicago	70
Zurich-Tel Aviv	66
Other Routes	2,980
Total	**4,397**



Taiwan

Total Footprint = 4,292 kt CO_2



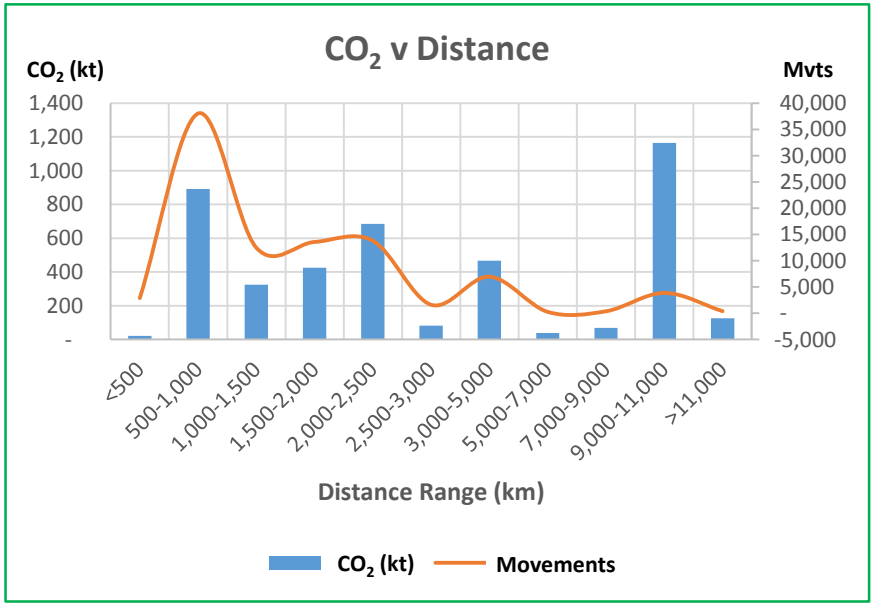


Origin Airports	CO_2 (kt)
Taipei	4,090
Kaohsiung	200
Taitung	<1
Hualien	<1
Magong	<1
Other Airports	0
Total	**4,290**

Destination Airports	CO_2 (kt)
Hong Kong	530
Los Angeles	503
San Francisco	288
Tokyo (Narita)	236
Singapore	198
Bangkok	174
Tokyo (Haneda)	133
Vancouver	124
Osaka	122
Seoul	115
Kuala Lumpur	111
Shanghai	111
Ho Chi Minh City	93
Macau	87
Jakarta	79
Other Airports	1,386
Total	**4,292**

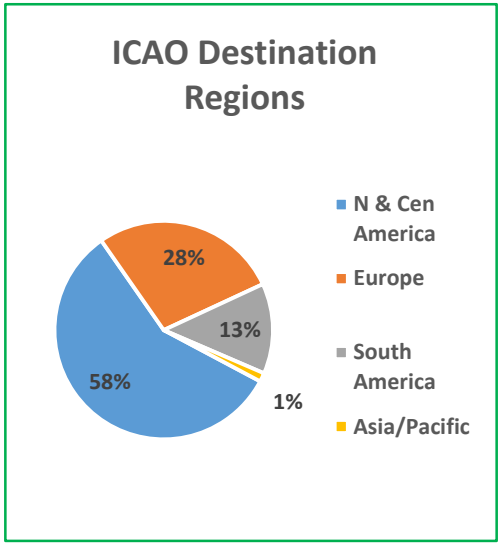
Airlines	CO_2 (kt)
China Airlines	1,511
EVA Air	1,346
Cathay Pacific	274
Japan Airlines	96
KLM Royal Dutch Airlines	86
TransAsia Airways	70
Dragonair, Hong Kong Dragon	70
Thai Airways International	59
Singapore Airlines	57
Uni Air	56
China Eastern Airlines	53
Air China	52
Mandarin Airlines	51
All Nippon Airways	45
China Southern Airlines	44
Other Airlines	421
Total	**4,292**

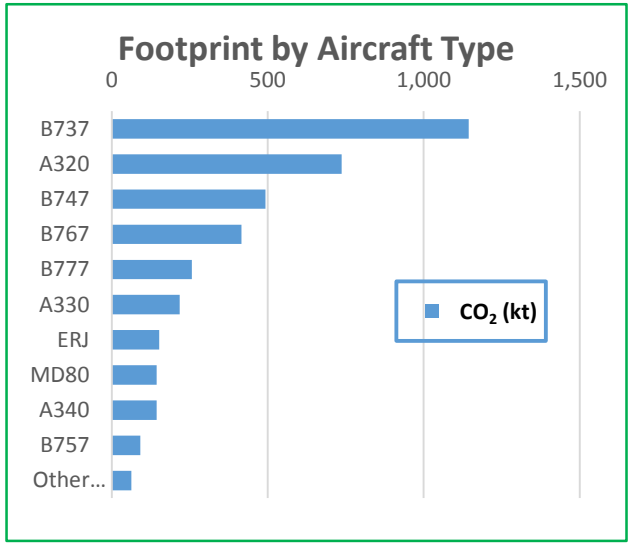
City-Pair Hierarchy	CO_2 (kt)
Taipei-Los Angeles	503
Taipei-Hong Kong	450
Taipei-San Francisco	288
Taipei-Tokyo (Narita)	215
Taipei-Singapore	194
Taipei-Bangkok	170
Taipei-Tokyo (Haneda)	133
Taipei-Vancouver	124
Taipei-Osaka	120
Taipei-Seoul	110
Taipei-Kuala Lumpur	108
Taipei-Shanghai	103
Taipei-Ho Chi Minh City	83
Kaohsiung-Hong Kong	80
Taipei-Jakarta	79
Other Routes	1,532
Total	**4,292**



Mexico

Total Footprint = 3,950 kt CO_2



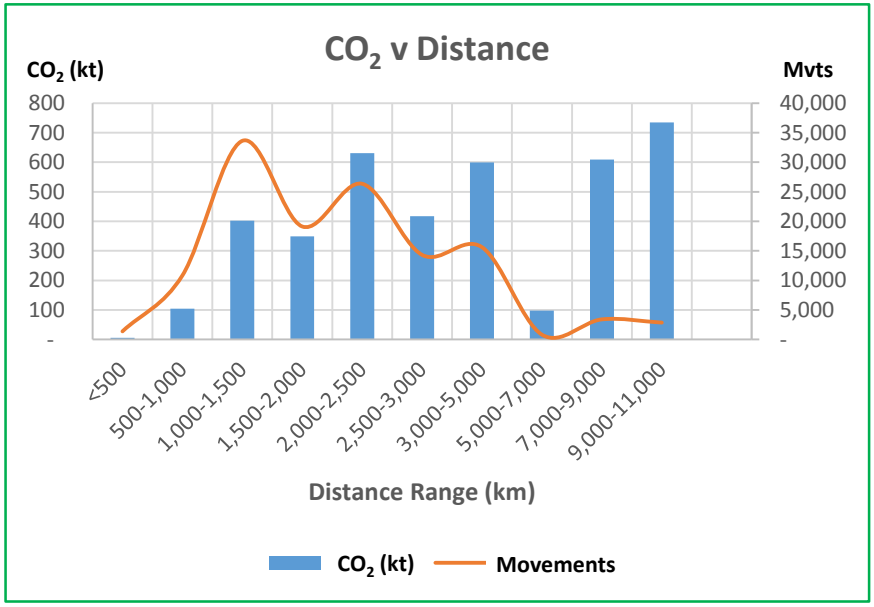


Origin Airports	CO_2 (kt)
Mexico City	1,893
Cancun	1,081
Guadalajara	229
Los Cabos	188
Puerto Vallarta	181
Monterrey	72
Tijuana	51
Leon	35
Cozumel	29
Mazatlan	21
Morelia	21
Ixtapa/Zihuatanejo	18
Aguascalientes	14
Queretaro	13
Veracruz	10
Other Airports	94
Total	**3,950**

Destination Airports	CO_2 (kt)
Madrid	303
Los Angeles	248
Houston	239
Paris (CDG)	231
Dallas-Fort Worth	199
Frankfurt	155
Amsterdam	145
Sao Paulo	129
Chicago	123
Atlanta	117
New York (JFK)	112
San Francisco	110
Miami	102
Phoenix	93
Buenos Aires	83
Other Airports	1,560
Total	**3,950**

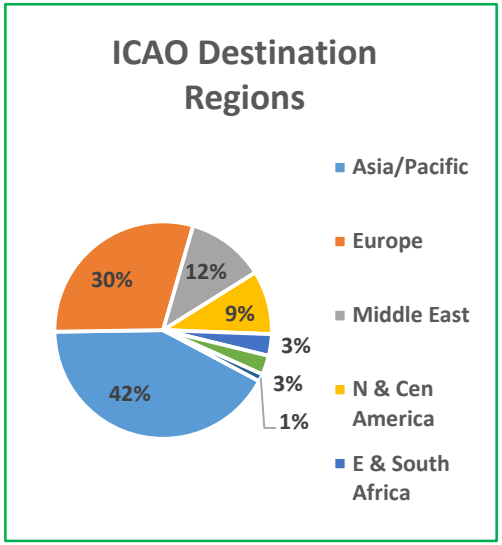
Airlines	CO_2 (kt)
AeroMéxico	747
United Airlines	362
American Airlines	309
Delta Air Lines	189
US Airways	152
Air France	151
Volaris Airlines	135
Alaska Airlines	131
Iberia Airlines	126
Lufthansa	123
KLM Royal Dutch Airlines	120
WestJet	113
LAN Airlines	94
Copa Airlines	93
British Airways	91
Other Airlines	1,015
Total	**3,950**

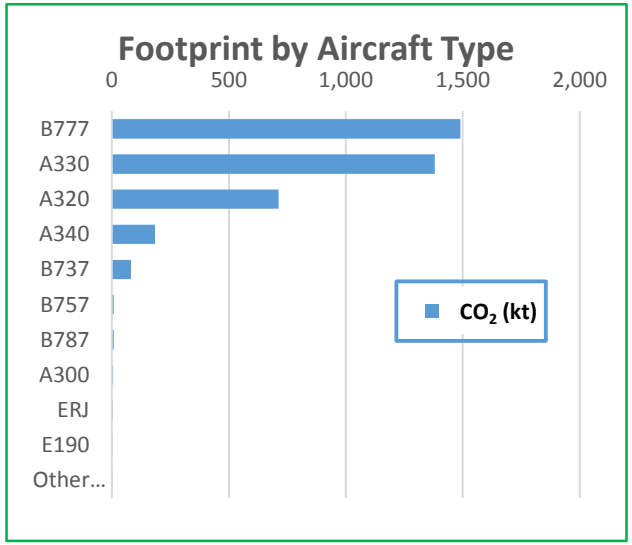
City-Pair Hierarchy	CO_2 (kt)
Mexico City-Madrid	214
Mexico City-Paris (CDG)	190
Mexico City-Sao Paulo	129
Mexico City-Frankfurt	123
Mexico City-Amsterdam	120
Cancun-Madrid	89
Mexico City-Los Angeles	82
Mexico City-Miami	76
Mexico City-New York (JFK)	75
Mexico City-Santiago de Chile	73
Mexico City-Buenos Aires	66
Cancun-London (Gatwick)	64
Mexico City-Lima	64
Guadalajara-Los Angeles	61
Mexico City-London (Heathrow)	61
Other Routes	2,462
Total	**3,950**



Qatar

Total Footprint = 3,881 kt CO_2



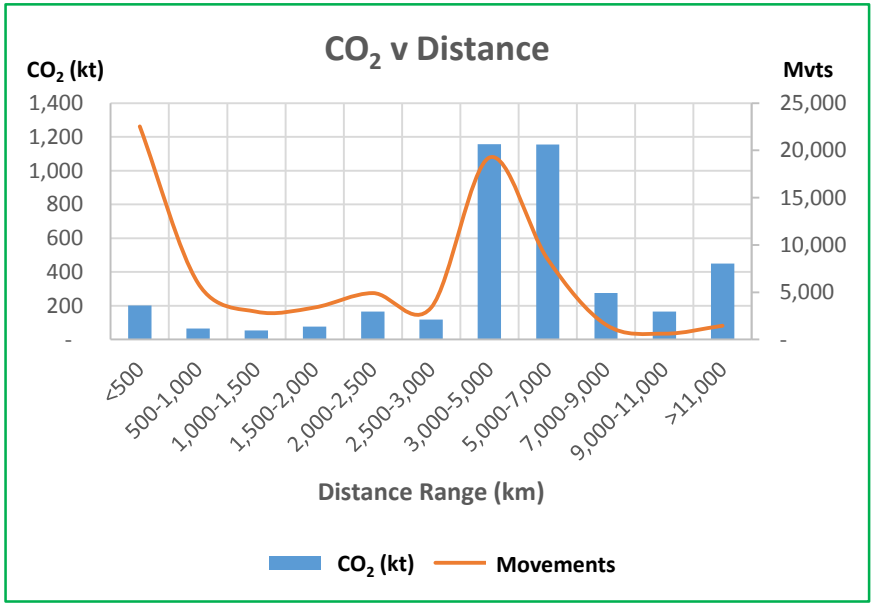


Origin Airports	CO_2 (kt)
Doha	3,881
Other Airports	0
Total	**3,881**

Destination Airports	CO_2 (kt)
London (Heathrow)	212
Bangkok	144
Manila	126
Houston	121
Kuala Lumpur	119
Singapore	113
Melbourne	112
Sao Paulo	111
Frankfurt	109
Dubai	107
Washington	104
New York (JFK)	101
Paris (CDG)	95
Hong Kong	86
Jakarta	73
Other Airports	2,147
Total	**3,881**

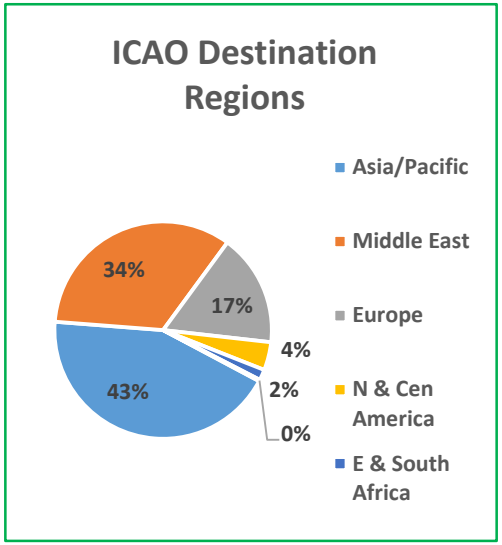
Airlines	CO_2 (kt)
Qatar Airways	3,560
Lufthansa	39
Emirates Airline	39
Jet Airways	30
KLM Royal Dutch Airlines	28
SriLankan Airlines	23
Flydubai	21
EgyptAir	18
Air India Express	16
Etihad Airways	11
Turkish Airlines	10
Gulf Air Bahrain	9
Oman Air	9
Middle East Airlines	8
Nepal Airlines	8
Other Airlines	52
Total	**3,881**

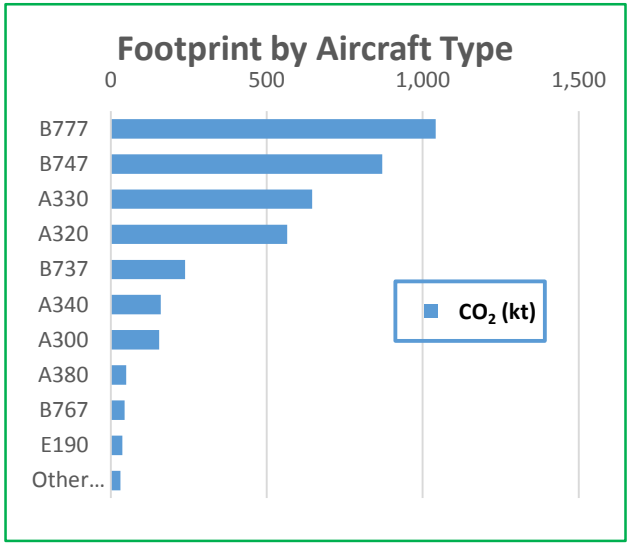
City-Pair Hierarchy	CO_2 (kt)
Doha-London (Heathrow)	212
Doha-Bangkok	144
Doha-Manila	126
Doha-Houston	121
Doha-Kuala Lumpur	119
Doha-Singapore	113
Doha-Melbourne	112
Doha-Sao Paulo	111
Doha-Frankfurt	109
Doha-Dubai	107
Doha-Washington	104
Doha-New York (JFK)	101
Doha-Paris (CDG)	95
Doha-Hong Kong	86
Doha-Jakarta	73
Other Routes	2,147
Total	**3,881**



Saudi Arabia

Total Footprint = 3,857 kt CO_2



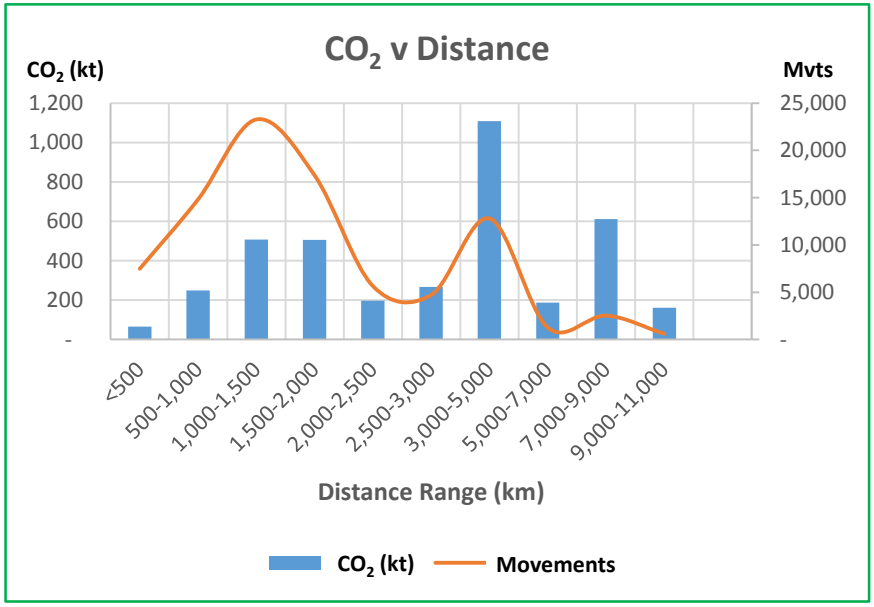


Origin Airports	CO_2 (kt)
Jeddah	2,014
Riyadh	1,304
Dammam	351
Medina	128
Yanbu	17
Khamis Mushayat	15
Gassim	14
Taif	14
Tabuk	<1
Other Airports	0
Total	**3,856**

Destination Airports	CO_2 (kt)
Jakarta	380
Cairo	322
Dubai	291
London (Heathrow)	176
Manila	145
Dhaka	131
Mumbai	123
Istanbul	119
Karachi	106
Lahore	98
Kuala Lumpur	96
Frankfurt	91
Calicut	84
Washington	82
Abu Dhabi	81
Other Airports	1,533
Total	**3,857**

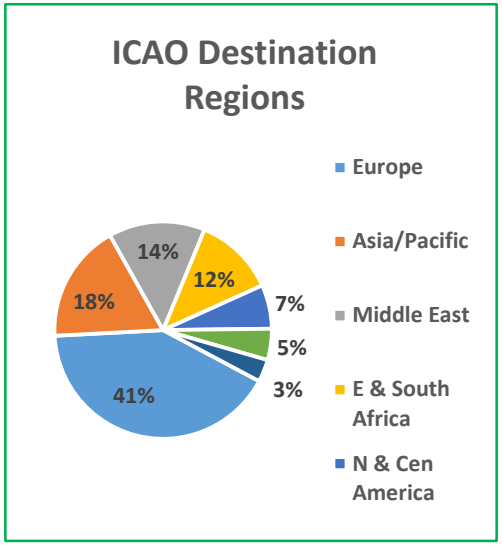
Airlines	CO_2 (kt)
Saudi Arabian Airlines	1,599
EgyptAir	185
Air India	165
Riau Airlines	144
Nas Air	127
Emirates Airline	115
Lufthansa	106
Garuda Indonesia	106
Lion Air (Lion Mentari Airlines	103
Turkish Airlines	85
Biman Bangladesh Airlines	77
British Airways	69
Batavia Air	61
Flydubai	60
Jet Airways	60
Other Airlines	797
Total	**3,857**

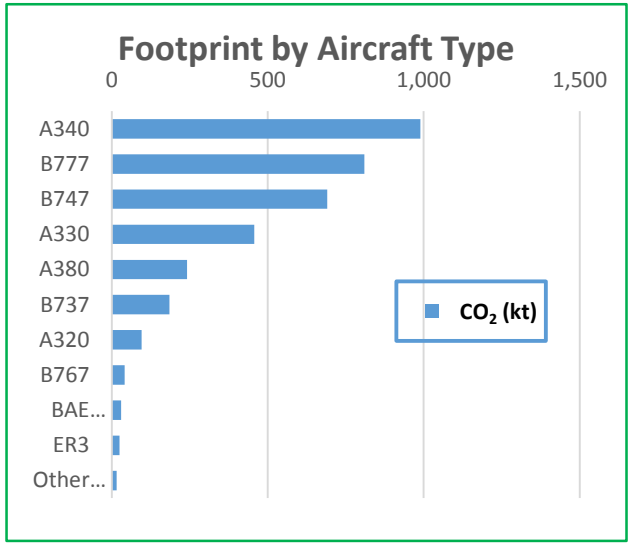
City-Pair Hierarchy	CO_2 (kt)
Jeddah-Jakarta	331
Jeddah-Cairo	154
Jeddah-Dubai	139
Riyadh-London (Heathrow)	111
Riyadh-Dubai	91
Riyadh-Cairo	79
Riyadh-Manila	74
Riyadh-Dhaka	73
Jeddah-Karachi	71
Jeddah-Kuala Lumpur	69
Jeddah-London (Heathrow)	65
Jeddah-New York (JFK)	62
Jeddah-Lahore	59
Jeddah-Casablanca	57
Riyadh-Mumbai	57
Other Routes	2,365
Total	**3,857**



South Africa

Total Footprint = 3,616 kt CO_2



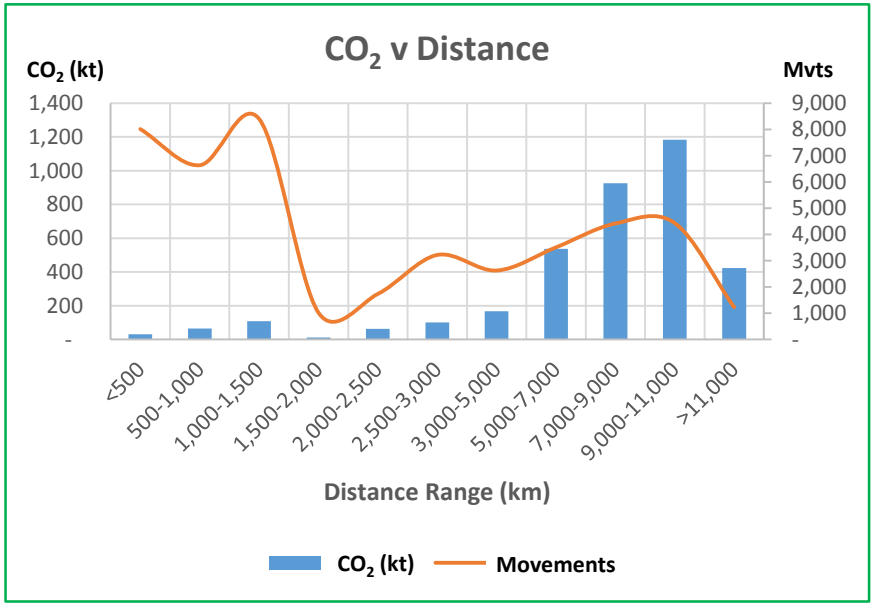


Origin Airports	CO_2 (kt)
Johannesburg	2,990
Cape Town	563
Durban	62
Nelspruit	2
Lanseria	<1
Other Airports	0
Total	**3,616**

Destination Airports	CO_2 (kt)
London (Heathrow)	743
Dubai	356
Frankfurt	217
Hong Kong	208
Amsterdam	161
Sydney	147
Atlanta	127
Paris (CDG)	127
New York (JFK)	109
Sao Paulo	89
Zurich	82
Munich	81
Singapore	80
Perth	64
Mumbai	61
Other Airports	966
Total	**3,616**

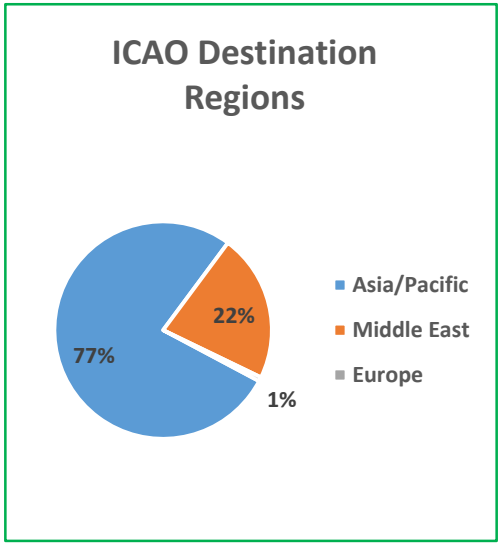
Airlines	CO_2 (kt)
South African Airways	1,151
British Airways	451
Emirates Airline	356
KLM Royal Dutch Airlines	161
Lufthansa	151
Qantas	147
Delta Air Lines	127
Air France	127
Virgin Atlantic Airways	125
Cathay Pacific	116
Singapore Airlines	80
Swiss European Air Lines	71
Turkish Airlines	60
Qatar Airways	57
Etihad Airways	50
Other Airlines	386
Total	**3,616**

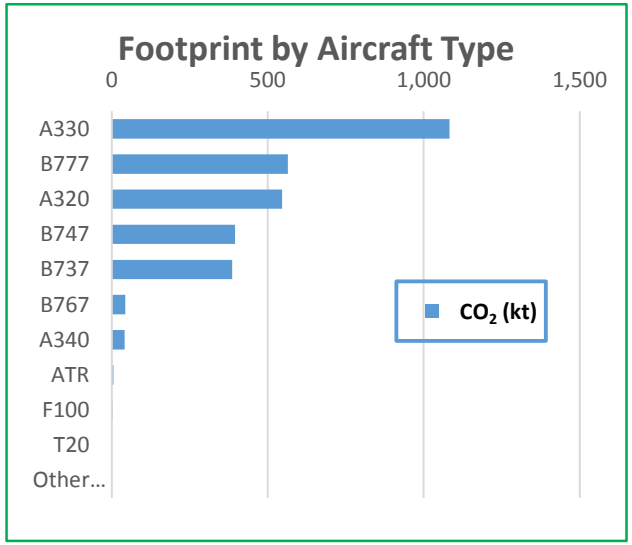
City-Pair Hierarchy	CO_2 (kt)
Johannesburg-London (Heathrow)	484
Cape Town-London (Heathrow)	259
Johannesburg-Hong Kong	208
Johannesburg-Frankfurt	186
Johannesburg-Dubai	181
Johannesburg-Sydney	147
Johannesburg-Atlanta	127
Cape Town-Dubai	118
Johannesburg-Paris (CDG)	111
Johannesburg-New York (JFK)	109
Johannesburg-Sao Paulo	89
Johannesburg-Amsterdam	83
Johannesburg-Singapore	80
Cape Town-Amsterdam	78
Johannesburg-Zurich	71
Other Routes	1,286
Total	**3,616**



Indonesia

Total Footprint = 3,065 kt CO_2



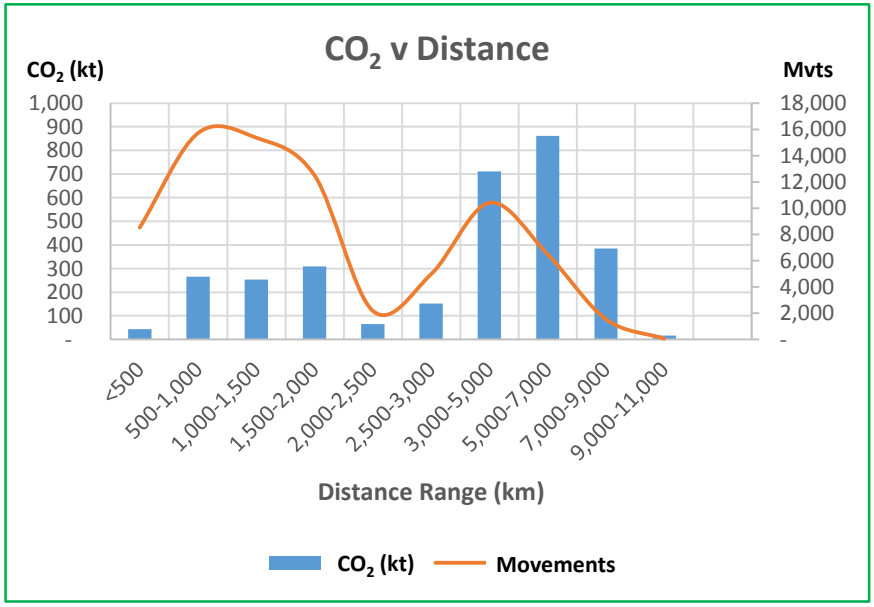


Origin Airports	CO_2 (kt)
Jakarta	1,825
Denpasar	930
Surabaya	137
Medan	50
Bandung	43
Yogyakarta	14
Ujung Pandang	11
Balikpapan	10
Semarang	8
Solo City	6
Palembang	5
Manado	5
Padang	5
Pekanbaru	4
Praya	3
Other Airports	7
Total	**3,065**

Destination Airports	CO_2 (kt)
Singapore	488
Kuala Lumpur	325
Jeddah	297
Hong Kong	289
Seoul	199
Tokyo (Narita)	182
Dubai	156
Sydney	148
Taipei	141
Bangkok	99
Perth	94
Melbourne	89
Doha	73
Abu Dhabi	61
Riyadh	48
Other Airports	377
Total	**3,065**

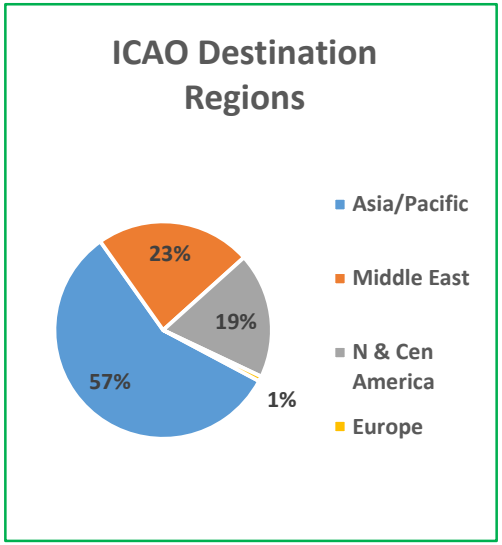
Airlines	CO_2 (kt)
Garuda Indonesia	752
Indonesia AirAsia	224
Lion Air (Lion Mentari Airlines	159
Cathay Pacific	159
Singapore Airlines	156
Korean Air	126
Emirates Airline	119
China Airlines	112
AirAsia	110
Saudi Arabian Airlines	107
Qatar Airways	92
Jetstar Airways	91
Batavia Air	88
Virgin Australia	79
Malaysia Airlines	73
Other Airlines	616
Total	**3,065**

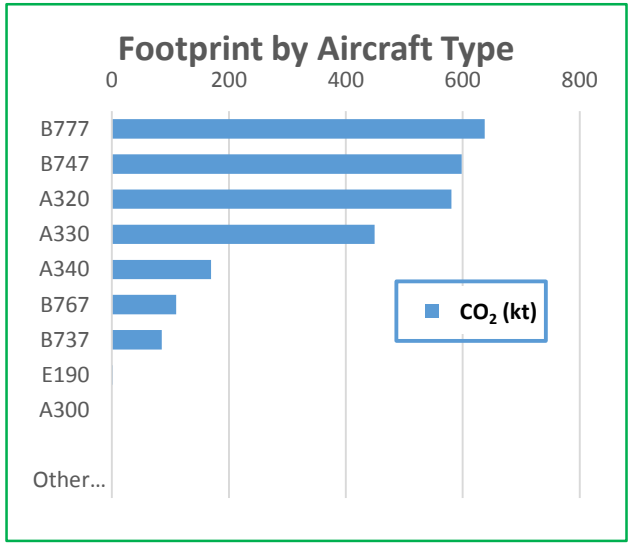
City-Pair Hierarchy	CO_2 (kt)
Jakarta-Jeddah	297
Jakarta-Singapore	242
Jakarta-Hong Kong	160
Jakarta-Dubai	156
Jakarta-Tokyo (Narita)	137
Denpasar-Singapore	135
Jakarta-Kuala Lumpur	124
Jakarta-Seoul	110
Denpasar-Hong Kong	100
Denpasar-Perth	90
Denpasar-Seoul	89
Denpasar-Sydney	83
Jakarta-Taipei	78
Jakarta-Doha	73
Denpasar-Kuala Lumpur	73
Other Routes	1,118
Total	**3,065**



Philippines

Total Footprint = 2,633 kt CO_2



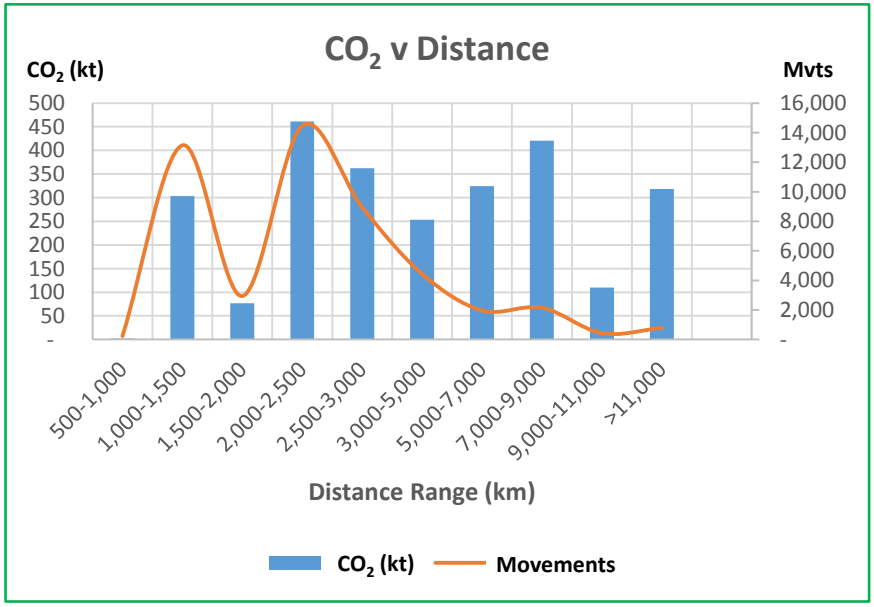


Origin Airports	CO_2 (kt)
Manila	2,330
Lapu-Lapu	176
Luzon	91
Kalibo	29
Davao City	4
Iloilo	<1
Bacolod	<1
Laoag	<1
Other Airports	0
Total	**2,631**

Destination Airports	CO_2 (kt)
Seoul	275
Singapore	268
Hong Kong	215
Los Angeles	164
Tokyo (Narita)	155
San Francisco	148
Doha	132
Abu Dhabi	126
Dubai	126
Bangkok	96
Vancouver	91
Bahrain	81
Riyadh	74
Kuala Lumpur	65
Honolulu	63
Other Airports	555
Total	**2,633**

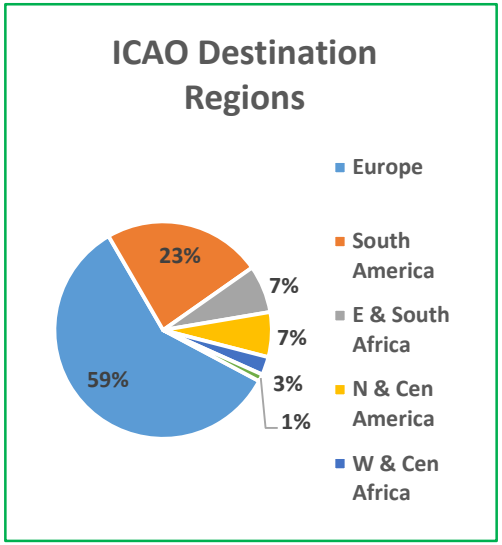
Airlines	CO_2 (kt)
Philippine Airlines	856
Cebu Pacific	218
Saudi Arabian Airlines	145
Qatar Airways	132
Etihad Airways	126
Emirates Airline	126
Cathay Pacific	104
Singapore Airlines	93
Korean Air	86
Gulf Air Bahrain	81
Delta Air Lines	70
Asiana Airlines	64
Japan Airlines	40
Zest Airways	38
Hawaiian Airlines	33
Other Airlines	421
Total	**2,633**

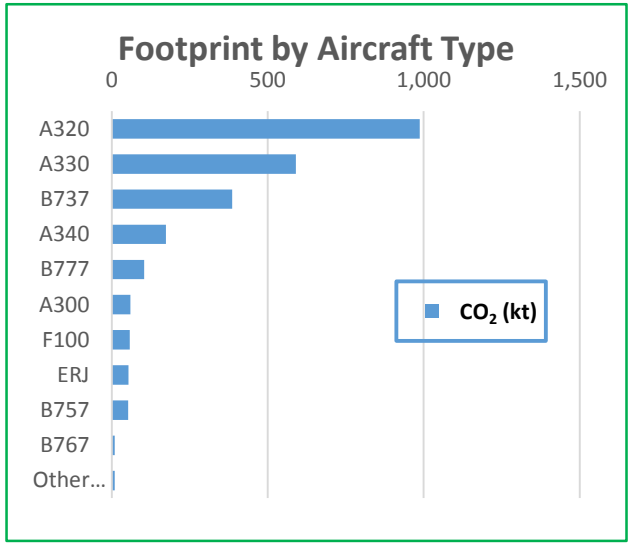
City-Pair Hierarchy	CO_2 (kt)
Manila-Singapore	222
Manila-Seoul	165
Manila-Los Angeles	164
Manila-Hong Kong	163
Manila-San Francisco	148
Manila-Tokyo (Narita)	134
Manila-Abu Dhabi	126
Manila-Dubai	126
Manila-Doha	126
Manila-Vancouver	91
Manila-Bangkok	87
Manila-Bahrain	81
Lapu-Lapu-Seoul	78
Manila-Riyadh	74
Manila-Honolulu	63
Other Routes	785
Total	**2,633**



Portugal

Total Footprint = 2,496 kt CO_2



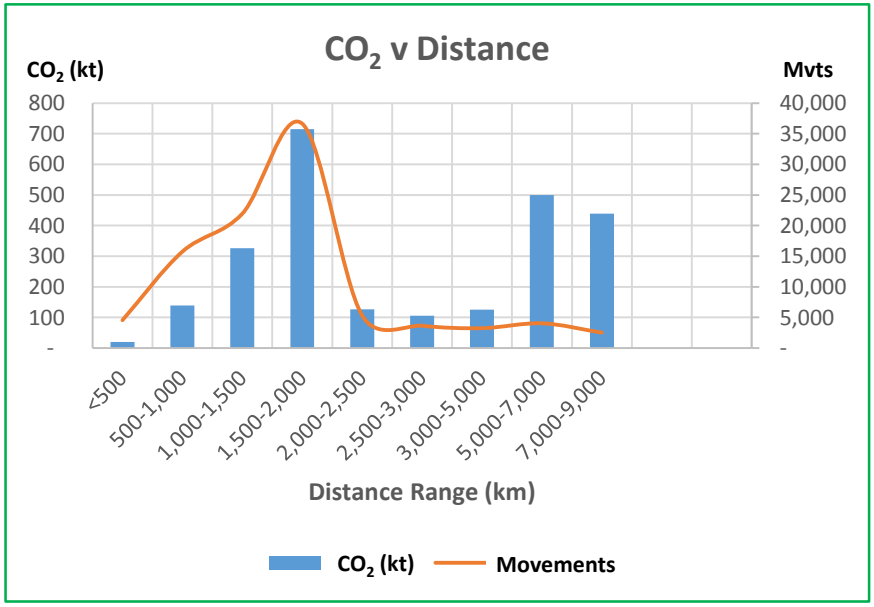


Origin Airports	CO_2 (kt)
Lisboa	1,689
Porto	374
Faro	321
Funchal	82
Ponta Delgada	26
Terceira	4
Porto Santo	2
Other Airports	0
Total	**2,496**

Destination Airports	CO_2 (kt)
Luanda	144
Sao Paulo	122
Rio de Janeiro	118
Paris (Orly)	93
London (Gatwick)	77
Newark	74
Frankfurt	70
Madrid	67
Amsterdam	62
London (Heathrow)	60
Brasilia	53
Geneva	53
Barcelona	53
Belo Horizonte	50
Salvador	49
Other Airports	1,349
Total	**2,496**

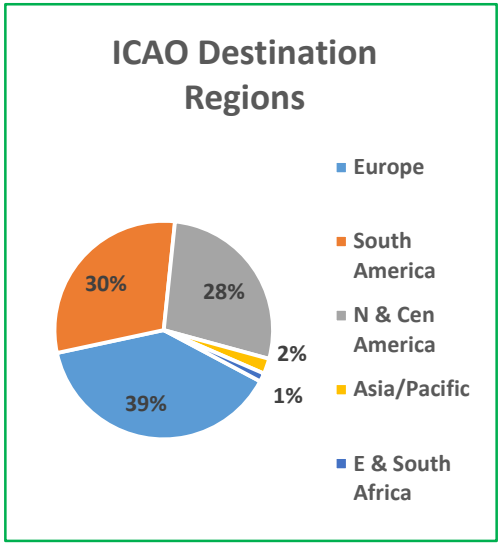
Airlines	CO_2 (kt)
TAP Portugal	1,380
Ryanair	204
Easyjet	198
TAAG Angola Airlines (Linhas A	77
Lufthansa	64
SATA International	46
Transavia	34
Air Berlin	31
Monarch Airlines	29
Jet2.com	27
British Airways	27
Emirates Airline	27
Air France	26
Aer Lingus	25
Iberia Airlines	23
Other Airlines	278
Total	**2,496**

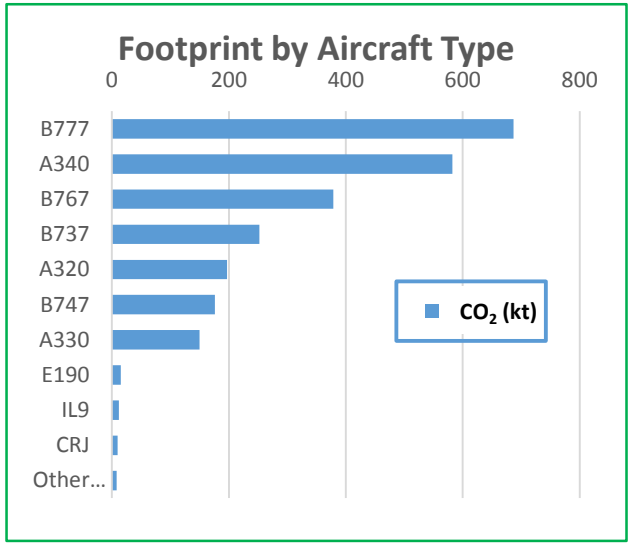
City-Pair Hierarchy	CO_2 (kt)
Lisboa-Luanda	129
Lisboa-Sao Paulo	101
Lisboa-Rio de Janeiro	98
Lisboa-Newark	60
Lisboa-London (Heathrow)	57
Lisboa-Brasilia	53
Lisboa-Paris (Orly)	52
Lisboa-Belo Horizonte	50
Lisboa-Salvador	49
Lisboa-Madrid	47
Lisboa-Amsterdam	45
Lisboa-Recife	43
Lisboa-Fortaleza	42
Lisboa-Frankfurt	41
Lisboa-Porto Alegre	37
Other Routes	1,590
Total	**2,496**



Argentina

Total Footprint = 2,480 kt CO_2



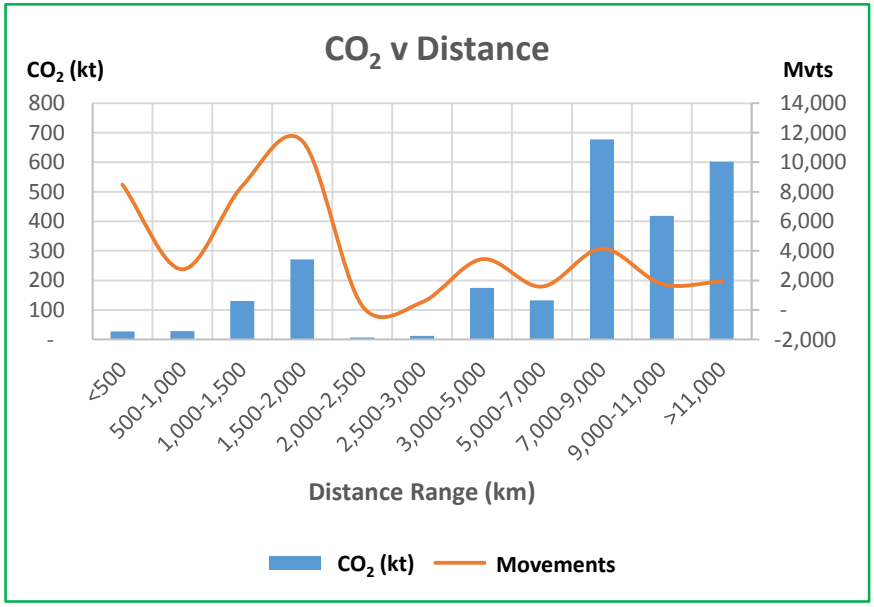


Origin Airports	CO_2 (kt)
Buenos Aires	2,417
Cordoba	46
Mendoza	7
Rosario	5
Iguassu	2
Salta	1
San Carlos de Bariloc	1
Rio Gallegos	<1
Other Airports	0
Total	**2,479**

Destination Airports	CO_2 (kt)
Madrid	342
Miami	265
Sao Paulo	166
Roma	160
Frankfurt	152
Lima	112
Santiago de Chile	107
London (Heathrow)	104
Paris (CDG)	102
Rio de Janeiro	95
New York (JFK)	79
Mexico City	76
Panama City	68
Dallas-Fort Worth	66
Barcelona	58
Other Airports	529
Total	**2,480**

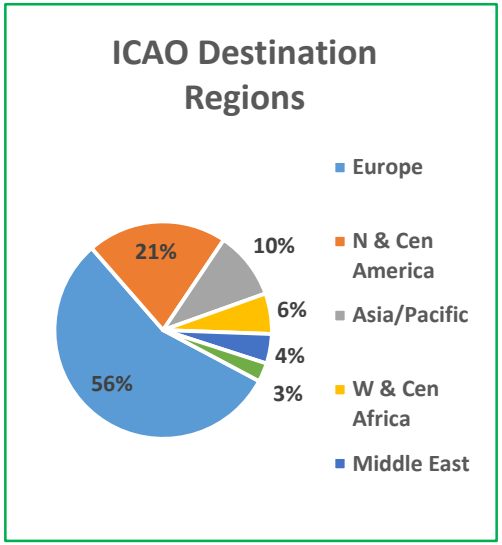
Airlines	CO_2 (kt)
Aerolineas Argentinas	481
American Airlines	295
LAN Airlines	177
Iberia Airlines	173
Lufthansa	152
Alitalia	105
British Airways	104
Air France	102
United Airlines	95
Gol Transportes Aéreos	86
Air Europa	80
TAM Airlines (TAM Linhas Aer	80
Copa Airlines	68
AeroMéxico	65
LAN Argentina	59
Other Airlines	359
Total	**2,480**

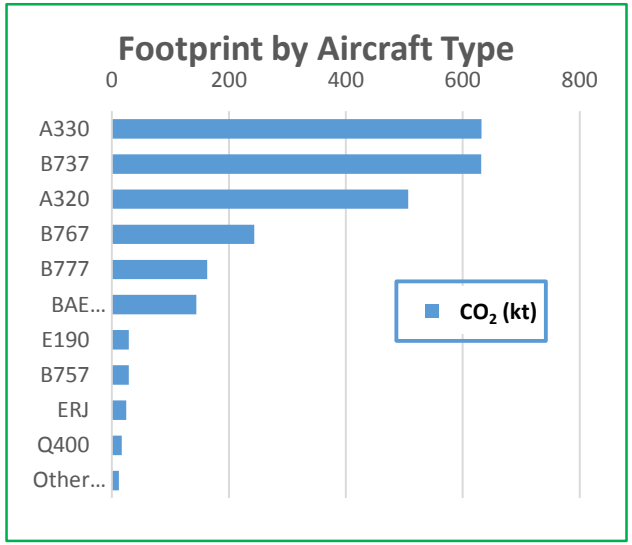
City-Pair Hierarchy	CO_2 (kt)
Buenos Aires-Madrid	340
Buenos Aires-Miami	265
Buenos Aires-Sao Paulo	164
Buenos Aires-Roma	160
Buenos Aires-Frankfurt	152
Buenos Aires-London (Heathrow)	104
Buenos Aires-Paris (CDG)	102
Buenos Aires-Lima	100
Buenos Aires-Santiago de Chile	93
Buenos Aires-Rio de Janeiro	92
Buenos Aires-New York (JFK)	79
Buenos Aires-Mexico City	76
Buenos Aires-Dallas-Fort Worth	66
Buenos Aires-Barcelona	58
Buenos Aires-Atlanta	54
Other Routes	575
Total	**2,480**



Belgium

Total Footprint = 2,479 kt CO_2



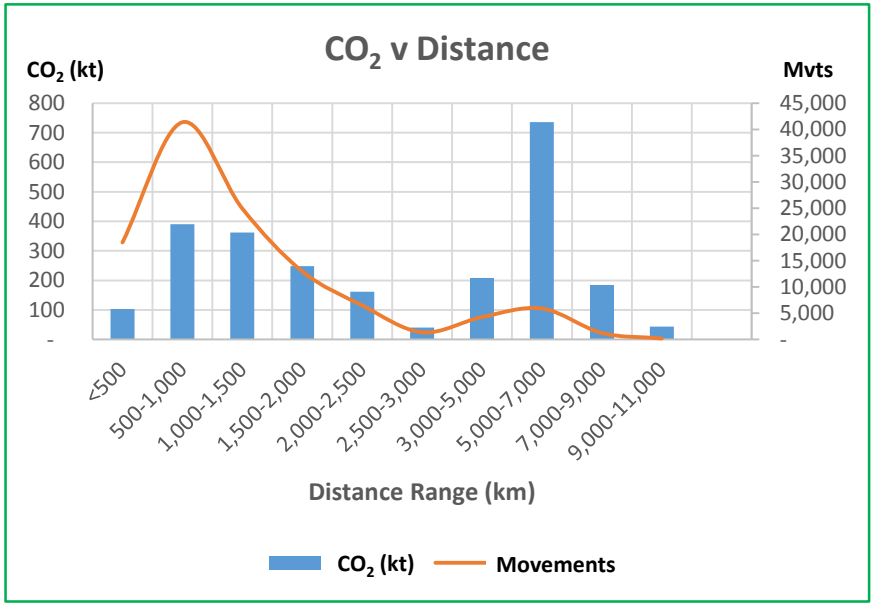


Origin Airports	CO_2 (kt)
Brussels	2,094
Charleroi	354
Liege	16
Oostende	10
Antwerpen	4
Other Airports	0
Total	**2,479**

Destination Airports	CO_2 (kt)
New York (JFK)	120
Newark	98
Mumbai	58
Washington	56
Chennai/Madras	52
Delhi	51
Madrid	50
Toronto	48
Abu Dhabi	47
Roma	46
Beijing	46
Istanbul	45
Barcelona	44
Chicago	41
Atlanta	40
Other Airports	1,634
Total	**2,479**

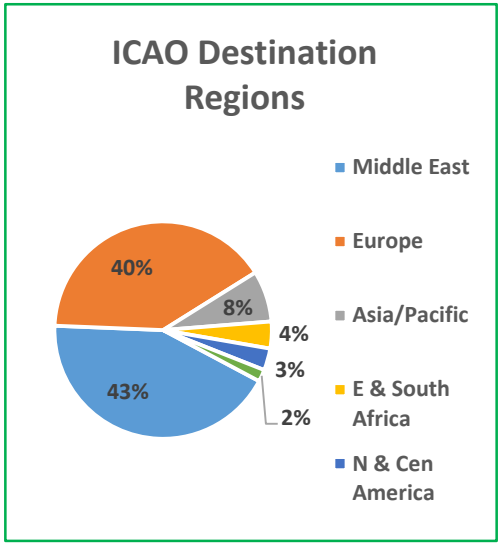
Airlines	CO_2 (kt)
Brussels Airlines	610
Jet Airways	289
Ryanair	284
Jetairfly	231
United Airlines	148
Delta Air Lines	75
Etihad Airways	47
Hainan Airlines	46
Turkish Airlines	42
Lufthansa	39
Thai Airways International	37
US Airways	34
Scandinavian Airlines System (	34
Easyjet	29
Air Canada	29
Other Airlines	502
Total	**2,479**

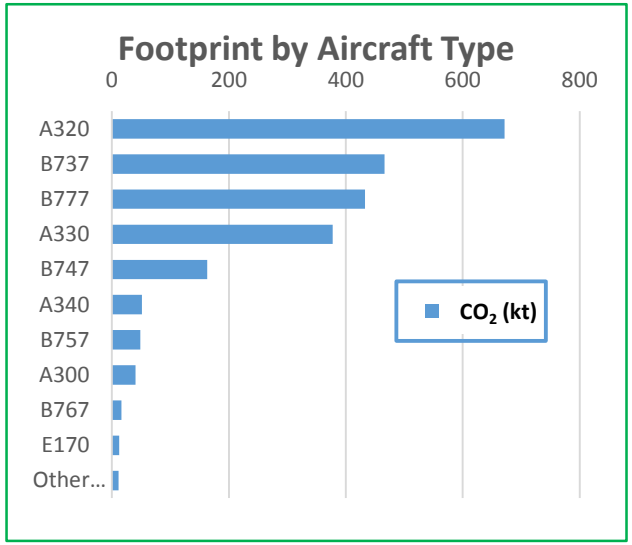
City-Pair Hierarchy	CO_2 (kt)
Brussels-New York (JFK)	120
Brussels-Newark	98
Brussels-Mumbai	58
Brussels-Washington	56
Brussels-Chennai/Madras	52
Brussels-Delhi	51
Brussels-Toronto	48
Brussels-Abu Dhabi	47
Brussels-Beijing	46
Brussels-Istanbul	44
Brussels-Chicago	41
Brussels-Atlanta	40
Brussels-Montreal	37
Brussels-Bangkok	37
Brussels-Madrid	35
Other Routes	1,669
Total	**2,479**



Egypt

Total Footprint = 2,310 kt CO_2



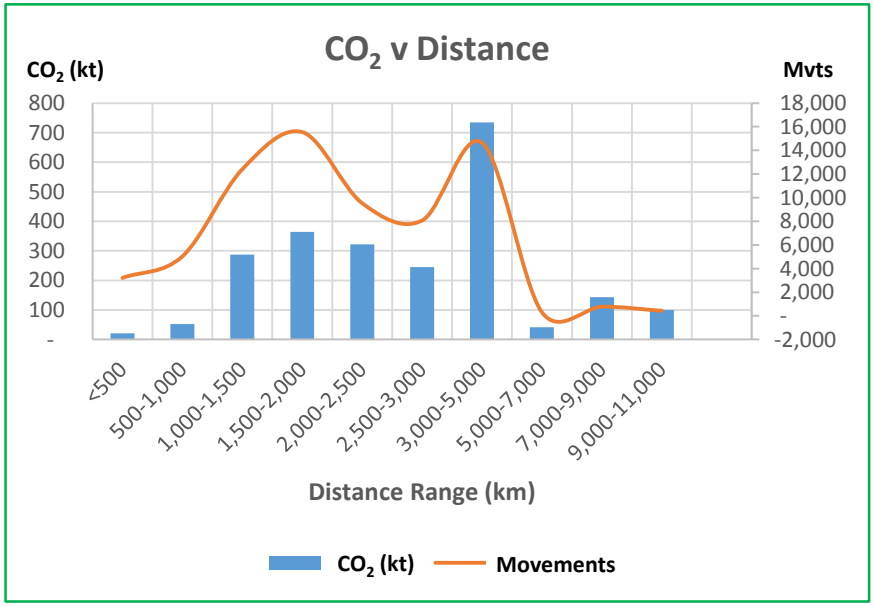


Origin Airports	CO_2 (kt)
Cairo	1,669
Hurghada	213
Ras Nasrani	201
Alexandria	154
Luxor	26
Marsa Alam	24
Assiut	18
Taba	4
Aswan	<1
Other Airports	0
Total	**2,310**

Destination Airports	CO_2 (kt)
Jeddah	196
Moscow	135
Dubai	118
Kuwait City	111
Riyadh	101
London (Heathrow)	99
New York (JFK)	75
Bangkok	66
Paris (CDG)	59
Doha	57
Frankfurt	51
Guangzhou	50
Abu Dhabi	48
Khartoum	48
Johannesburg	41
Other Airports	1,053
Total	**2,310**

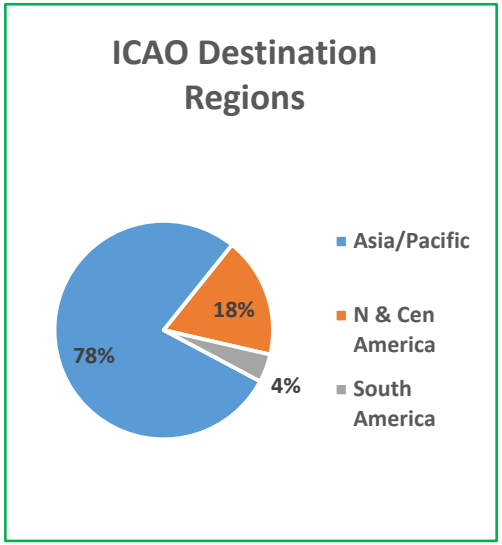
Airlines	CO_2 (kt)
EgyptAir	1,072
Saudi Arabian Airlines	138
Transaero Airlines	136
Thomson	51
Air Berlin	50
Emirates Airline	44
Qatar Airways	43
Easyjet	37
Guinee Airlines	34
British Airways	34
Kuwait Airways	33
Magnicharters	31
Etihad Airways	29
Samara Airlines	27
Air Arabia	26
Other Airlines	525
Total	**2,310**

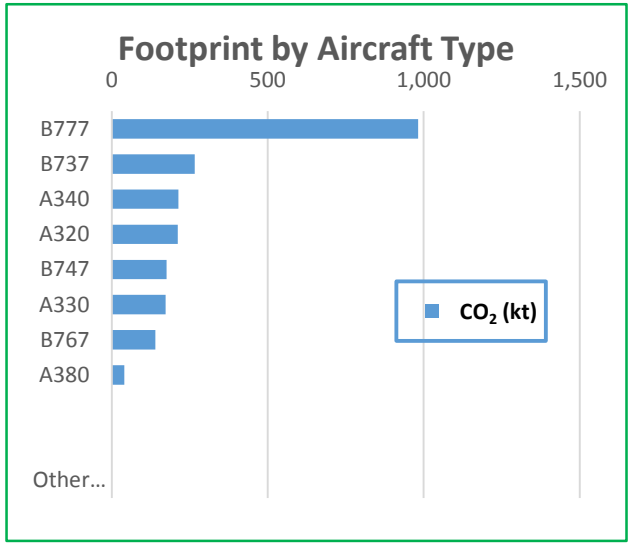
City-Pair Hierarchy	CO_2 (kt)
Cairo-Jeddah	154
Cairo-Dubai	99
Cairo-London (Heathrow)	92
Cairo-Riyadh	79
Hurghada-Moscow	78
Cairo-New York (JFK)	75
Cairo-Kuwait City	72
Cairo-Bangkok	66
Cairo-Paris (CDG)	59
Cairo-Guangzhou	50
Ras Nasrani-Moscow	48
Cairo-Khartoum	48
Cairo-Abu Dhabi	47
Cairo-Doha	44
Cairo-Johannesburg	41
Other Routes	1,257
Total	**2,310**



New Zealand

Total Footprint = 2,200 kt CO_2



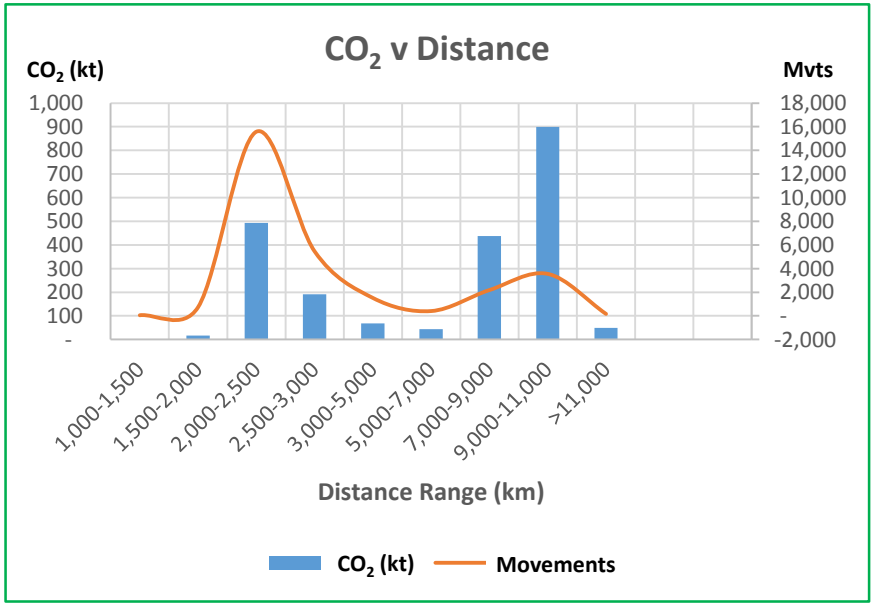


Origin Airports	CO_2 (kt)
Auckland	1,895
Christchurch	198
Wellington	75
Queenstown	20
Dunedin	7
Hamilton	4
Rotorua	2
Other Airports	0
Total	**2,200**

Destination Airports	CO_2 (kt)
Sydney	268
Singapore	255
Los Angeles	217
Hong Kong	190
Melbourne	168
Brisbane	155
San Francisco	109
Seoul	87
Kuala Lumpur	85
Guangzhou	74
Santiago de Chile	73
Bangkok	61
Shanghai	56
Tokyo (Narita)	55
Vancouver	49
Other Airports	298
Total	**2,200**

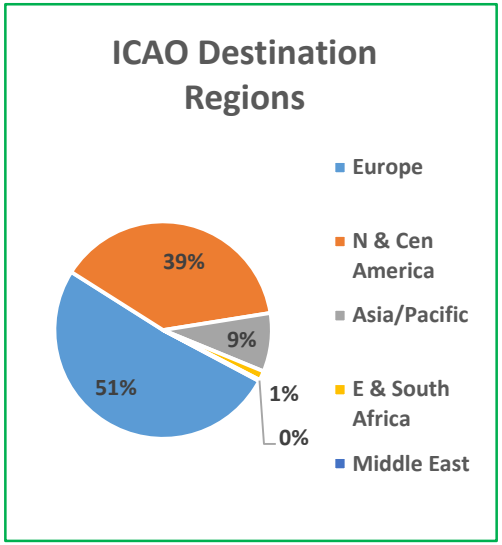
Airlines	CO_2 (kt)
Air New Zealand	934
Singapore Airlines	214
Qantas	167
Virgin Australia	116
Emirates Airline	104
Cathay Pacific	101
LAN Airlines	90
Korean Air	87
China Southern Airlines	74
Malaysia Airlines	69
Jetstar Airways	67
Thai Airways International	61
Air Pacific	23
Aerolineas Argentinas	23
Jetstar Asia Airways	20
Other Airlines	51
Total	**2,200**

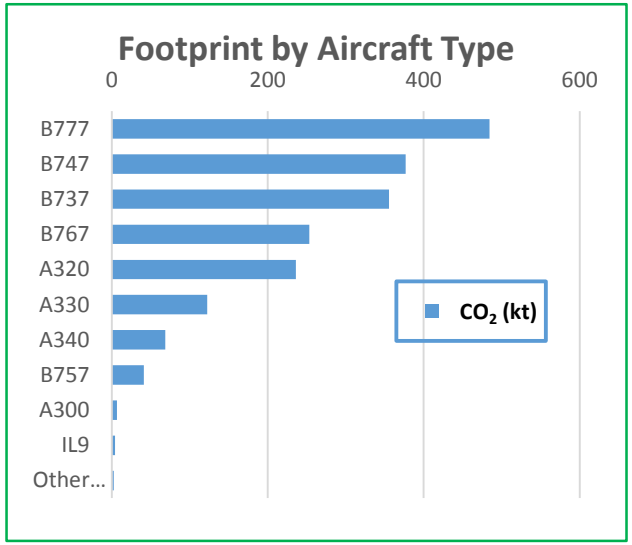
City-Pair Hierarchy	CO_2 (kt)
Auckland-Los Angeles	217
Auckland-Hong Kong	190
Auckland-Singapore	178
Auckland-Sydney	170
Auckland-Melbourne	120
Auckland-San Francisco	109
Auckland-Brisbane	99
Auckland-Seoul	87
Christchurch-Singapore	77
Auckland-Guangzhou	74
Auckland-Santiago de Chile	73
Auckland-Kuala Lumpur	69
Auckland-Bangkok	61
Auckland-Shanghai	56
Auckland-Tokyo (Narita)	55
Other Routes	565
Total	**2,200**



Israel

Total Footprint = 1,952 kt CO_2



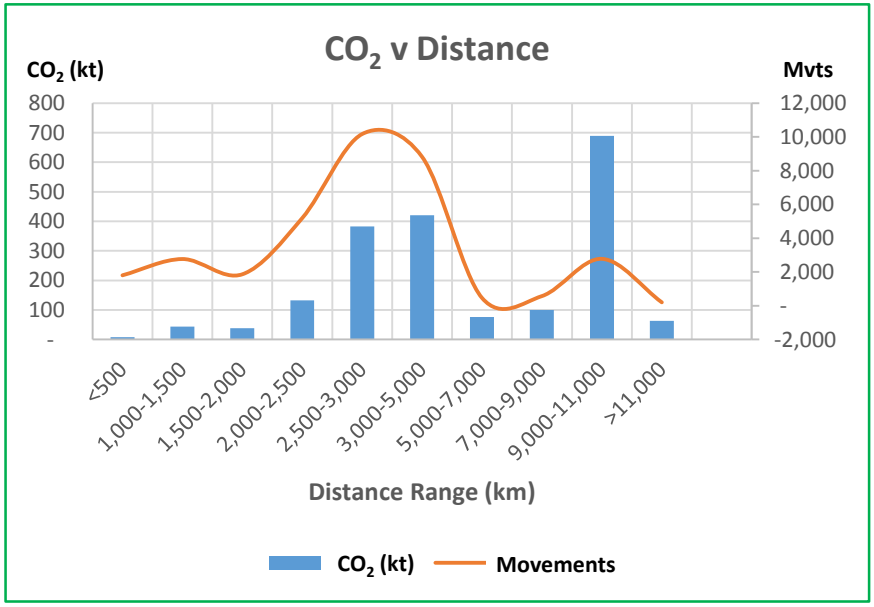


Origin Airports	CO_2 (kt)
Tel Aviv	1,945
Eilat	8
Other Airports	0
Total	**1,952**

Destination Airports	CO_2 (kt)
New York (JFK)	305
Newark	245
London (Heathrow)	110
Moscow	91
Paris (CDG)	91
Philadelphia	74
Zurich	66
Toronto	65
Los Angeles	63
Frankfurt	62
Bangkok	59
Madrid	49
Roma	47
Hong Kong	46
Kiev	35
Other Airports	544
Total	**1,952**

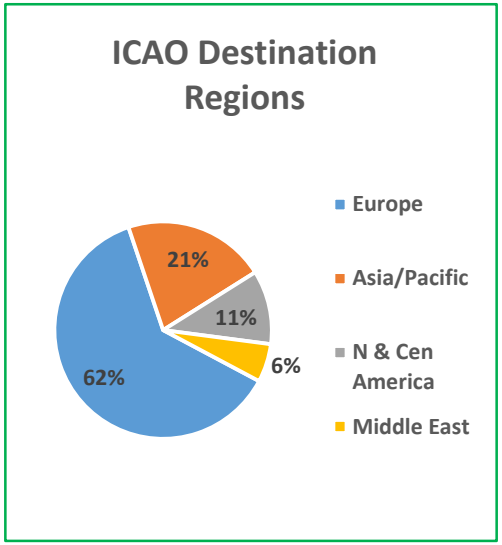
Airlines	CO_2 (kt)
El Al Israel Airlines	894
United Airlines	124
Delta Air Lines	118
US Airways	74
Lufthansa	63
British Airways	52
Swiss European Air Lines	48
Continental Airlines	42
Air Canada	39
Transaero Airlines	33
Korean Air	31
Iberia Airlines	29
Air France	29
Alitalia	28
Aerosvit Airlines	27
Other Airlines	322
Total	**1,952**

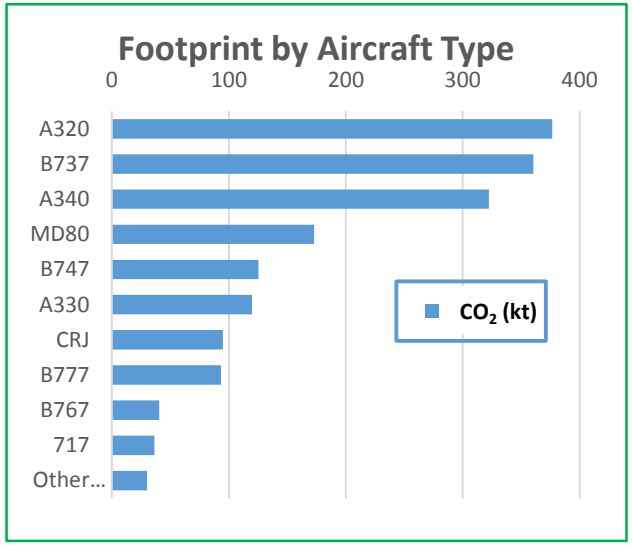
City-Pair Hierarchy	CO_2 (kt)
Tel Aviv-New York (JFK)	305
Tel Aviv-Newark	245
Tel Aviv-London (Heathrow)	110
Tel Aviv-Paris (CDG)	90
Tel Aviv-Moscow	85
Tel Aviv-Philadelphia	74
Tel Aviv-Zurich	66
Tel Aviv-Toronto	65
Tel Aviv-Los Angeles	63
Tel Aviv-Frankfurt	62
Tel Aviv-Bangkok	59
Tel Aviv-Madrid	49
Tel Aviv-Roma	47
Tel Aviv-Hong Kong	46
Tel Aviv-Kiev	35
Other Routes	551
Total	**1,952**



Denmark

Total Footprint = 1,905 kt CO_2



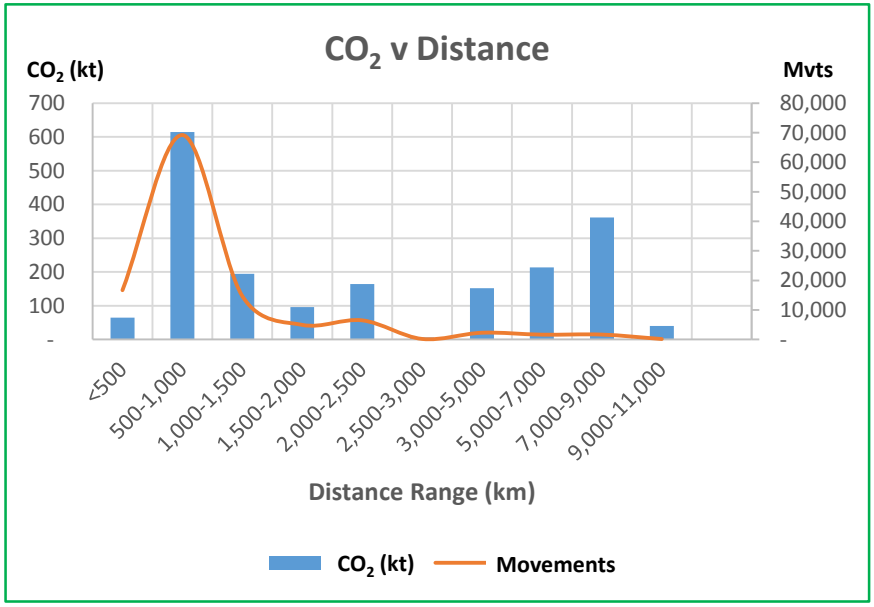


Origin Airports	CO_2 (kt)
Copenhagen	1,779
Billund	100
Aarhus	13
Aalborg	12
Esbjerg	2
Bornholm	<1
Other Airports	0
Total	**1,905**

Destination Airports	CO_2 (kt)
Bangkok	173
Tokyo (Narita)	70
Newark	67
Oslo	62
Beijing	58
Chicago	55
London (Heathrow)	54
Stockholm	54
Paris (CDG)	52
Helsinki	49
Washington	49
Amsterdam	47
Dubai	45
Frankfurt	43
Reykjavik	42
Other Airports	985
Total	**1,905**

Airlines	CO_2 (kt)
Scandinavian Airlines System (	793
Norwegian Air Shuttle	151
Thai Airways International	125
Ryanair	54
Easyjet	53
British Airways	44
Emirates Airline	44
Singapore Airlines	40
Qatar Airways	37
Lufthansa	35
Air France	32
Cimber Air	32
Blue1	31
Icelandair	30
KLM Royal Dutch Airlines	30
Other Airlines	374
Total	**1,905**

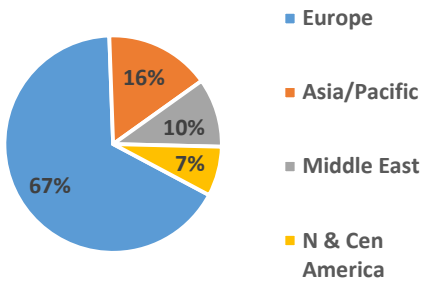
City-Pair Hierarchy	CO_2 (kt)
Copenhagen-Bangkok	173
Copenhagen-Tokyo (Narita)	70
Copenhagen-Newark	67
Copenhagen-Beijing	58
Copenhagen-Chicago	55
Copenhagen-London (Heathrow)	54
Copenhagen-Oslo	54
Copenhagen-Stockholm	50
Copenhagen-Helsinki	49
Copenhagen-Washington	49
Copenhagen-Paris (CDG)	46
Copenhagen-Dubai	45
Copenhagen-Reykjavik	40
Copenhagen-Singapore	40
Copenhagen-Shanghai	39
Other Routes	1,016
Total	**1,905**



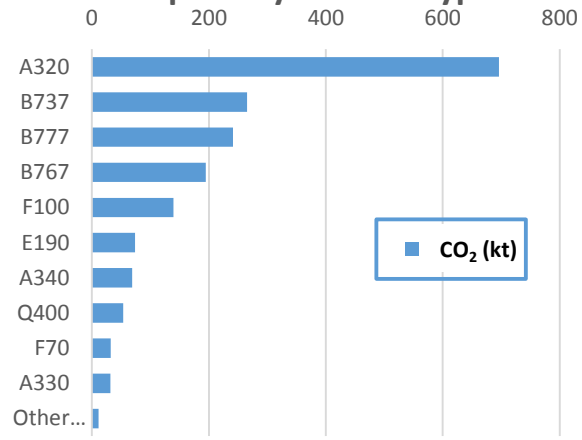
Austria

Total Footprint = 1,849 kt CO_2

ICAO Destination Regions



Footprint by Aircraft Type



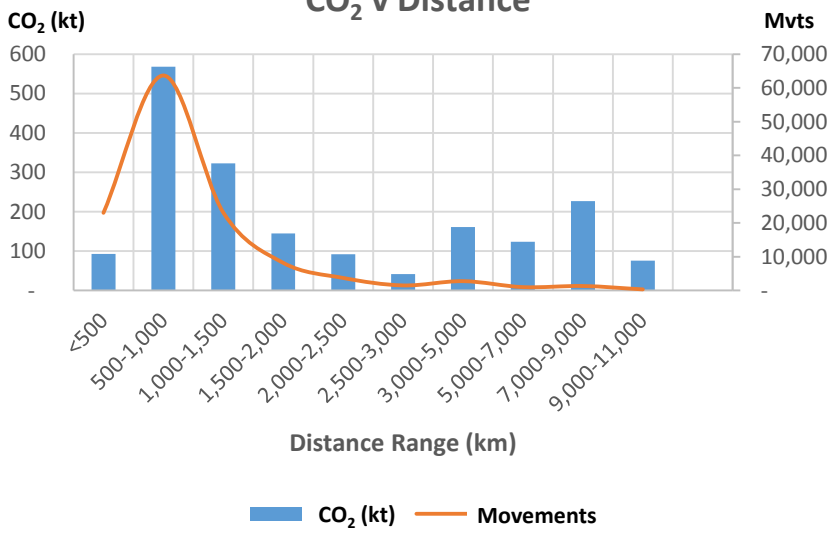
Origin Airports	CO_2 (kt)
Wien	1,687
Salzburg	71
Graz	36
Linz	26
Innsbruck	21
Klagenfurt	8
Other Airports	0
Total	**1,849**

Destination Airports	CO_2 (kt)
Bangkok	107
Dubai	100
Frankfurt	84
Tokyo (Narita)	76
Moscow	59
New York (JFK)	55
Dusseldorf	51
London (Heathrow)	49
Zurich	44
Washington	43
Paris (CDG)	42
Berlin	36
Istanbul	34
Toronto	34
Hamburg	34
Other Airports	1,001
Total	**1,849**

Airlines	CO_2 (kt)
Austrian Airlines	929
Niki	191
Lufthansa	94
Air Berlin	77
Emirates Airline	72
China Airlines	33
Germanwings	32
EVA Air	29
British Airways	28
Turkish Airlines	24
Aeroflot Russian Airlines	21
Air France	19
SunExpress	16
Iberia Airlines	15
Swiss European Air Lines	15
Other Airlines	255
Total	**1,849**

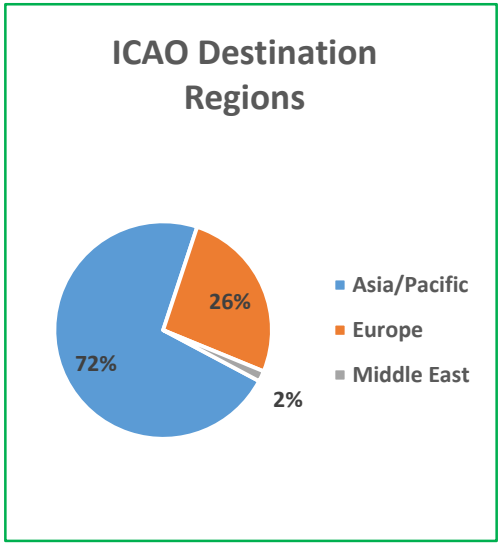
City-Pair Hierarchy	CO_2 (kt)
Wien-Bangkok	107
Wien-Dubai	100
Wien-Tokyo (Narita)	76
Wien-New York (JFK)	55
Wien-Moscow	54
Wien-Frankfurt	52
Wien-London (Heathrow)	49
Wien-Zurich	44
Wien-Washington	43
Wien-Paris (CDG)	42
Wien-Dusseldorf	40
Wien-Toronto	34
Wien-Istanbul	34
Wien-Beijing	33
Wien-Taipei	33
Other Routes	1,052
Total	**1,849**

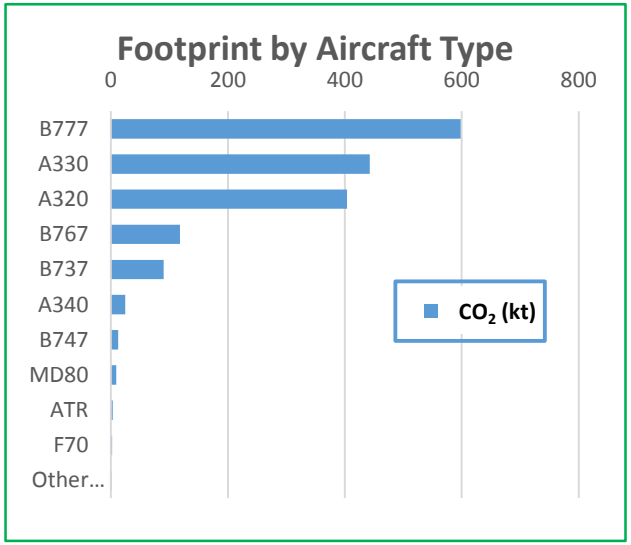
CO_2 v Distance



Vietnam

Total Footprint = 1,707 kt CO_2



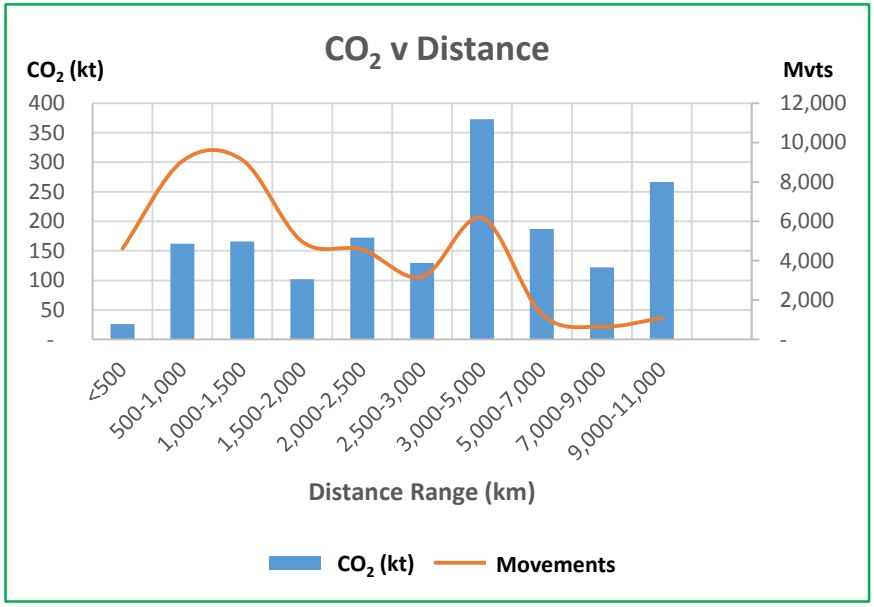


Origin Airports	CO_2 (kt)
Ho Chi Minh City	1,068
Hanoi	616
Da Nang	22
Nha Trang	<1
Cam Rahn	<1
Can Tho	<1
Other Airports	0
Total	**1,706**

Destination Airports	CO_2 (kt)
Seoul	212
Paris (CDG)	174
Tokyo (Narita)	154
Singapore	127
Bangkok	119
Moscow	119
Taipei	112
Frankfurt	97
Kuala Lumpur	75
Hong Kong	59
Sydney	53
Melbourne	51
Busan	44
Osaka	43
London (Gatwick)	43
Other Airports	226
Total	**1,707**

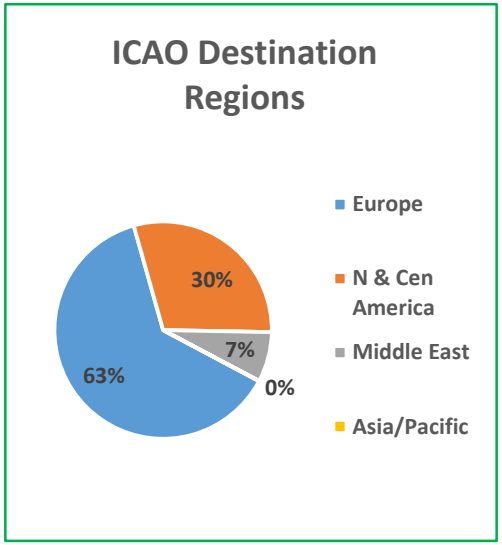
Airlines	CO_2 (kt)
Vietnam Airlines	835
Asiana Airlines	89
Korean Air	70
Air France	53
Japan Airlines	51
Singapore Airlines	51
China Airlines	47
Thai Airways International	45
Aeroflot Russian Airlines	45
EVA Air	35
Cathay Pacific	32
AirAsia	29
Malaysia Airlines	28
All Nippon Airways	28
Emirates Airline	27
Other Airlines	242
Total	**1,707**

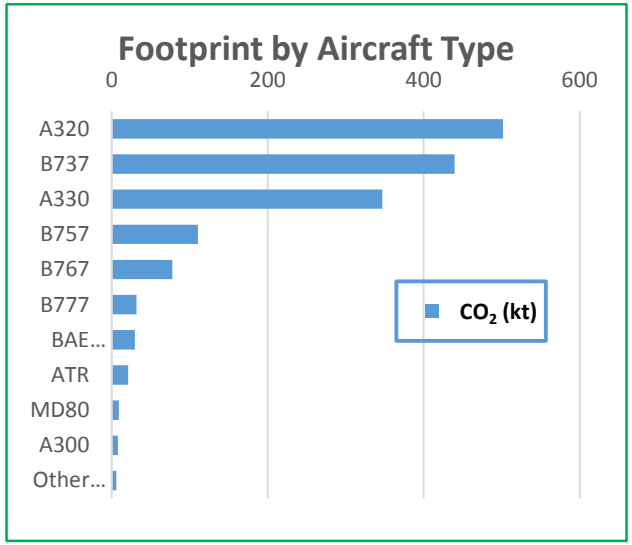
City-Pair Hierarchy	CO_2 (kt)
Ho Chi Minh City-Seoul	128
Ho Chi Minh City-Tokyo (Narita)	100
Ho Chi Minh City-Paris (CDG)	94
Ho Chi Minh City-Taipei	82
Hanoi-Paris (CDG)	81
Hanoi-Seoul	74
Ho Chi Minh City-Singapore	73
Ho Chi Minh City-Bangkok	68
Ho Chi Minh City-Moscow	64
Hanoi-Moscow	55
Hanoi-Tokyo (Narita)	54
Ho Chi Minh City-Sydney	53
Hanoi-Singapore	52
Hanoi-Bangkok	51
Ho Chi Minh City-Melbourne	51
Other Routes	628
Total	**1,707**



Ireland

Total Footprint = 1,584 kt CO_2



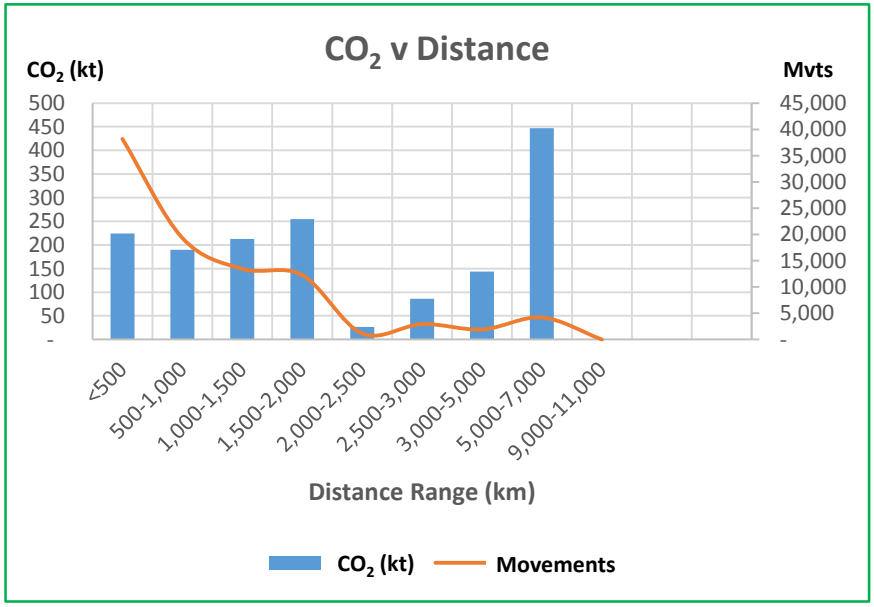


Origin Airports	CO_2 (kt)
Dublin	1,299
Shannon	129
Cork	110
Knock	32
Killarney/Kerry	12
Waterford	3
Carrickfinn	<1
Other Airports	0
Total	**1,584**

Destination Airports	CO_2 (kt)
New York (JFK)	156
London (Heathrow)	81
Abu Dhabi	68
Chicago	68
Boston	66
Dubai	50
Newark	50
London (Gatwick)	45
London (Stansted)	41
Atlanta	40
Malaga	38
Paris (CDG)	38
Amsterdam	30
Faro	29
Philadelphia	28
Other Airports	758
Total	**1,584**

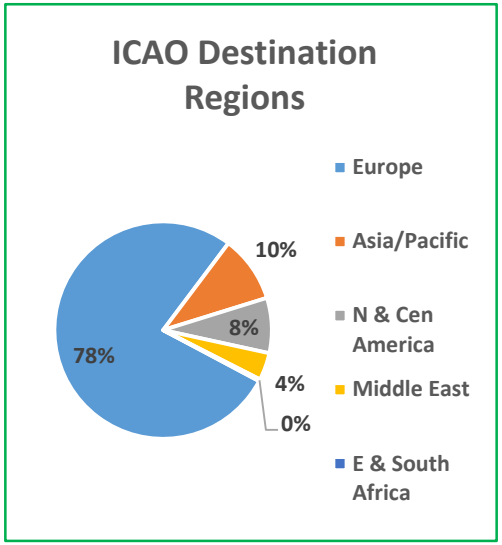
Airlines	CO_2 (kt)
Aer Lingus	665
Ryanair	414
Delta Air Lines	78
Etihad Airways	68
United Airlines	50
Emirates Airline	50
US Airways	37
British Airways	33
Air France	30
American Airlines	21
Scandinavian Airlines System (	18
Lufthansa	16
Wizz Air	13
Continental Airlines	12
Air Transat	11
Other Airlines	66
Total	**1,584**

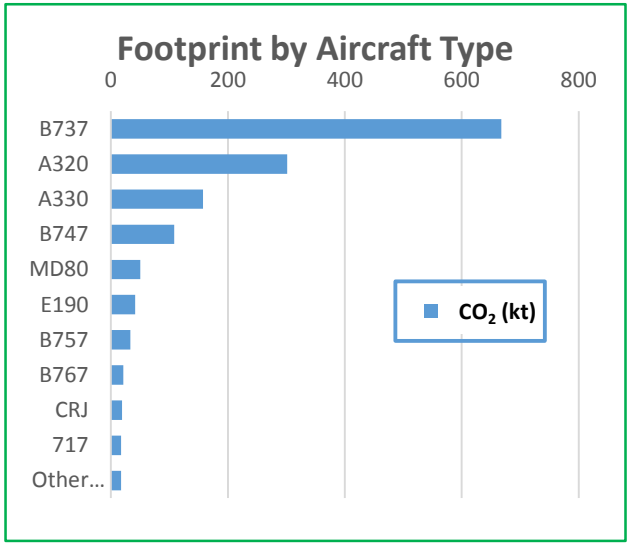
City-Pair Hierarchy	CO_2 (kt)
Dublin-New York (JFK)	107
Dublin-Abu Dhabi	68
Dublin-Chicago	68
Dublin-London (Heathrow)	55
Dublin-Boston	51
Dublin-Dubai	50
Shannon-New York (JFK)	49
Dublin-Atlanta	40
Dublin-Paris (CDG)	33
Dublin-London (Gatwick)	31
Dublin-Malaga	29
Dublin-Philadelphia	28
Dublin-Newark	25
Dublin-Frankfurt	25
Shannon-Newark	25
Other Routes	901
Total	**1,584**



Sweden

Total Footprint = 1,548 kt CO_2



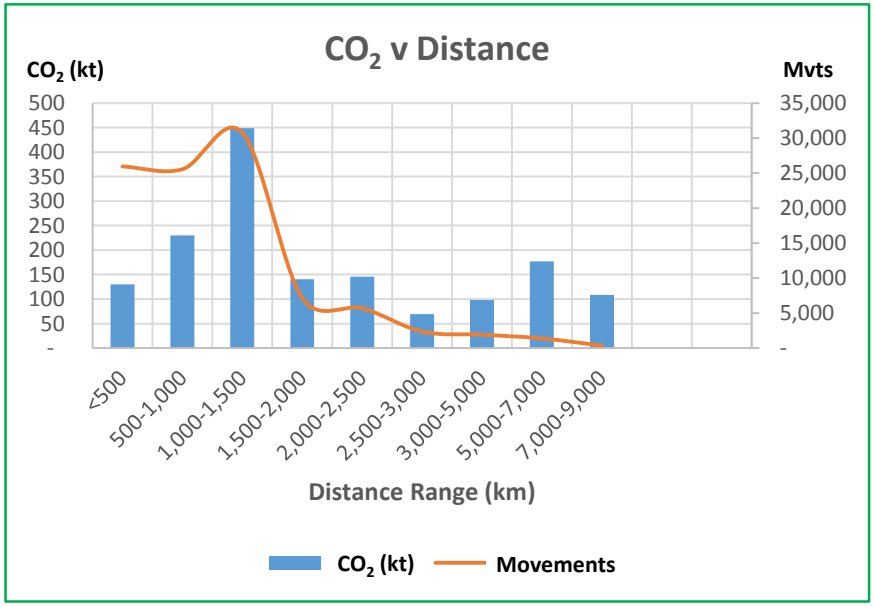


Origin Airports	CO_2 (kt)
Stockholm	1,289
Gothenburg	212
Malmo	27
Linkoping	7
Vaxjo	4
Karlstad	3
Skelleftea	2
Norrkoping	2
Umea	<1
Arvidsjaur	<1
Pajala	<1
Visby	<1
Sveg	<1
Orebro	<1
Torsby	<1
Other Airports	2
Total	**1,548**

Destination Airports	CO_2 (kt)
Bangkok	103
London (Heathrow)	85
Newark	70
Copenhagen	64
Frankfurt	58
Amsterdam	56
Helsinki	52
Chicago	47
Beijing	46
Oslo	45
Istanbul	42
Paris (CDG)	42
Doha	37
Munich	35
Brussels	35
Other Airports	730
Total	**1,548**

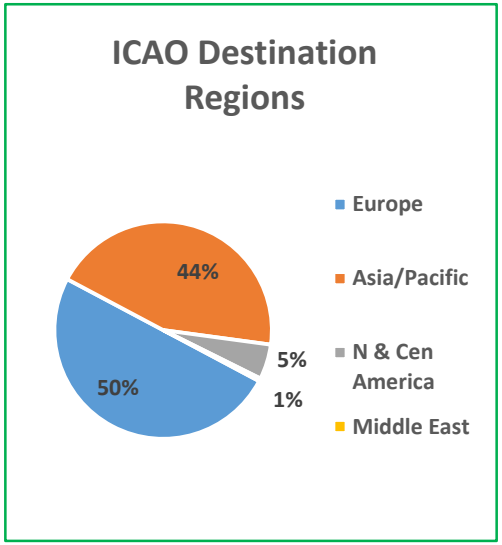
Airlines	CO_2 (kt)
Scandinavian Airlines System (	369
Ryanair	201
Norwegian Air Shuttle	167
Thai Airways International	108
Lufthansa	89
British Airways	53
Air China	46
KLM Royal Dutch Airlines	43
Turkish Airlines	38
Qatar Airways	37
Wizz Air	34
Finnair	27
Air France	27
Brussels Airlines	25
Blue1	24
Other Airlines	260
Total	**1,548**

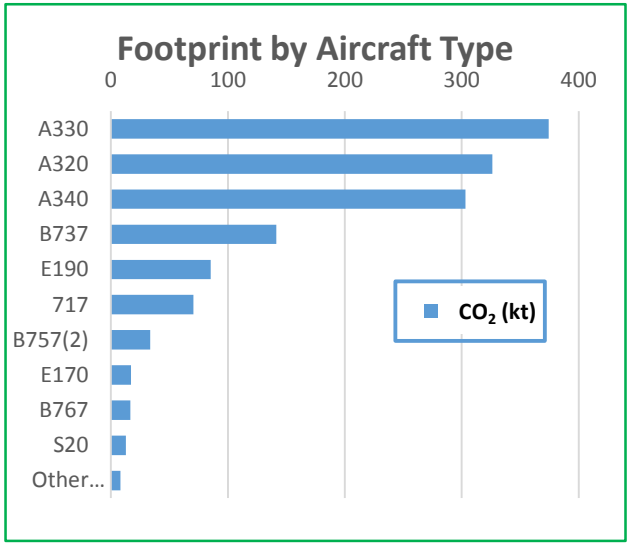
City-Pair Hierarchy	CO_2 (kt)
Stockholm-Bangkok	103
Stockholm-Newark	70
Stockholm-London (Heathrow)	67
Stockholm-Copenhagen	50
Stockholm-Chicago	47
Stockholm-Beijing	46
Stockholm-Oslo	42
Stockholm-Helsinki	42
Stockholm-Frankfurt	40
Stockholm-Doha	37
Stockholm-Amsterdam	37
Stockholm-Paris (CDG)	34
Stockholm-Istanbul	31
Stockholm-Barcelona	29
Stockholm-Zurich	28
Other Routes	848
Total	**1,548**



Finland

Total Footprint = 1,413 kt CO_2



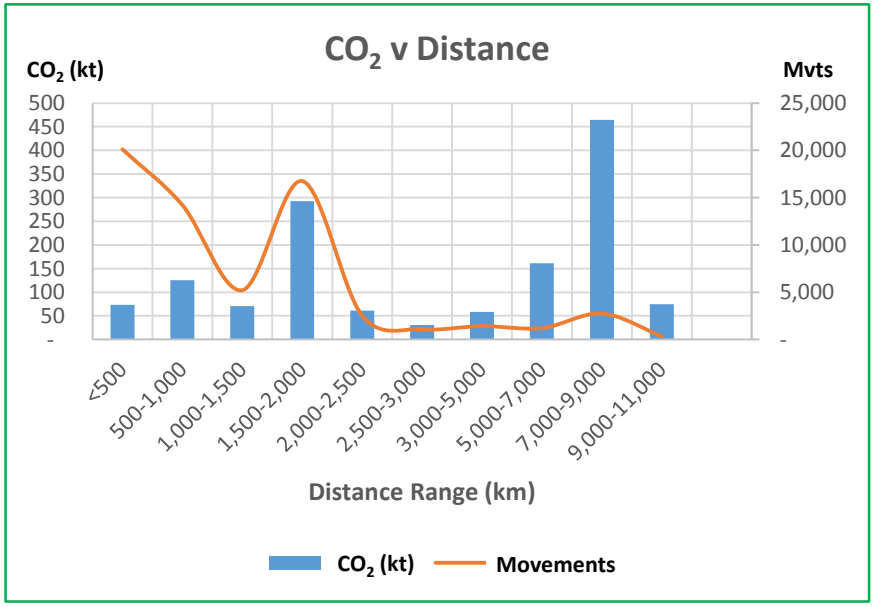


Origin Airports	CO_2 (kt)
Helsinki	1,335
Tampere	33
Turku	18
Vaasa	8
Lappeenranta	7
Oulu	6
Kokkola/Pietarsaari	2
Mariehamn	2
Pori	1
Kittila	<1
Kajaani	<1
Jyvõskylõ	<1
Joensuu	<1
Rovaniemi	<1
Ivalo	<1
Other Airports	2
Total	**1,413**

Destination Airports	CO_2 (kt)
Bangkok	89
Singapore	75
Tokyo (Narita)	73
Hong Kong	71
Copenhagen	62
Shanghai	59
Osaka	57
Stockholm	56
Nagoya	54
New York (JFK)	51
Beijing	49
Seoul	46
London (Heathrow)	43
Paris (CDG)	35
Delhi	35
Other Airports	558
Total	**1,413**

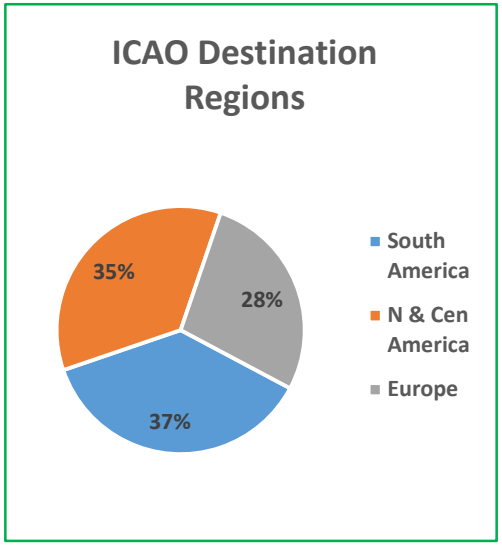
Airlines	CO_2 (kt)
Finnair	1,031
Blue1	70
Norwegian Air Shuttle	55
Lufthansa	49
Ryanair	38
Scandinavian Airlines System (	20
KLM Royal Dutch Airlines	19
American Airlines	17
Turkish Airlines	15
British Airways	15
Air Finland	14
Air Berlin	14
Air Baltic	12
TAP Portugal	8
Icelandair	7
Other Airlines	29
Total	**1,413**

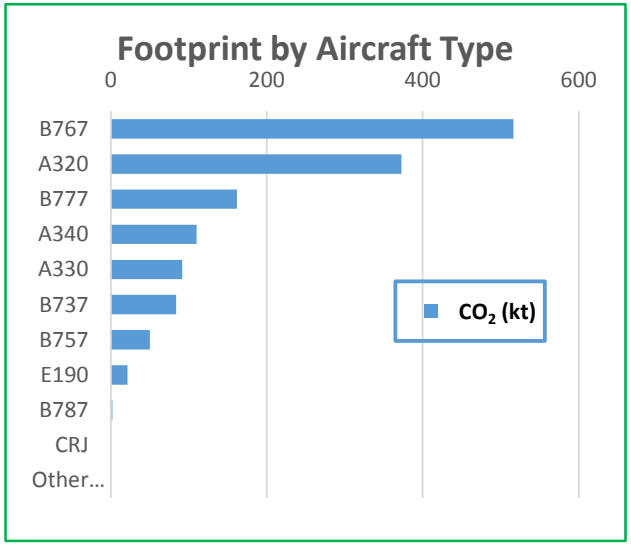
City-Pair Hierarchy	CO_2 (kt)
Helsinki-Bangkok	89
Helsinki-Singapore	75
Helsinki-Tokyo (Narita)	73
Helsinki-Hong Kong	71
Helsinki-Shanghai	59
Helsinki-Osaka	57
Helsinki-Nagoya	54
Helsinki-New York (JFK)	51
Helsinki-Copenhagen	49
Helsinki-Beijing	49
Helsinki-Seoul	46
Helsinki-London (Heathrow)	43
Helsinki-Stockholm	42
Helsinki-Paris (CDG)	35
Helsinki-Delhi	35
Other Routes	585
Total	**1,413**



Peru

Total Footprint = 1,410 kt CO_2



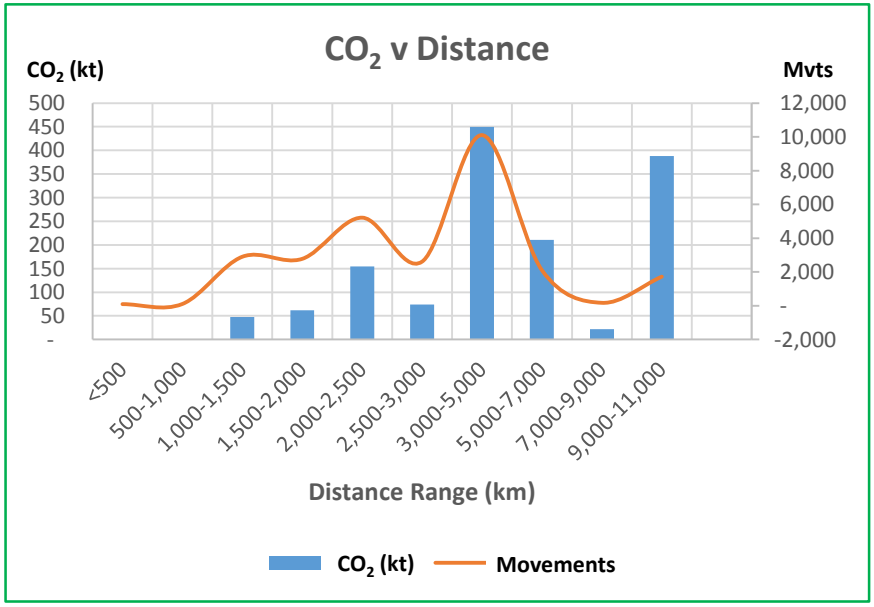


Origin Airports	CO_2 (kt)
Lima	1,408
Cuzco	<1
Arequipa	<1
Iquitos	<1
Other Airports	0
Total	**1,408**

Destination Airports	CO_2 (kt)
Madrid	226
Miami	119
Santiago de Chile	111
Amsterdam	98
Buenos Aires	97
Los Angeles	67
Sao Paulo	65
Paris (CDG)	63
Mexico City	60
Bogota	51
Panama City	43
New York (JFK)	40
Atlanta	34
Caracas	32
Houston	32
Other Airports	269
Total	**1,410**

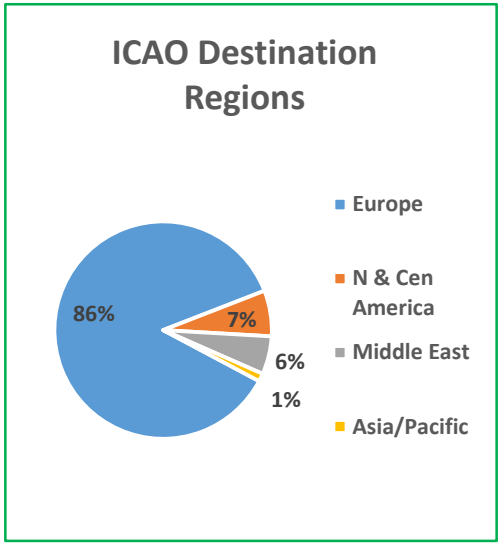
Airlines	CO_2 (kt)
LAN Airlines	568
TACA Airlines	213
Iberia Airlines	101
KLM Royal Dutch Airlines	98
Air Europa	64
Air France	63
United Airlines	46
American Airlines	45
Copa Airlines	43
Delta Air Lines	34
AeroMéxico	29
Avianca - Aerovias Nacionales	23
LACSA	19
Air Canada	17
TAM Airlines (TAM Linhas Aer	15
Other Airlines	33
Total	**1,410**

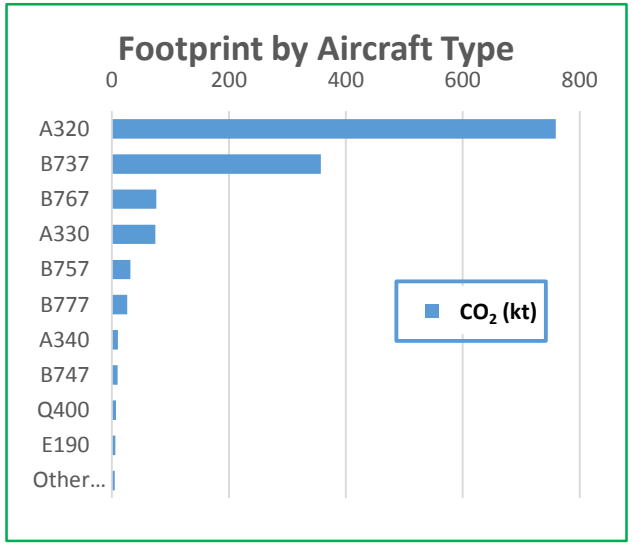
City-Pair Hierarchy	CO_2 (kt)
Lima-Madrid	226
Lima-Miami	119
Lima-Santiago de Chile	111
Lima-Amsterdam	98
Lima-Buenos Aires	97
Lima-Los Angeles	67
Lima-Sao Paulo	65
Lima-Paris (CDG)	63
Lima-Mexico City	60
Lima-Bogota	51
Lima-Panama City	43
Lima-New York (JFK)	40
Lima-Atlanta	34
Lima-Caracas	32
Lima-Houston	32
Other Routes	270
Total	**1,410**



Greece

Total Footprint = 1,392 kt CO_2



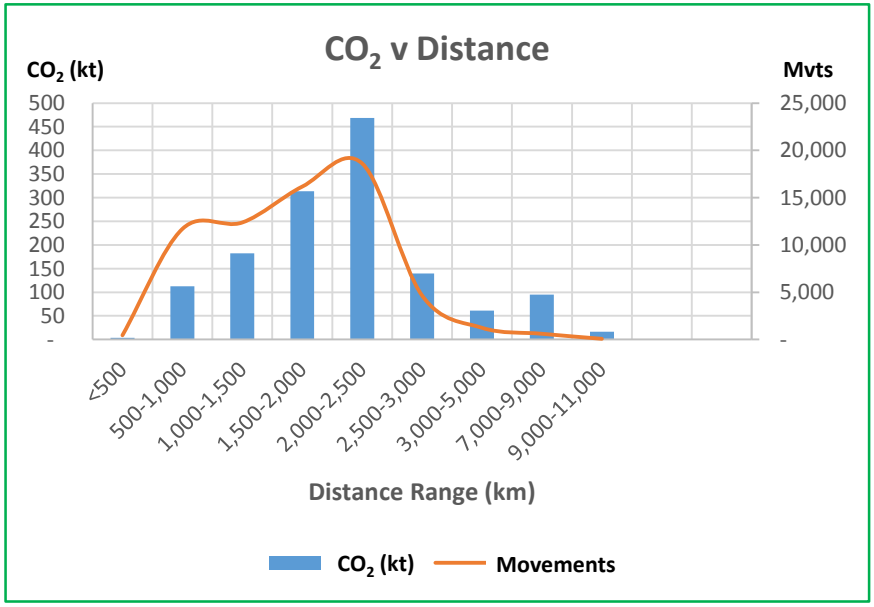


Origin Airports	CO_2 (kt)
Athens	723
Heraklion	158
Thessaloniki	152
Rhodos	108
Kos	58
Kerkyra	57
Chania	42
Santorini	18
Mykonos Island	15
Zakinthos	14
Kefallinia Island	8
Kavala	7
Samos	7
Patras	7
Volos	5
Other Airports	13
Total	**1,392**

Destination Airports	CO_2 (kt)
London (Heathrow)	69
London (Gatwick)	68
Larnaca	59
Munich	58
Paris (CDG)	55
Frankfurt	53
Moscow	52
New York (JFK)	50
Roma	43
Brussels	37
Amsterdam	36
Zurich	36
Dusseldorf	35
Milano	32
Wien	28
Other Airports	681
Total	**1,392**

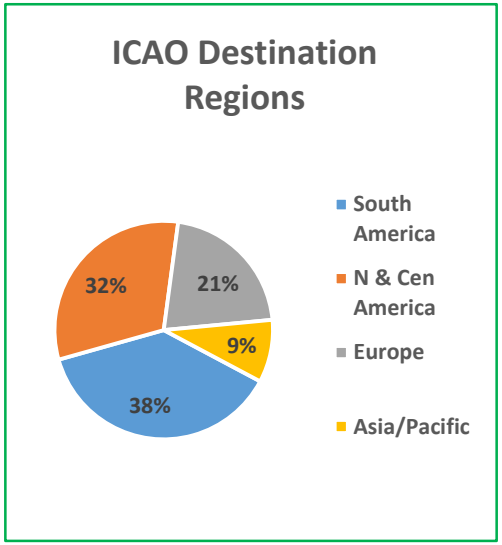
Airlines	CO_2 (kt)
Aegean Airlines	202
Easyjet	123
Ryanair	101
TUIfly	54
Air Berlin	50
Delta Air Lines	45
Thomson	44
British Airways	43
Air France	40
Lufthansa	37
Swiss European Air Lines	36
Condor Flugdienst	34
Olympic Airlines	34
Emirates Airline	27
Transavia	27
Other Airlines	494
Total	**1,392**

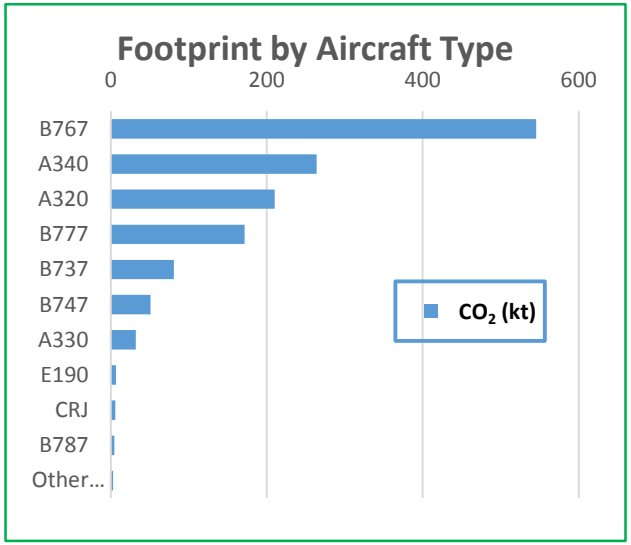
City-Pair Hierarchy	CO_2 (kt)
Athens-London (Heathrow)	69
Athens-New York (JFK)	50
Athens-Paris (CDG)	49
Athens-Larnaca	42
Athens-Roma	28
Athens-Munich	27
Athens-Dubai	27
Athens-Frankfurt	27
Athens-Brussels	21
Athens-Doha	21
Athens-Istanbul	20
Athens-Philadelphia	20
Athens-Zurich	19
Athens-Amsterdam	18
Athens-Milano	17
Other Routes	936
Total	**1,392**



Chile

Total Footprint = 1,375 kt CO_2



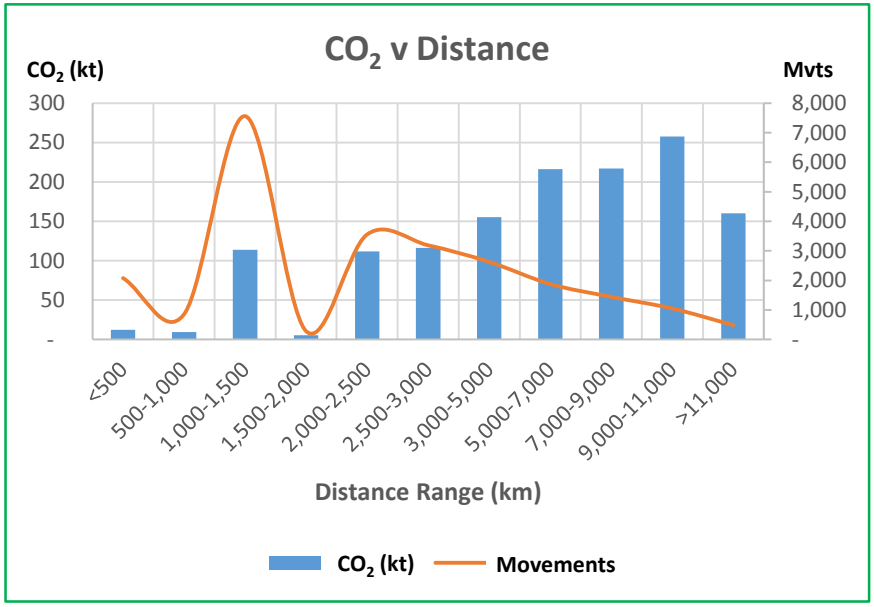


Origin Airports	CO_2 (kt)
Santiago de Chile	1,356
Isla de Pascua	10
Iquique	4
Arica	3
Antofagasta	2
Punta Arenas	<1
Other Airports	0
Total	**1,375**

Destination Airports	CO_2 (kt)
Madrid	185
Miami	125
Lima	119
Paris (CDG)	109
Sao Paulo	97
Buenos Aires	94
Mexico City	73
Auckland	73
Panama City	65
Bogota	60
Toronto	57
New York (JFK)	53
Dallas-Fort Worth	51
Sydney	51
Atlanta	49
Other Airports	114
Total	**1,375**

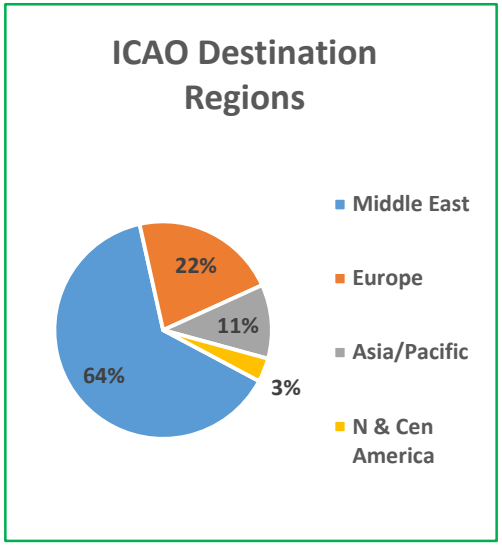
Airlines	CO_2 (kt)
LAN Airlines	682
Air France	109
American Airlines	104
Iberia Airlines	92
Air Canada	67
Copa Airlines	65
Qantas	51
Delta Air Lines	49
TAM Airlines (TAM Linhas Aer	36
Avianca - Aerovias Nacionales	33
AeroMéxico	30
Sky Airline	15
Aerolineas Argentinas	13
Gol Transportes Aéreos	7
LACSA	7
Other Airlines	15
Total	**1,375**

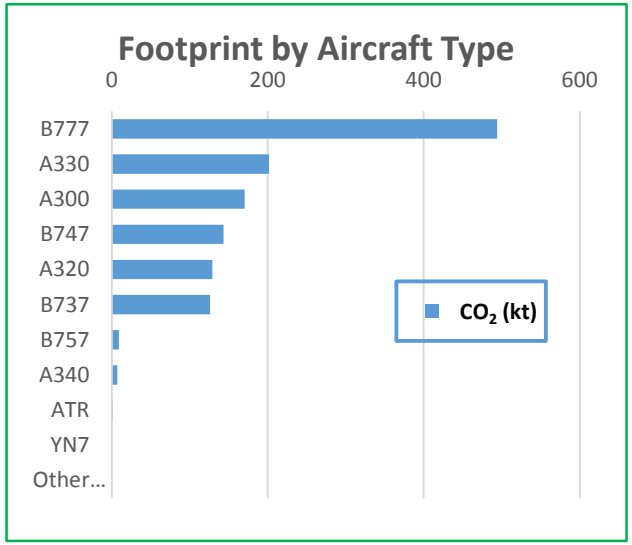
City-Pair Hierarchy	CO_2 (kt)
Santiago de Chile-Madrid	185
Santiago de Chile-Miami	125
Santiago de Chile-Lima	111
Santiago de Chile-Paris (CDG)	109
Santiago de Chile-Sao Paulo	97
Santiago de Chile-Buenos Aires	94
Santiago de Chile-Mexico City	73
Santiago de Chile-Auckland	73
Santiago de Chile-Panama City	65
Santiago de Chile-Bogota	60
Santiago de Chile-Toronto	57
Santiago de Chile-New York (JFK)	53
Santiago de Chile-Dallas-Fort Worth	51
Santiago de Chile-Sydney	51
Santiago de Chile-Atlanta	49
Other Routes	122
Total	**1,375**



Morocco

Total Footprint = 1,327 kt CO_2



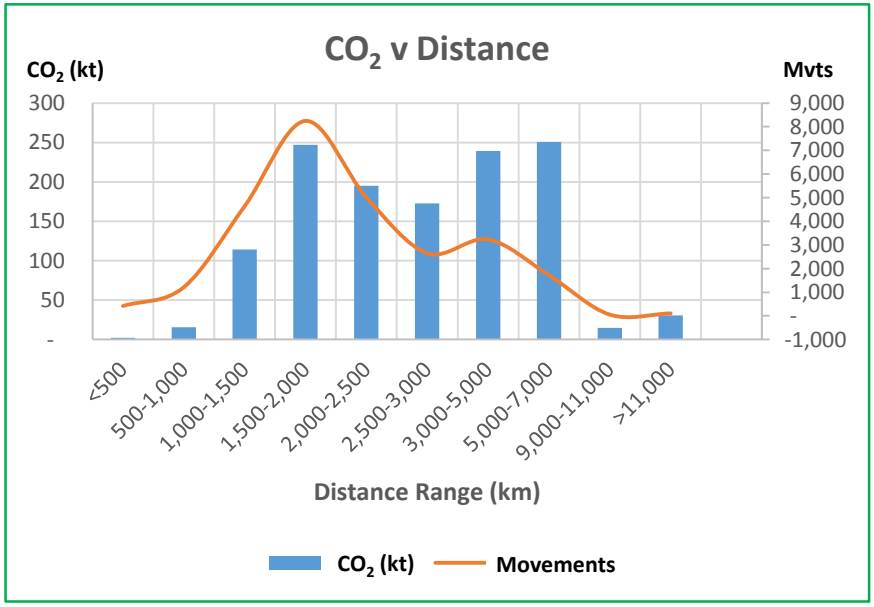


Origin Airports	CO_2 (kt)
Casablanca	820
Marrakech	231
Agadir	80
Tanger	53
Fes	41
Nador	41
Rabat	28
Oujda	25
Essaouira	3
Al Hoceima	3
Ouarzazate	2
Tetuan	<1
El Aaiun	<1
Goulimime	<1
Other Airports	0
Total	**1,326**

Destination Airports	CO_2 (kt)
Paris (Orly)	168
Paris (CDG)	74
Dubai	54
Jeddah	53
Brussels	48
Marseille Provence	42
Istanbul	41
Charleroi	39
Montreal	36
Amsterdam	35
Abu Dhabi	35
Tunis	34
New York (JFK)	34
Madrid	30
Lyon	30
Other Airports	573
Total	**1,327**

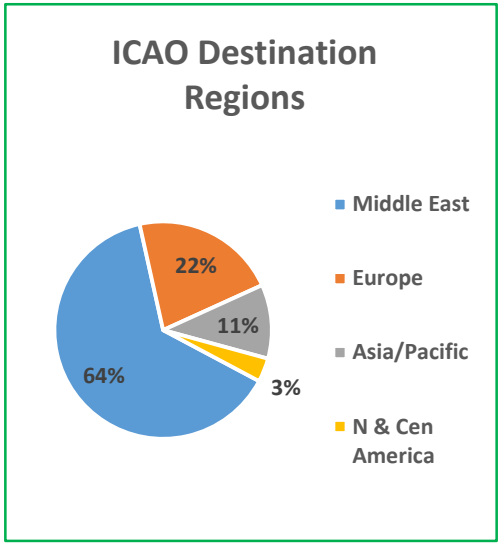
Airlines	CO_2 (kt)
Royal Air Maroc	630
Ryanair	105
Easyjet	80
Jetairfly	65
Air Arabia Maroc	58
Emirates Airline	54
Air France	54
Saudi Arabian Airlines	37
Etihad Airways	35
Turkish Airlines	26
Thomson	26
Iberia Airlines	16
Qatar Airways	16
Jet4you	15
EgyptAir	14
Other Airlines	96
Total	**1,327**

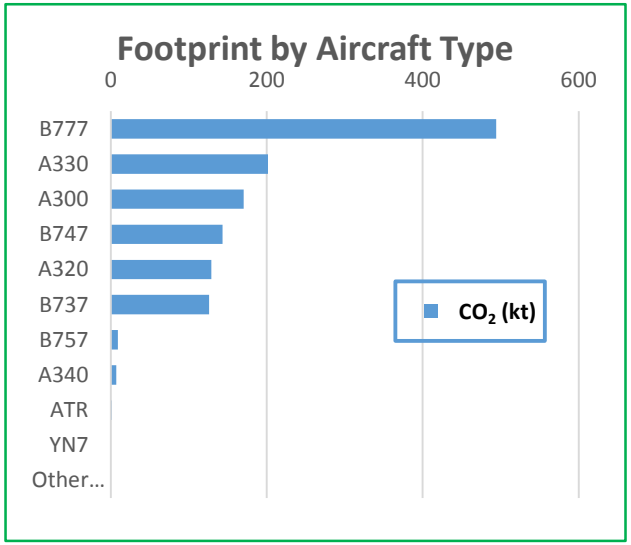
City-Pair Hierarchy	CO_2 (kt)
Casablanca-Paris (Orly)	54
Casablanca-Dubai	54
Casablanca-Jeddah	51
Marrakech-Paris (Orly)	50
Casablanca-Istanbul	41
Casablanca-Paris (CDG)	38
Casablanca-Montreal	36
Casablanca-Abu Dhabi	35
Casablanca-Tunis	34
Casablanca-New York (JFK)	34
Agadir-Paris (Orly)	25
Casablanca-Cairo	24
Casablanca-Milano	20
Casablanca-Brussels	19
Marrakech-London (Gatwick)	19
Other Routes	794
Total	**1,327**



Pakistan

Total Footprint = 1,282 kt CO_2



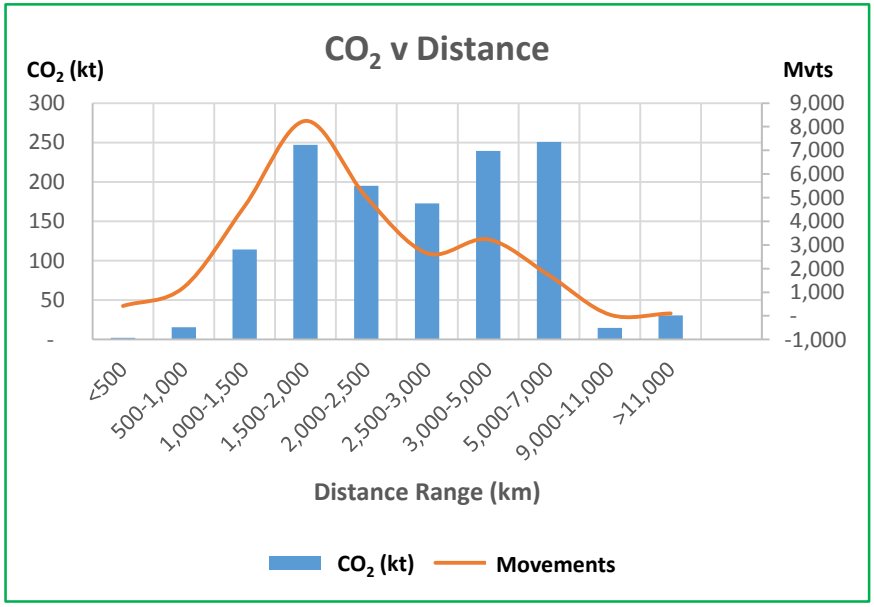


Origin Airports	CO_2 (kt)
Karachi	393
Islamabad	377
Lahore	374
Peshawar	109
Sialkot	23
Quetta	2
Faisalabad	2
Rahim Yar Khan	<1
Turbat	<1
Multan	<1
Gwadar	<1
Other Airports	0
Total	**1,280**

Destination Airports	CO_2 (kt)
Dubai	222
Jeddah	183
Riyadh	103
Abu Dhabi	83
London (Heathrow)	80
Manchester	75
Bangkok	73
Doha	49
Muscat	46
Toronto	45
Bahrain	32
Birmingham	30
Sharjah	27
Dammam	26
Kuwait City	26
Other Airports	182
Total	**1,282**

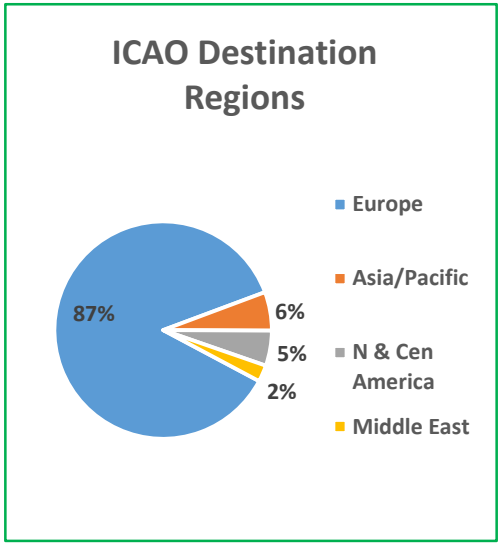
Airlines	CO_2 (kt)
Riau Airlines	589
Saudi Arabian Airlines	142
Emirates Airline	118
Shaheen Air International	68
Thai Airways International	54
Qatar Airways	45
Etihad Airways	40
Airblue	30
Gulf Air Bahrain	30
Air Berlin	27
Nas Air	26
Turkish Airlines	21
Oman Air	19
Cathay Pacific	17
Kuwait Airways	11
Other Airlines	44
Total	**1,282**

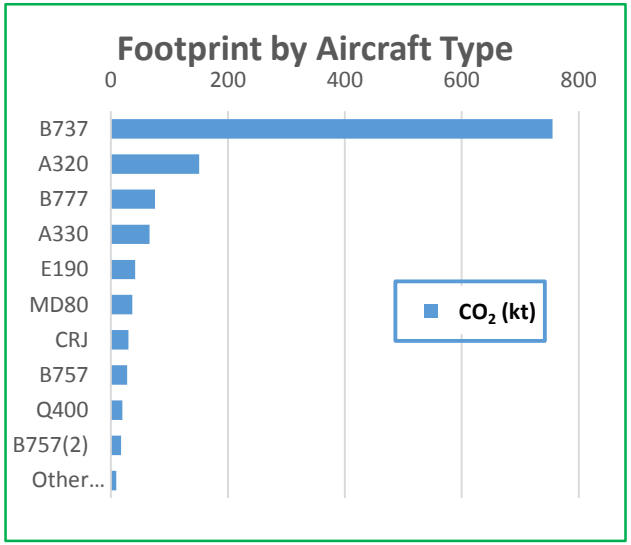
City-Pair Hierarchy	CO_2 (kt)
Karachi-Dubai	92
Karachi-Jeddah	70
Lahore-Jeddah	59
Lahore-Dubai	53
Islamabad-Dubai	45
Lahore-Manchester	40
Islamabad-Jeddah	39
Islamabad-Manchester	34
Karachi-Bangkok	34
Islamabad-London (Heathrow)	32
Islamabad-Birmingham	30
Islamabad-Riyadh	30
Lahore-Abu Dhabi	30
Peshawar-Dubai	28
Lahore-London (Heathrow)	27
Other Routes	637
Total	**1,282**



Norway

Total Footprint = 1,276 kt CO_2



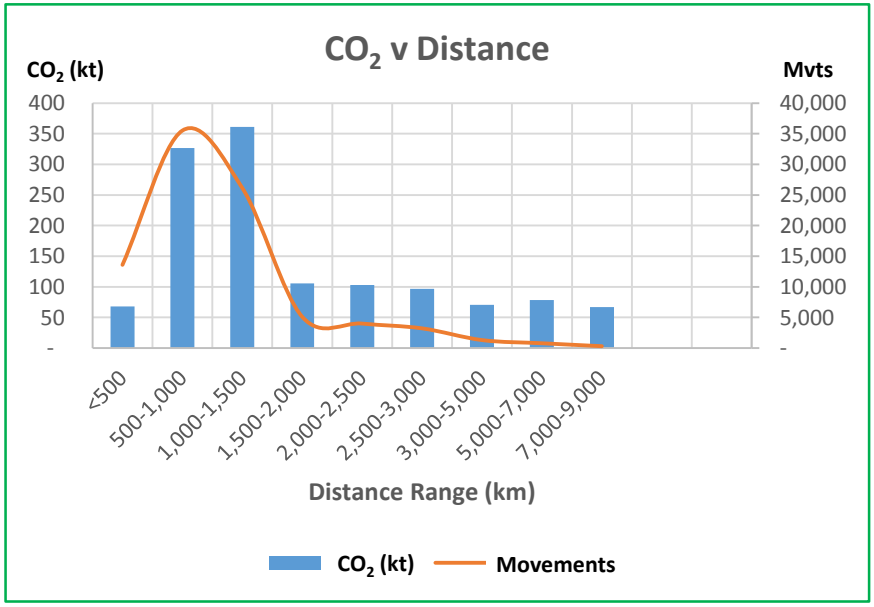


Origin Airports	CO_2 (kt)
Oslo	835
Rygge	115
Bergen	96
Stavanger	94
Sandefjord	63
Trondheim	43
Haugesund	11
Kristiansand	9
Alesund	7
Tromso	1
Bodo	1
Evenes	<1
Roros	<1
Other Airports	0
Total	**1,275**

Destination Airports	CO_2 (kt)
Copenhagen	109
Amsterdam	84
Newark	67
Bangkok	66
London (Heathrow)	65
Stockholm	50
Frankfurt	48
Alicante	44
Malaga	38
London (Gatwick)	37
Doha	27
Las Palmas	26
Paris (CDG)	26
Reykjavik	25
Berlin	25
Other Airports	538
Total	**1,276**

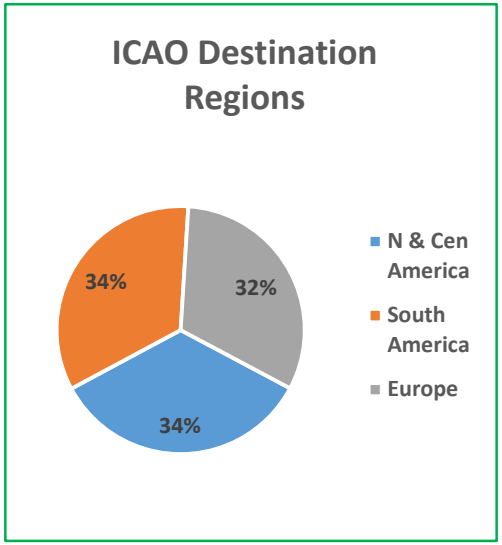
Airlines	CO_2 (kt)
Scandinavian Airlines System (	318
Norwegian Air Shuttle	314
Ryanair	147
KLM Royal Dutch Airlines	73
Thai Airways International	66
Lufthansa	57
British Airways	31
Qatar Airways	27
Wizz Air	27
United Airlines	21
Wideroe	19
Turkish Airlines	18
Icelandair	18
Air Baltic	16
Aeroflot Russian Airlines	12
Other Airlines	114
Total	**1,276**

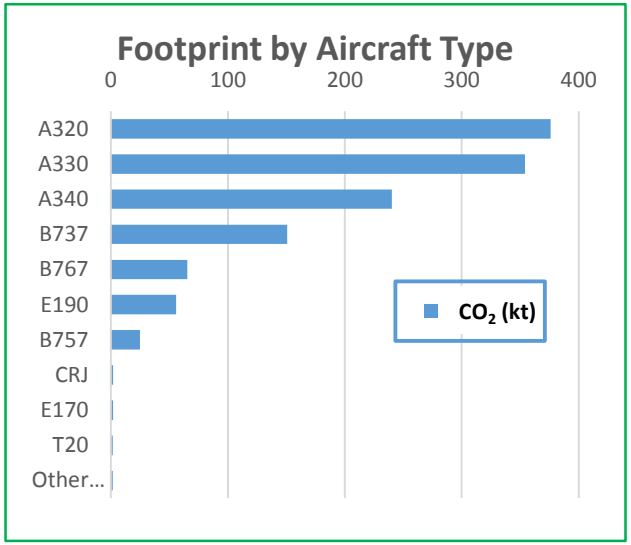
City-Pair Hierarchy	CO_2 (kt)
Oslo-Newark	67
Oslo-Bangkok	66
Oslo-Copenhagen	54
Oslo-London (Heathrow)	47
Oslo-Stockholm	42
Oslo-Amsterdam	35
Oslo-Frankfurt	34
Oslo-Doha	27
Oslo-Paris (CDG)	25
Oslo-Munich	23
Oslo-Helsinki	21
Oslo-Reykjavik	21
Bergen-Copenhagen	20
Oslo-Istanbul	18
Oslo-Alicante	18
Other Routes	758
Total	**1,276**



Colombia

Total Footprint = 1,275 kt CO_2



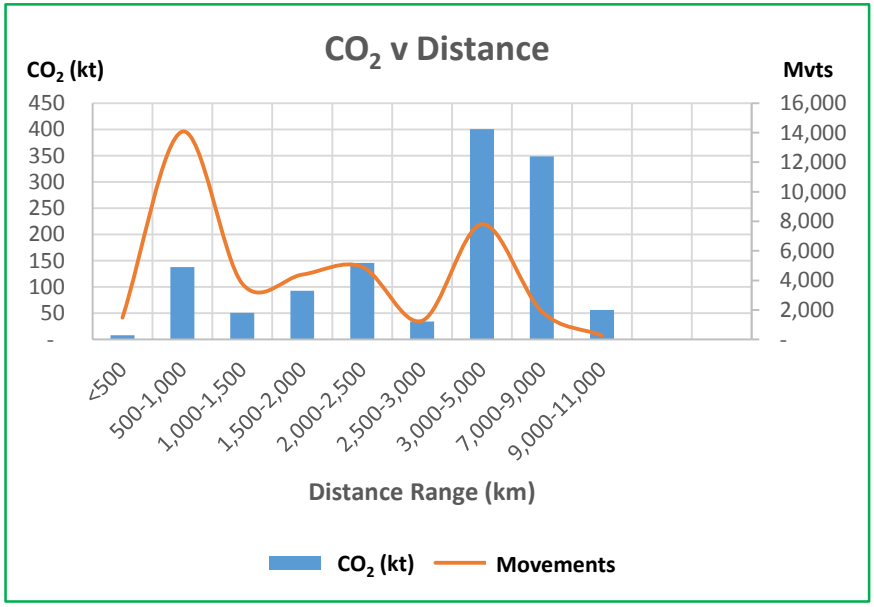


Origin Airports	CO_2 (kt)
Bogota	1,077
Cali	85
Rio Negro	76
Cartagena de Indias	16
Barranquilla	11
Armenia	3
Pereira	2
Cucuta	1
Bucaramanga	1
San Andreas Island	1
Rio Hacha	<1
Other Airports	0
Total	**1,274**

Destination Airports	CO_2 (kt)
Madrid	241
Miami	128
Panama City	73
Sao Paulo	72
Paris (CDG)	69
New York (JFK)	67
Santiago de Chile	60
Mexico City	59
Frankfurt	56
Lima	54
Quito	43
Buenos Aires	41
Barcelona	39
Fort Lauderdale	38
Caracas	35
Other Airports	200
Total	**1,275**

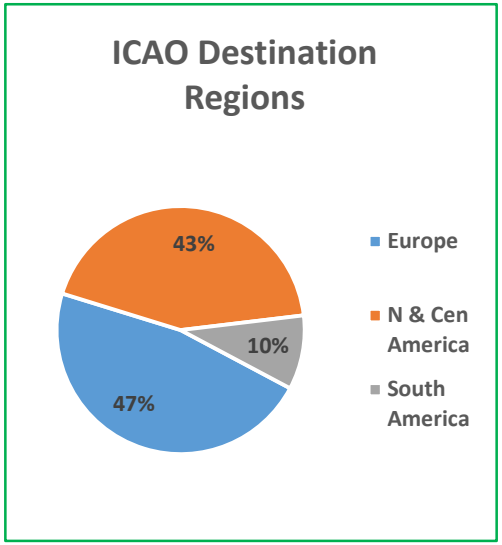
Airlines	CO_2 (kt)
Avianca - Aerovias Nacionales	596
Iberia Airlines	95
Copa Airlines	90
Air France	69
LAN Airlines	66
Lufthansa	56
American Airlines	55
United Airlines	33
Delta Air Lines	30
TACA Airlines	28
Spirit Airlines	22
Aerolineas Argentinas	20
Aerolineas Galapagos (Aeroga	19
Air Canada	17
JetBlue Airways	17
Other Airlines	62
Total	**1,275**

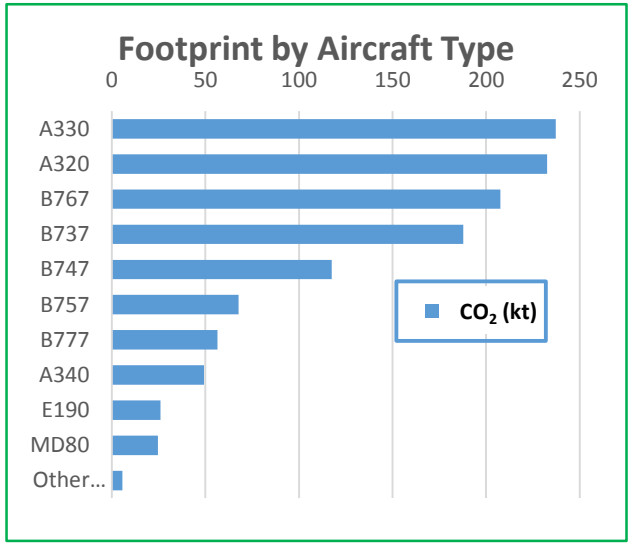
City-Pair Hierarchy	CO_2 (kt)
Bogota-Madrid	172
Bogota-Miami	78
Bogota-Sao Paulo	72
Bogota-Paris (CDG)	69
Bogota-Santiago de Chile	60
Bogota-New York (JFK)	60
Bogota-Mexico City	59
Bogota-Frankfurt	56
Bogota-Lima	52
Cali-Madrid	50
Bogota-Buenos Aires	41
Bogota-Barcelona	39
Bogota-Panama City	36
Bogota-Quito	35
Bogota-Caracas	32
Other Routes	363
Total	**1,275**



Dominican Republic

Total Footprint = 1,231 kt CO_2



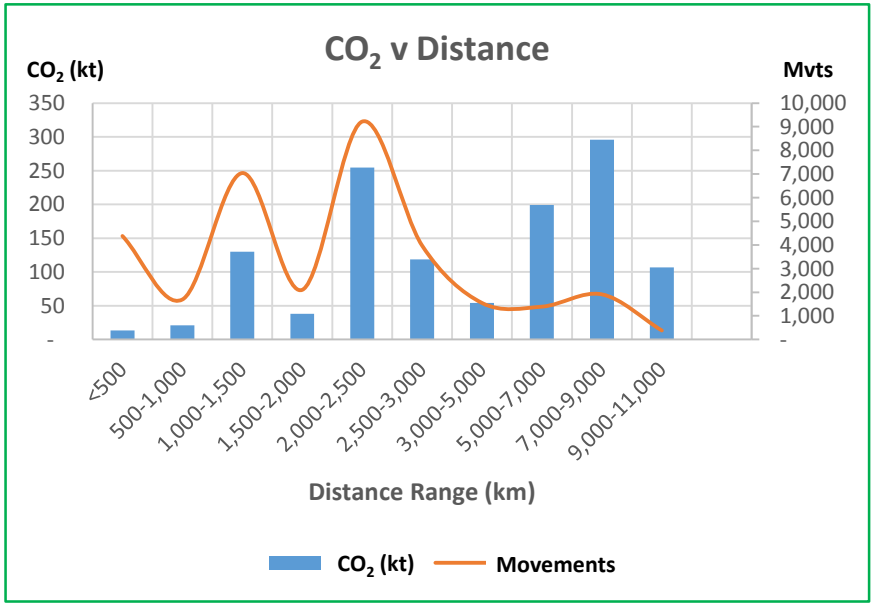


Origin Airports	CO_2 (kt)
Higuey	611
Santo Domingo	408
Santiago de los Caba	102
Puerto Plata	70
La Romana	27
San Jose	12
Other Airports	0
Total	**1,231**

Destination Airports	CO_2 (kt)
New York (JFK)	197
Madrid	162
Moscow	107
Paris (CDG)	92
Frankfurt	83
Miami	72
Panama City	56
Toronto	40
Atlanta	40
Newark	35
Dusseldorf	29
Montreal	23
Lima	19
Boston	18
Charlotte	17
Other Airports	241
Total	**1,231**

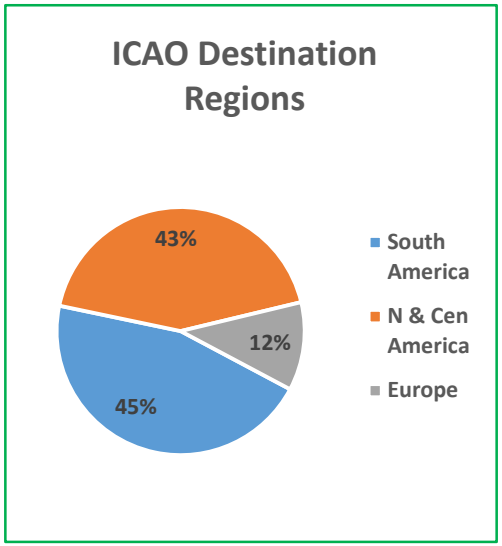
Airlines	CO_2 (kt)
JetBlue Airways	154
American Airlines	110
Condor Flugdienst	93
Air Europa	90
Transaero Airlines	88
Delta Air Lines	68
Air France	54
Copa Airlines	54
Iberia Airlines	49
Air Berlin	49
XL Airways France	46
US Airways	32
United Airlines	27
Aeroflot Russian Airlines	25
Flexflight	24
Other Airlines	268
Total	**1,231**

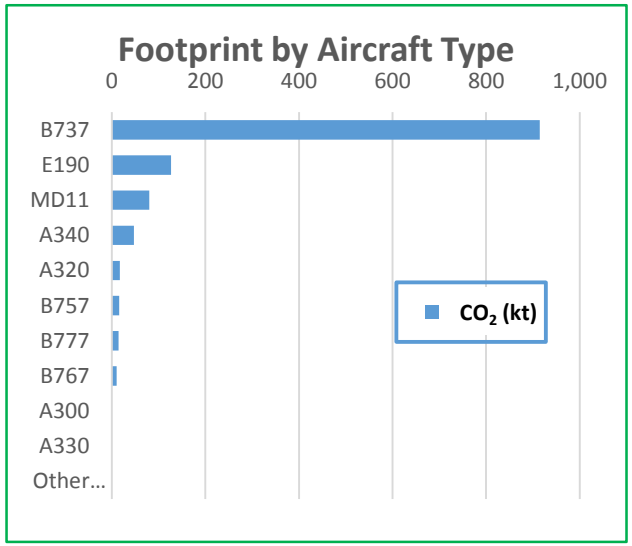
City-Pair Hierarchy	CO_2 (kt)
Higuey-Moscow	107
Santo Domingo-Madrid	105
Santiago de los Caballeros-New York	84
Santo Domingo-New York (JFK)	82
Higuey-Madrid	56
Higuey-Paris (CDG)	52
Higuey-Frankfurt	37
Santo Domingo-Miami	33
Santo Domingo-Panama City	32
Santo Domingo-Paris (CDG)	32
Higuey-Atlanta	31
Higuey-Toronto	28
Santo Domingo-Frankfurt	23
Higuey-Miami	21
Higuey-Dusseldorf	21
Other Routes	488
Total	**1,231**



Panama

Total Footprint = 1,227 kt CO_2



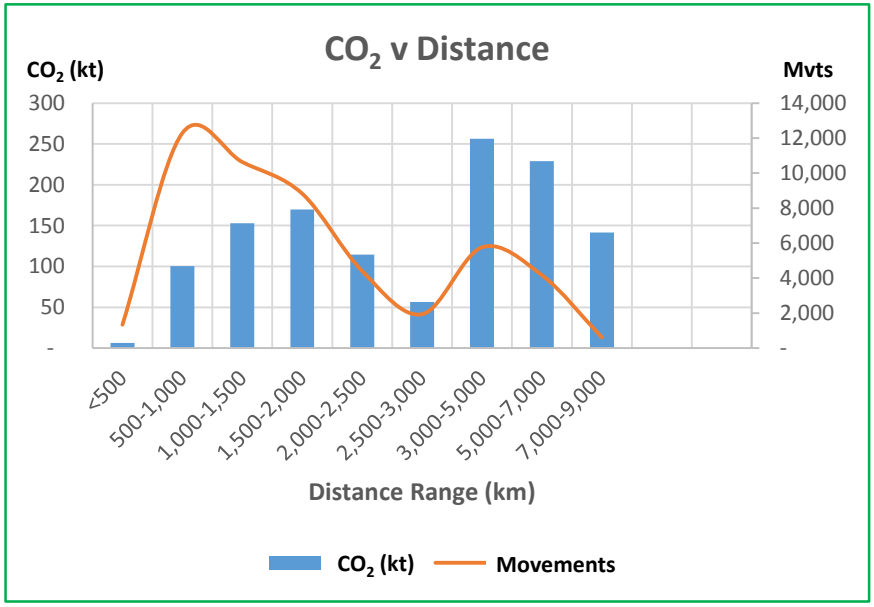


Origin Airports	CO_2 (kt)
Panama City	1,227
David	<1
Bocas del Toro	<1
Other Airports	0
Total	**1,227**

Destination Airports	CO_2 (kt)
Amsterdam	94
Sao Paulo	72
Santiago de Chile	65
Miami	58
Buenos Aires	49
Madrid	47
Lima	43
Rio de Janeiro	41
Mexico City	40
Los Angeles	37
Bogota	35
La Habana	33
Santo Domingo	32
Caracas	29
New York (JFK)	28
Other Airports	524
Total	**1,227**

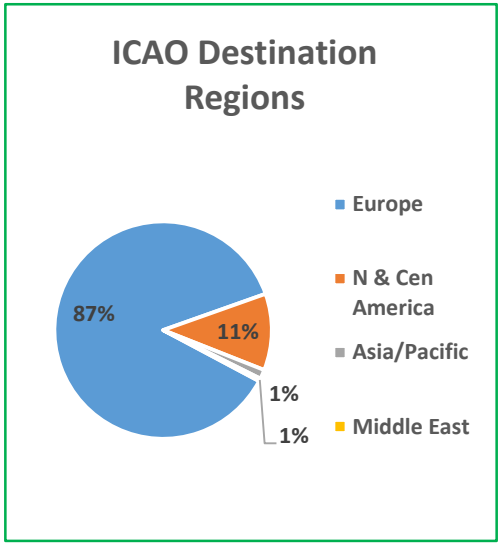
Airlines	CO_2 (kt)
Copa Airlines	945
KLM Royal Dutch Airlines	94
Iberia Airlines	47
United Airlines	30
American Airlines	26
Gol Transportes Aéreos	13
Avianca - Aerovias Nacionales	12
Delta Air Lines	12
Continental Airlines	11
Santa Barbara Airlines	10
LACSA	6
TACA Airlines	5
Spirit Airlines	4
TAME	3
Aerosur	2
Other Airlines	5
Total	**1,227**

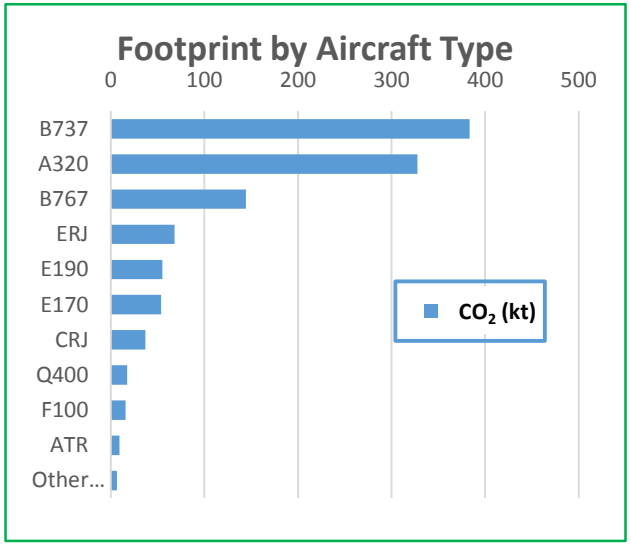
City-Pair Hierarchy	CO_2 (kt)
Panama City-Amsterdam	94
Panama City-Sao Paulo	72
Panama City-Santiago de Chile	65
Panama City-Miami	58
Panama City-Buenos Aires	49
Panama City-Madrid	47
Panama City-Lima	43
Panama City-Rio de Janeiro	41
Panama City-Mexico City	40
Panama City-Los Angeles	37
Panama City-Bogota	35
Panama City-La Habana	33
Panama City-Santo Domingo	32
Panama City-Caracas	29
Panama City-New York (JFK)	28
Other Routes	524
Total	**1,227**



Poland

Total Footprint = 1,127 kt CO_2



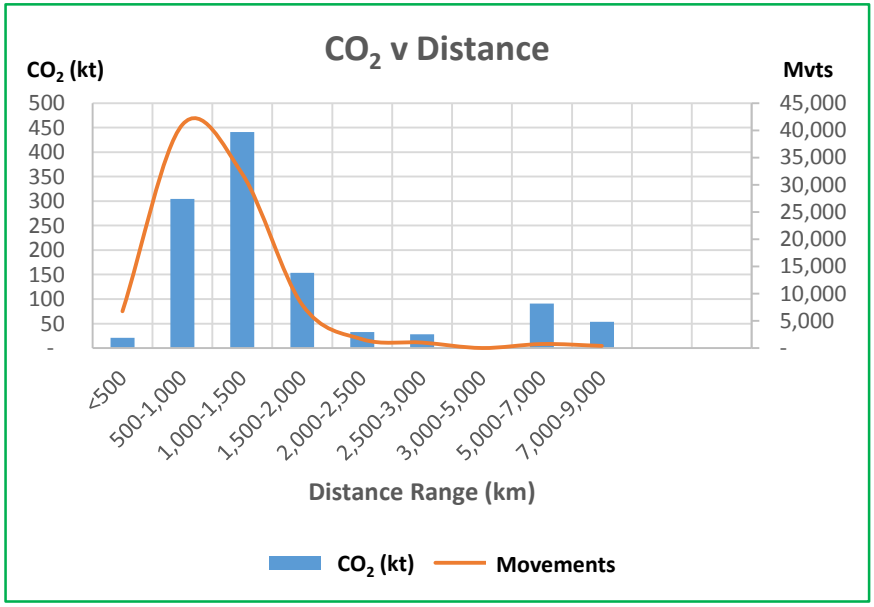


Origin Airports	CO_2 (kt)
Warsaw	597
Krakow	156
Gdansk	100
Katowice	85
Wroclaw	67
Poznan	53
Rzeszow	24
Lodz	22
Bydgoszcz	14
Szczecin	9
Other Airports	0
Total	**1,127**

Destination Airports	CO_2 (kt)
London (Stansted)	63
Frankfurt	56
London (Luton)	54
Chicago	48
Dublin	45
Munich	43
Paris (CDG)	39
Toronto	30
New York (JFK)	30
London (Heathrow)	28
Roma	25
Liverpool	22
Amsterdam	22
Stockholm	21
Newark	19
Other Airports	579
Total	**1,127**

Airlines	CO_2 (kt)
LOT Polish Airlines	358
Ryanair	271
Wizz Air	204
Lufthansa	74
Easyjet	25
Norwegian Air Shuttle	23
Air France	21
Scandinavian Airlines System (	14
KLM Royal Dutch Airlines	14
Swiss European Air Lines	13
Aeroflot Russian Airlines	13
British Airways	12
Aer Lingus	10
Finnair	8
TAP Portugal	7
Other Airlines	58
Total	**1,127**

City-Pair Hierarchy	CO_2 (kt)
Warsaw-Chicago	48
Warsaw-Paris (CDG)	32
Warsaw-Toronto	30
Warsaw-New York (JFK)	30
Warsaw-London (Heathrow)	28
Warsaw-Frankfurt	27
Warsaw-Amsterdam	21
Warsaw-Newark	19
Warsaw-London (Luton)	19
Warsaw-Moscow	17
Warsaw-Zurich	17
Warsaw-Munich	16
Warsaw-Tel Aviv	15
Warsaw-Roma	14
Warsaw-Brussels	13
Other Routes	780
Total	**1,127**



Profile F3

Airport Footprint Profiles

Profile F3 contains carbon footprint profiles for the 15 airports listed at the bottom of the figure to the right. The top 20 airports capture about 40% of the global carbon footprint for scheduled international passenger flights in 2012.

The profiles for the top five airports (dark orange colour in the figure), are contained in Chapter 5.

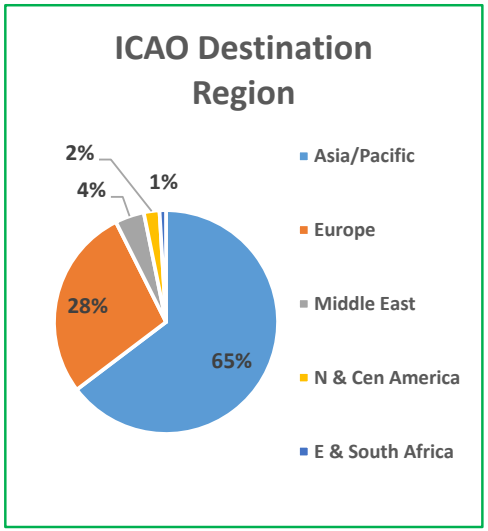
The Innovata database identifies 1,368 separate airports that were used for scheduled international passenger flights in 2012. After grouping there were 1,274 airports (more correctly termed cities in cases where the airport grouping has been applied) in the dataset (see Section 8.2).

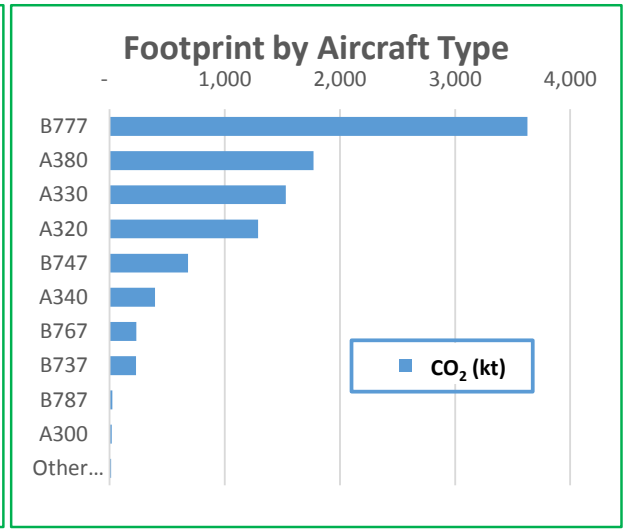
The profiles are ordered by descending weight of CO_2.

Airport	CO_2 (kt)	Cumulative %
London (Heathrow)	16,394	4.5
Dubai	10,976	7.6
Hong Kong	10,363	10.5
Frankfurt	10,193	13.3
Paris (CDG)	10,132	16.1
Singapore	9,816	18.8
Tokyo (Narita)	8,905	21.3
New York (JFK)	8,201	23.5
Seoul	7,919	25.7
Bangkok	7,583	27.8
Amsterdam	7,300	29.9
Los Angeles	7,007	31.8
Beijing	5,074	33.2
Shanghai	4,965	34.6
Sydney	4,817	35.9
Madrid	4,788	37.3
Moscow	4,512	38.5
Kuala Lumpur	4,237	39.7
Istanbul	4,146	40.8
Taipei	4,090	42.0
Other Airports	209,440	100.0
Total	**360,857**	

Singapore

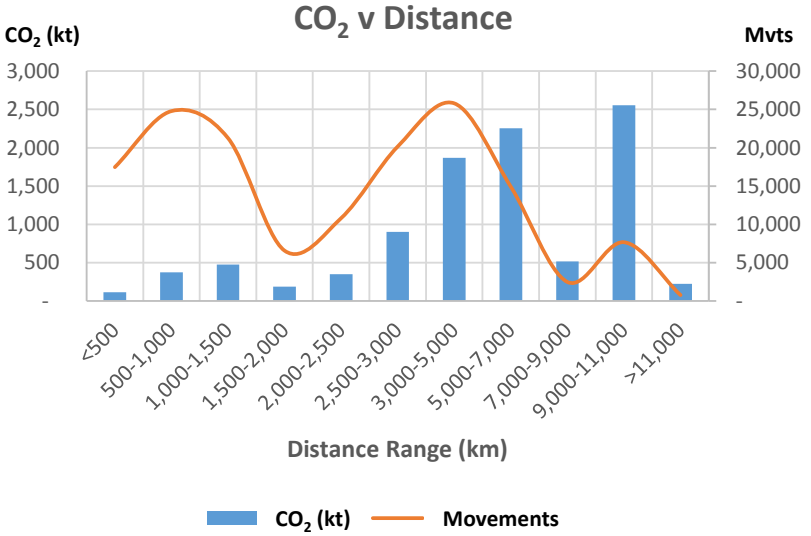
Total Footprint = 9,816 kt CO_2

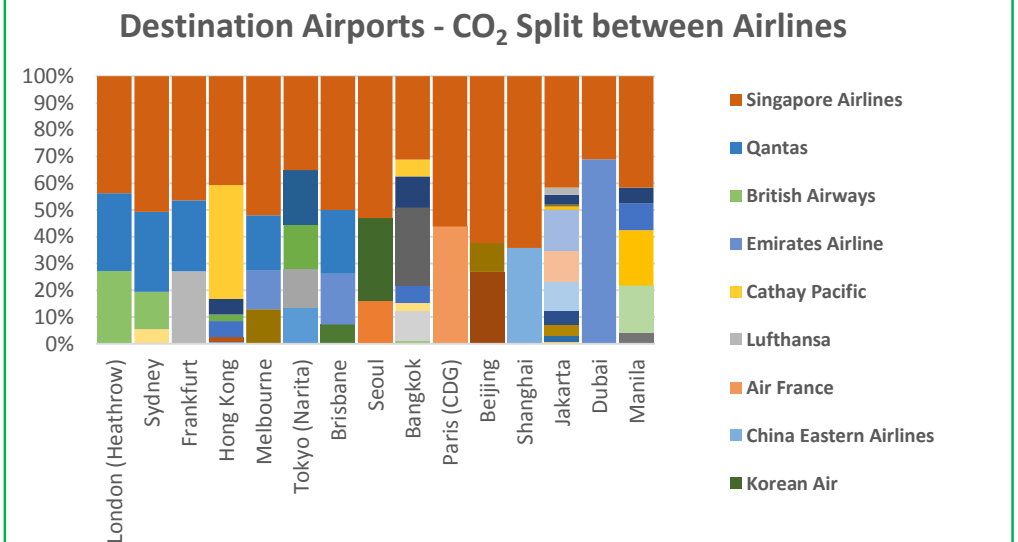




Destination Airports	CO_2 (kt)
London (Heathrow)	1,015
Sydney	529
Frankfurt	502
Hong Kong	451
Melbourne	376
Tokyo (Narita)	334
Brisbane	295
Seoul	274
Bangkok	263
Paris (CDG)	258
Beijing	256
Shanghai	253
Jakarta	242
Dubai	234
Manila	222
Other Airports	4,313
Total	**9,816**

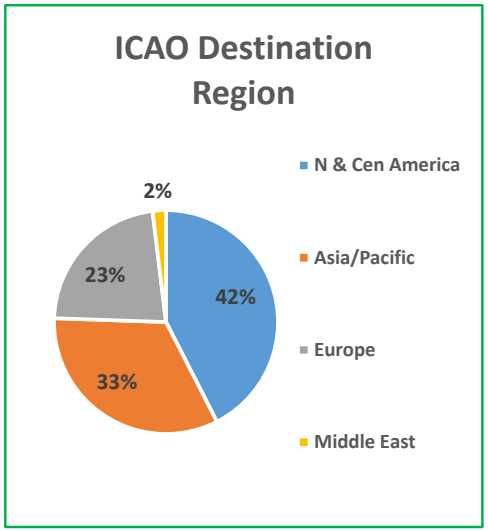
Airlines	CO_2 (kt)
Singapore Airlines	4,726
Qantas	818
British Airways	350
Emirates Airline	299
SilkAir	279
Tiger Airways	271
Cathay Pacific	223
Jetstar Asia Airways	208
Lufthansa	195
Qatar Airways	131
KLM Royal Dutch Airlines	115
Jetstar Airways	113
Air France	113
China Eastern Airlines	112
All Nippon Airways	101
Other Airlines	1,761
Total	**9,816**

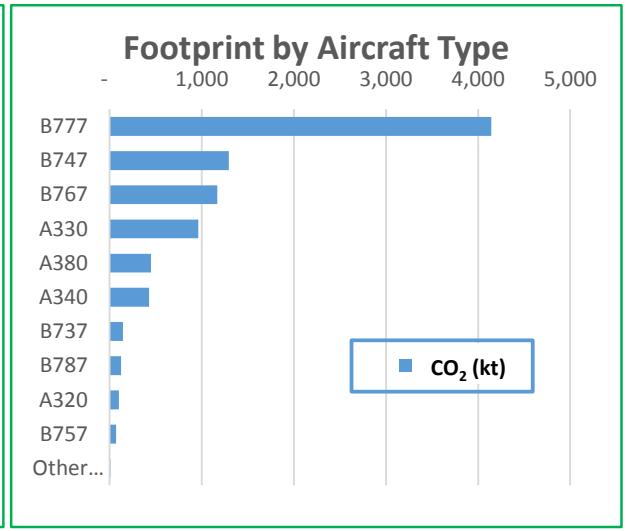




Tokyo (Narita)

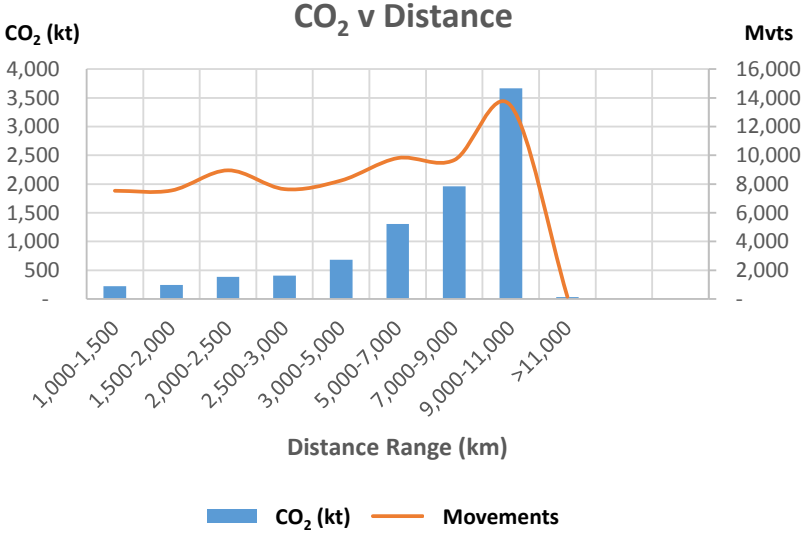
Total Footprint = 8,905 kt CO_2

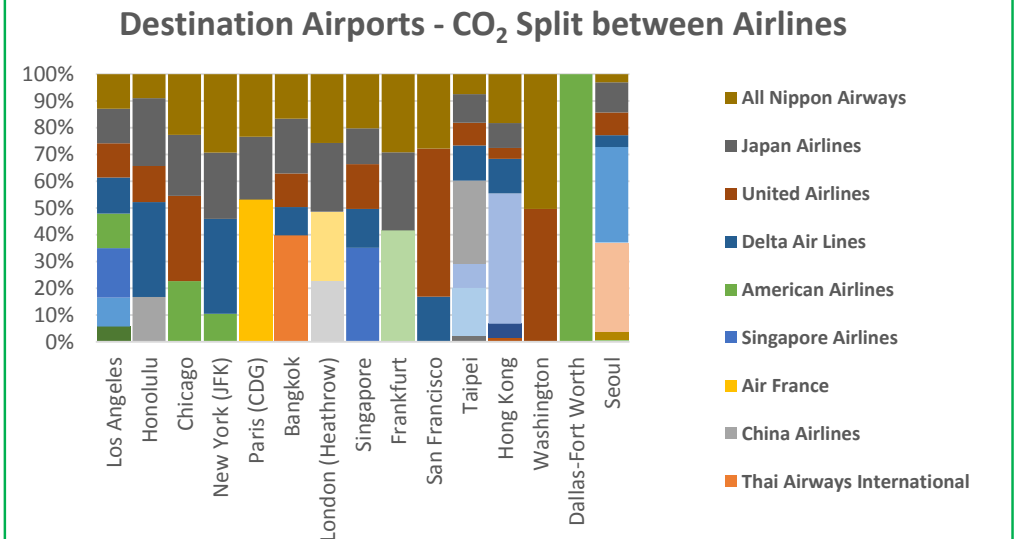




Destination Airports	CO_2 (kt)
Los Angeles	626
Honolulu	464
Chicago	414
New York (JFK)	408
Paris (CDG)	386
Bangkok	350
London (Heathrow)	347
Singapore	333
Frankfurt	298
San Francisco	272
Taipei	216
Hong Kong	211
Washington	202
Dallas-Fort Worth	193
Seoul	177
Other Airports	4,010
Total	**8,905**

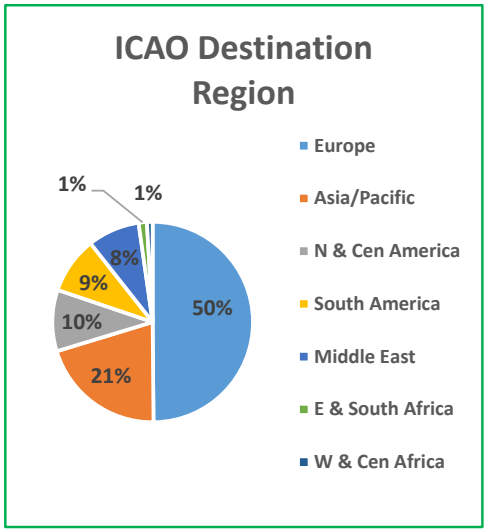
Airlines	CO_2 (kt)
Japan Airlines	1,408
All Nippon Airways	1,348
Delta Air Lines	1,198
United Airlines	943
American Airlines	410
Singapore Airlines	232
Air France	205
Lufthansa	199
Air Canada	177
Alitalia	171
Korean Air	151
KLM Royal Dutch Airlines	150
China Airlines	150
Thai Airways International	139
Cathay Pacific	122
Other Airlines	1,901
Total	**8,905**

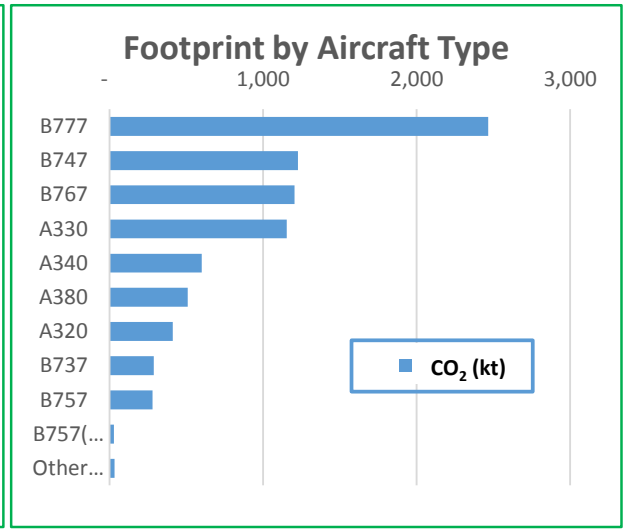




New York (JFK)

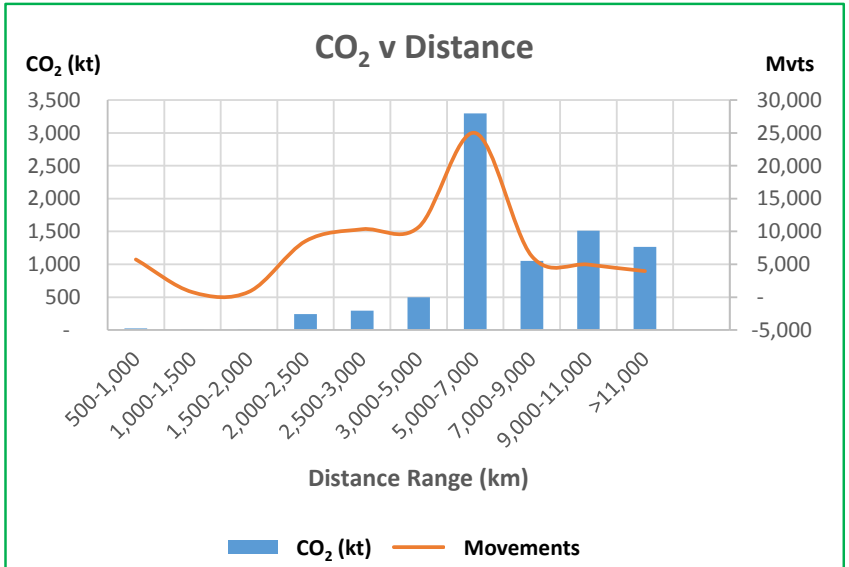
Total Footprint = 8,201 kt CO_2

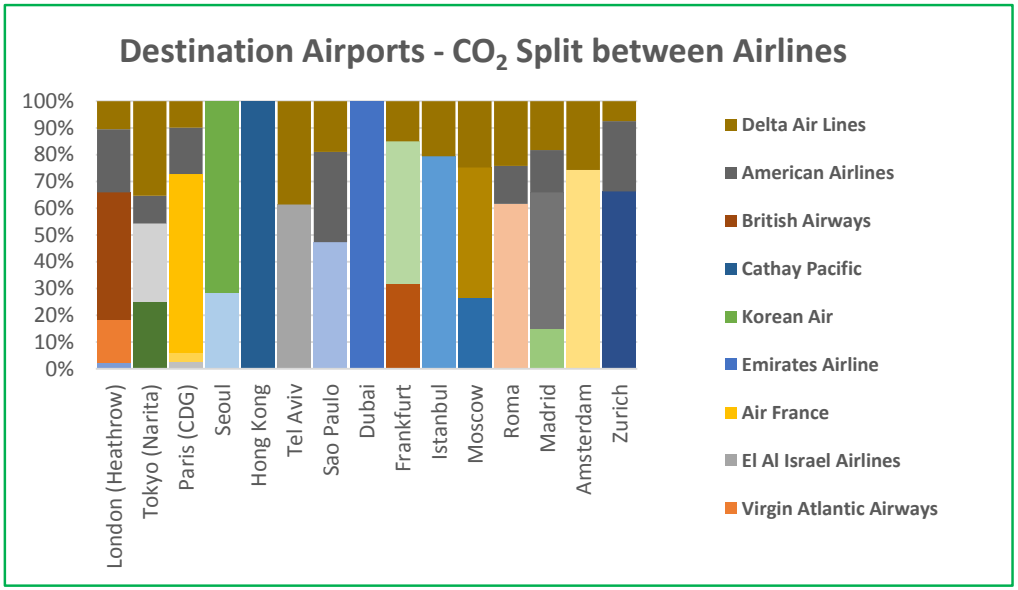




Destination Airports	CO_2 (kt)
London (Heathrow)	1,000
Tokyo (Narita)	408
Paris (CDG)	372
Seoul	367
Hong Kong	348
Tel Aviv	305
Sao Paulo	260
Dubai	253
Frankfurt	248
Istanbul	201
Moscow	193
Roma	180
Madrid	175
Amsterdam	165
Zurich	152
Other Airports	3,575
Total	**8,201**

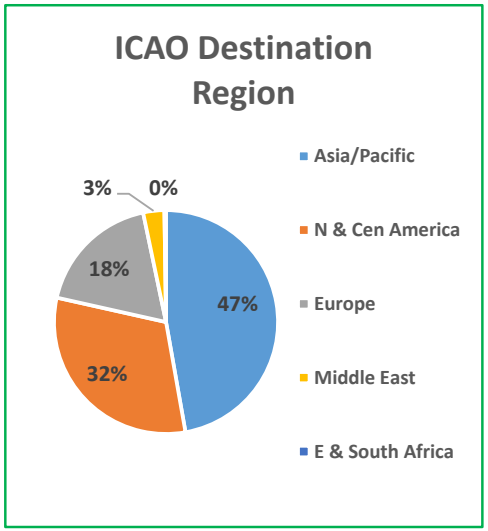
Airlines	CO_2 (kt)
Delta Air Lines	1,229
American Airlines	1,040
British Airways	503
Cathay Pacific	384
JetBlue Airways	332
Korean Air	262
Emirates Airline	253
Air France	249
El Al Israel Airlines	187
Lufthansa	180
TAM Airlines (TAM Linhas Aere	176
Virgin Atlantic Airways	163
Turkish Airlines	159
Swiss European Air Lines	150
Alitalia	147
Other Airlines	2,785
Total	**8,201**

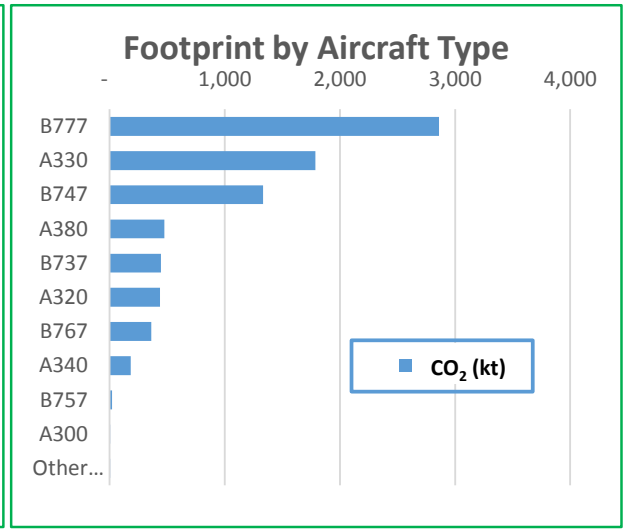




Seoul

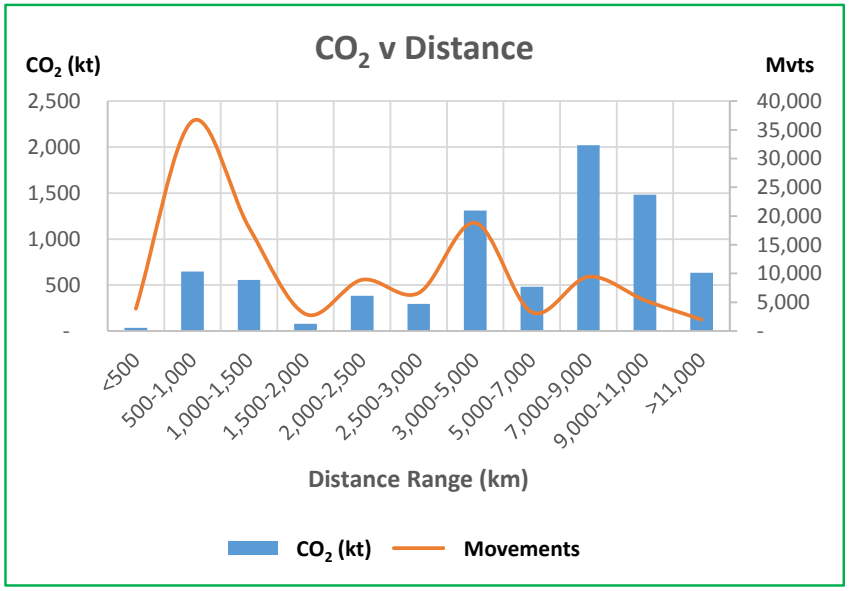
Total Footprint = 7,919 kt CO_2

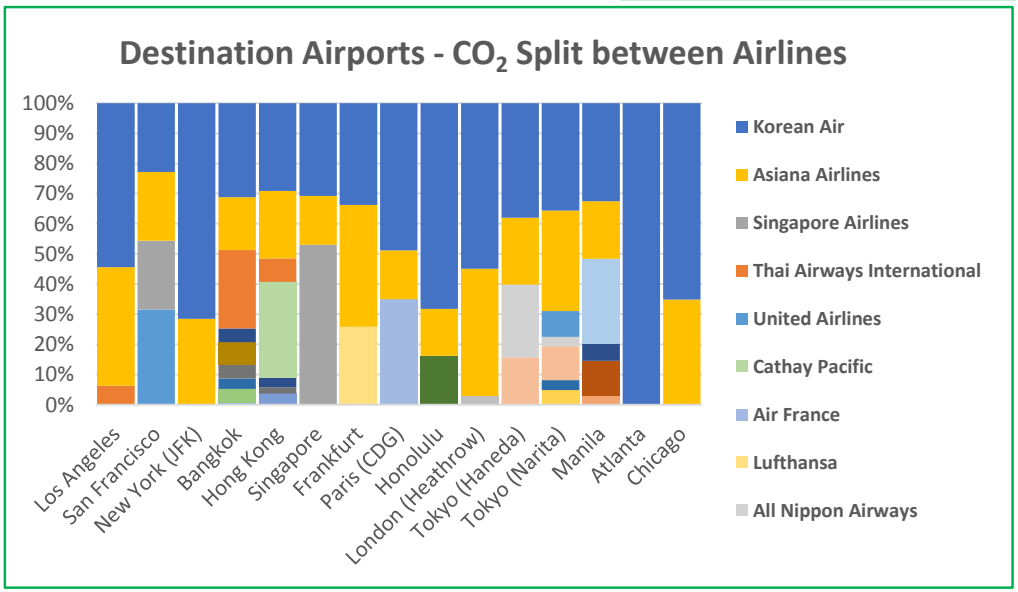




Destination Airports	CO_2 (kt)
Los Angeles	541
San Francisco	368
New York (JFK)	367
Bangkok	315
Hong Kong	280
Singapore	274
Frankfurt	270
Paris (CDG)	230
Honolulu	224
London (Heathrow)	193
Tokyo (Haneda)	183
Tokyo (Narita)	177
Manila	164
Atlanta	163
Chicago	163
Other Airports	4,007
Total	**7,919**

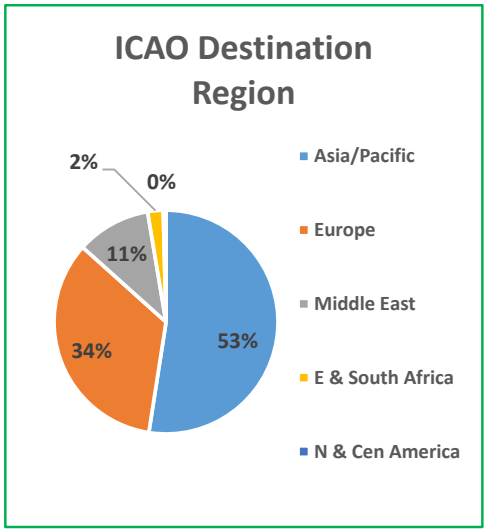
Airlines	CO_2 (kt)
Korean Air	3,736
Asiana Airlines	1,698
Singapore Airlines	229
Thai Airways International	170
United Airlines	131
Lufthansa	125
KLM Royal Dutch Airlines	106
Cathay Pacific	105
Delta Air Lines	96
Emirates Airline	81
Air France	81
Garuda Indonesia	74
Jeju Air	70
Turkish Airlines	67
Philippine Airlines	65
Other Airlines	1,084
Total	**7,919**

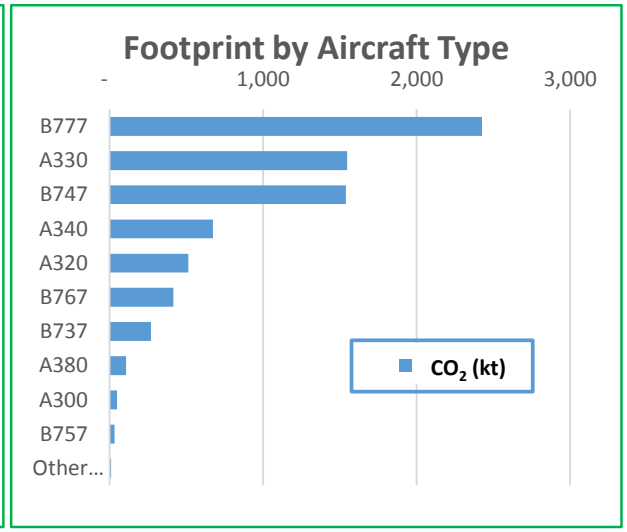




Bangkok

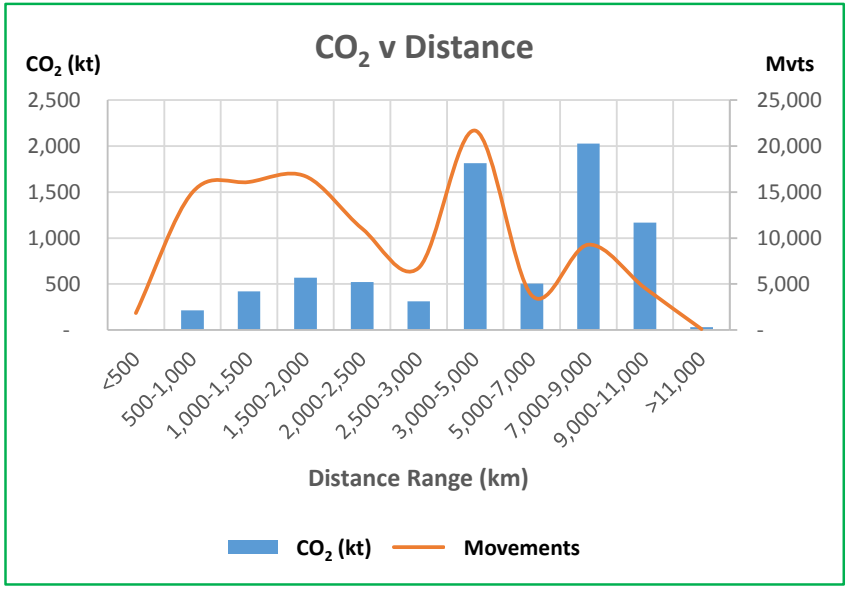
Total Footprint = 7,583 kt CO_2

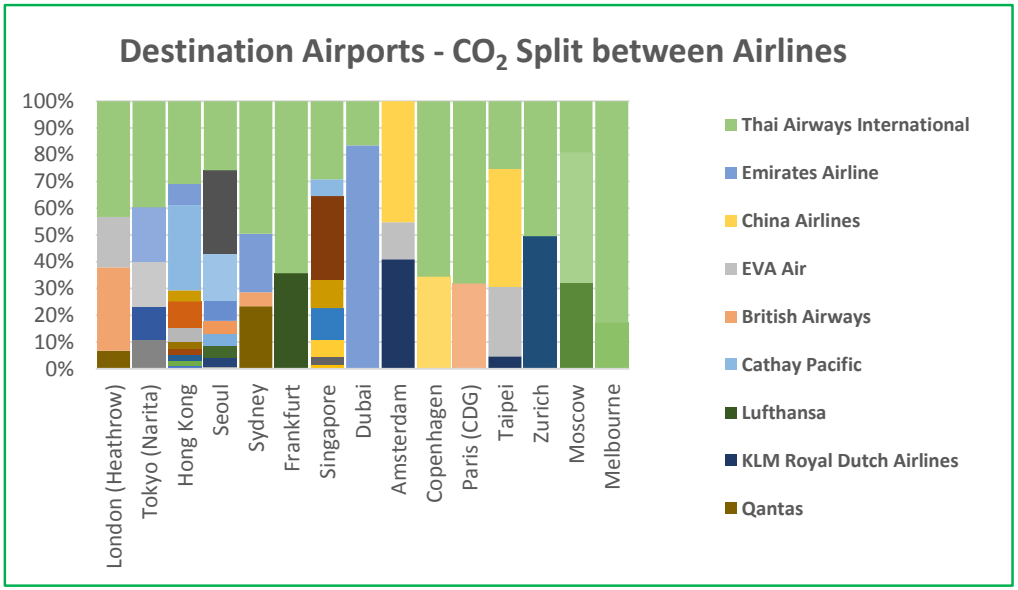




Destination Airports	CO_2 (kt)
London (Heathrow)	402
Tokyo (Narita)	350
Hong Kong	322
Seoul	315
Sydney	314
Frankfurt	306
Singapore	264
Dubai	237
Amsterdam	228
Copenhagen	190
Paris (CDG)	174
Taipei	169
Zurich	155
Moscow	154
Melbourne	146
Other Airports	3,857
Total	**7,583**

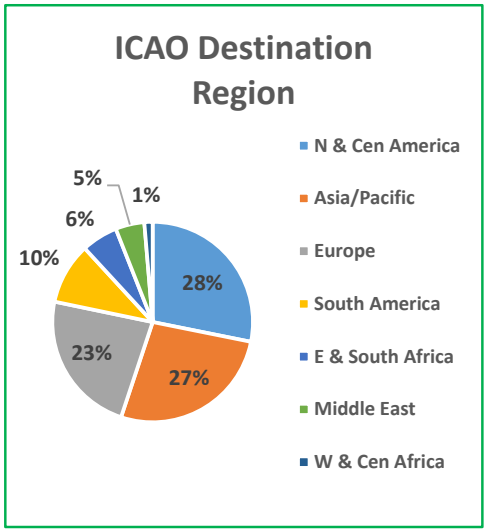
Airlines	CO_2 (kt)
Thai Airways International	3,033
Emirates Airline	292
China Airlines	183
EVA Air	180
Cathay Pacific	178
Thai AirAsia	176
Qatar Airways	169
British Airways	142
Korean Air	130
Japan Airlines	127
Lufthansa	126
Etihad Airways	123
Turkish Airlines	117
Transaero Airlines	106
KLM Royal Dutch Airlines	101
Other Airlines	2,402
Total	**7,583**

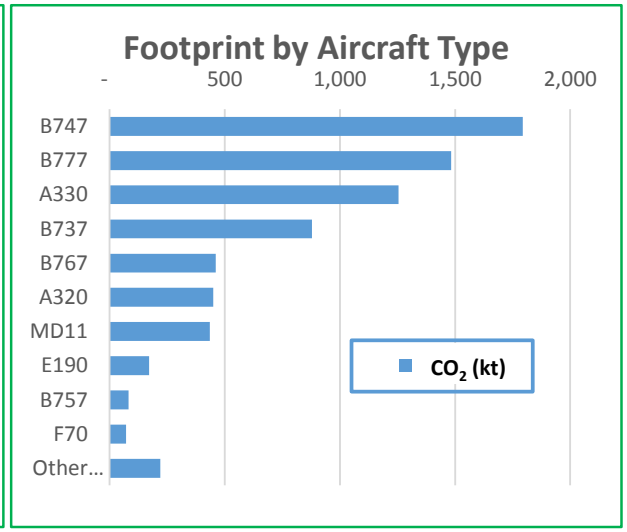




Amsterdam

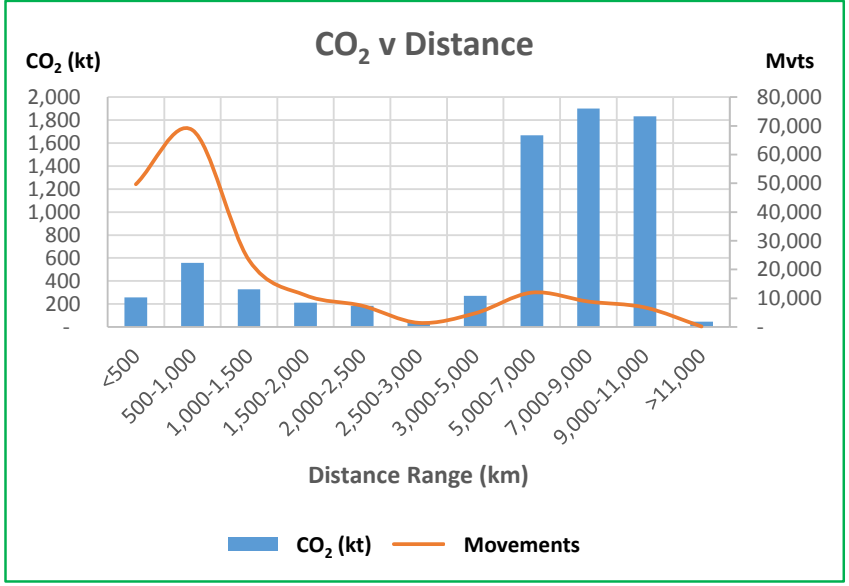
Total Footprint = 7,300 kt CO_2

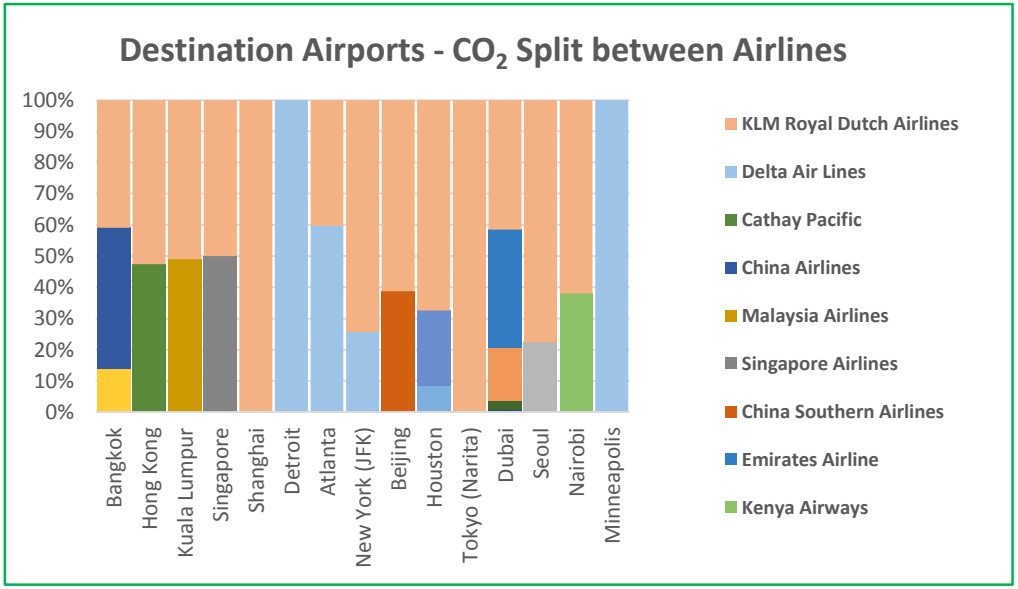




Destination Airports	CO_2 (kt)
Bangkok	228
Hong Kong	228
Kuala Lumpur	207
Singapore	197
Shanghai	188
Detroit	177
Atlanta	173
New York (JFK)	165
Beijing	159
Houston	155
Tokyo (Narita)	150
Dubai	145
Seoul	137
Nairobi	135
Minneapolis	129
Other Airports	4,730
Total	**7,300**

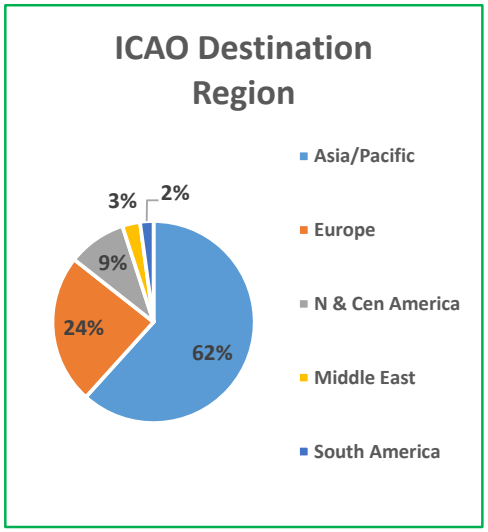
Airlines	CO_2 (kt)
KLM Royal Dutch Airlines	4,458
Delta Air Lines	743
Transavia	207
Easyjet	124
Arkefly	121
United Airlines	120
China Southern Airlines	119
Cathay Pacific	113
China Airlines	103
Malaysia Airlines	101
Singapore Airlines	98
Emirates Airline	55
Air France	52
Kenya Airways	51
Surinam Airways	42
Other Airlines	792
Total	**7,300**

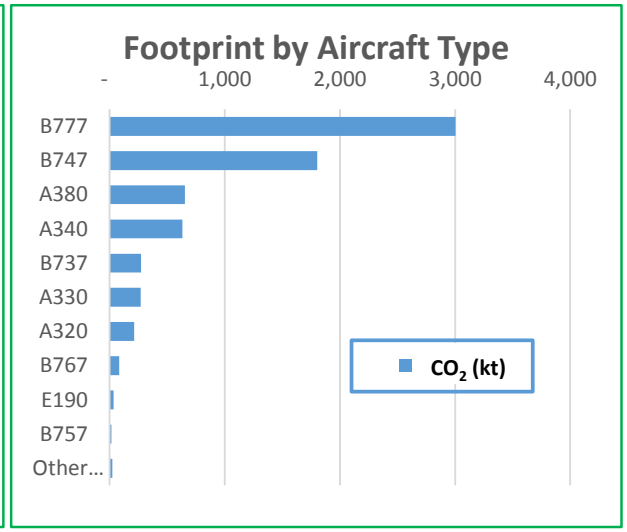




Los Angeles

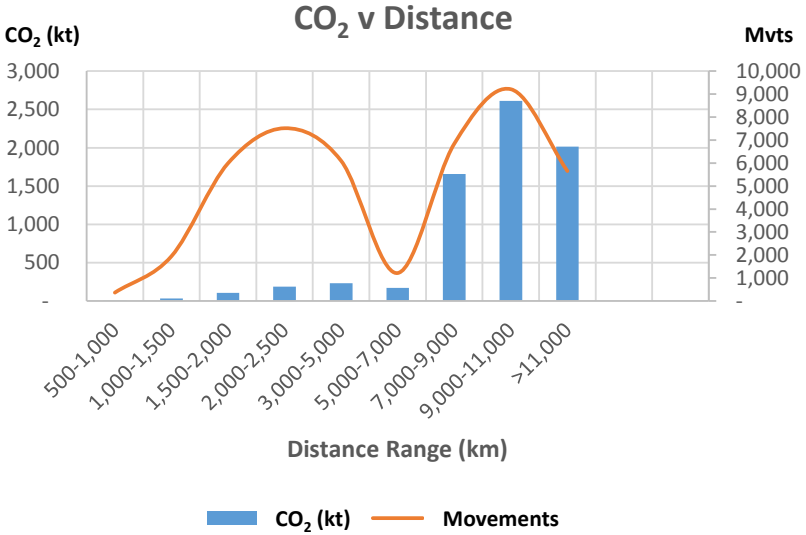
Total Footprint = 7,007 kt CO_2

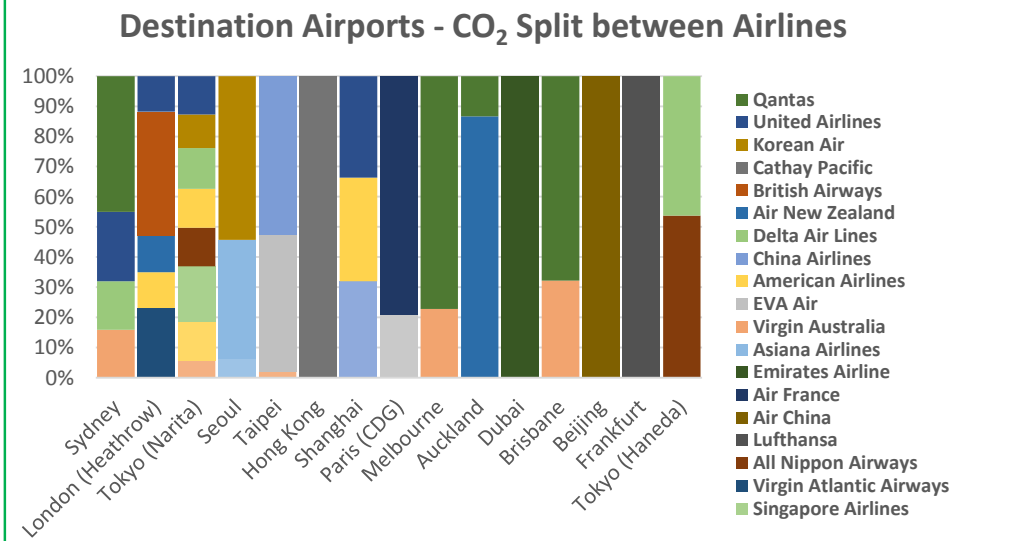




Destination Airports	CO_2 (kt)
Sydney	705
London (Heathrow)	664
Tokyo (Narita)	628
Seoul	541
Taipei	503
Hong Kong	297
Shanghai	281
Paris (CDG)	238
Melbourne	225
Auckland	217
Dubai	199
Brisbane	192
Beijing	168
Frankfurt	166
Tokyo (Haneda)	151
Other Airports	1,832
Total	**7,007**

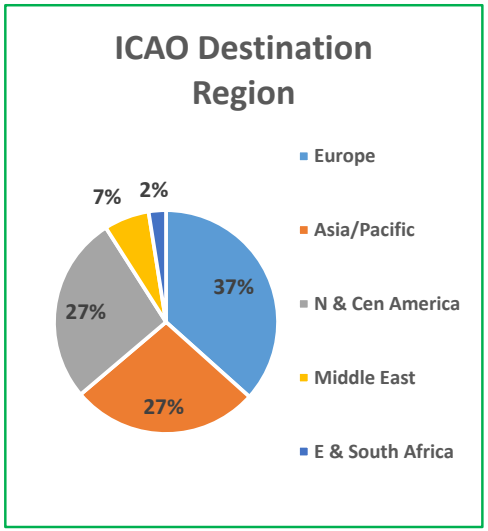
Airlines	CO_2 (kt)
Qantas	650
United Airlines	458
Korean Air	404
Cathay Pacific	297
Delta Air Lines	291
American Airlines	286
Air New Zealand	276
British Airways	272
China Airlines	265
Lufthansa	234
EVA Air	228
Virgin Australia	226
Air France	214
Asiana Airlines	213
Singapore Airlines	201
Other Airlines	2,493
Total	**7,007**

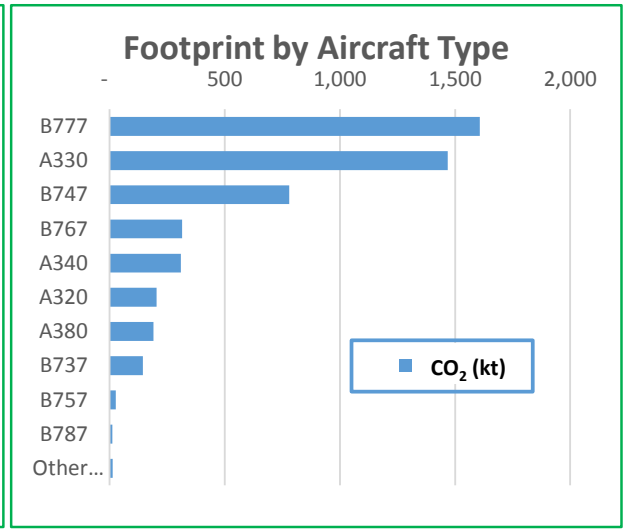




Beijing

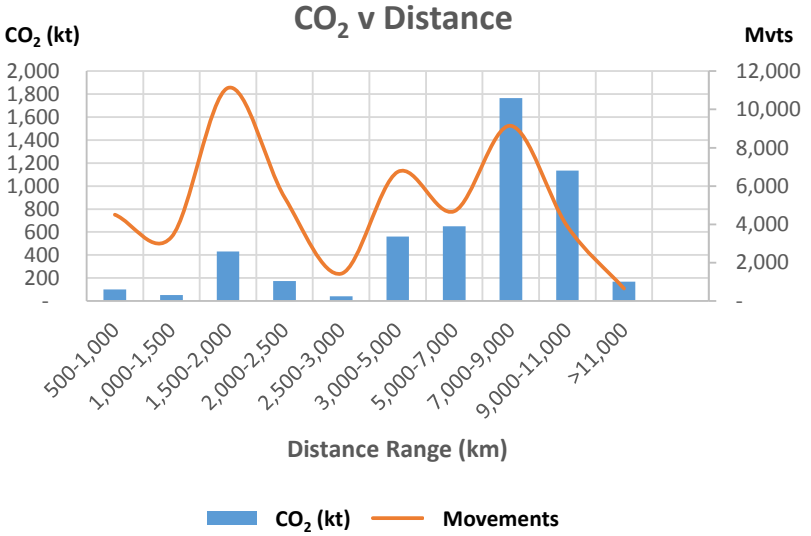
Total Footprint = 5,074 kt CO_2

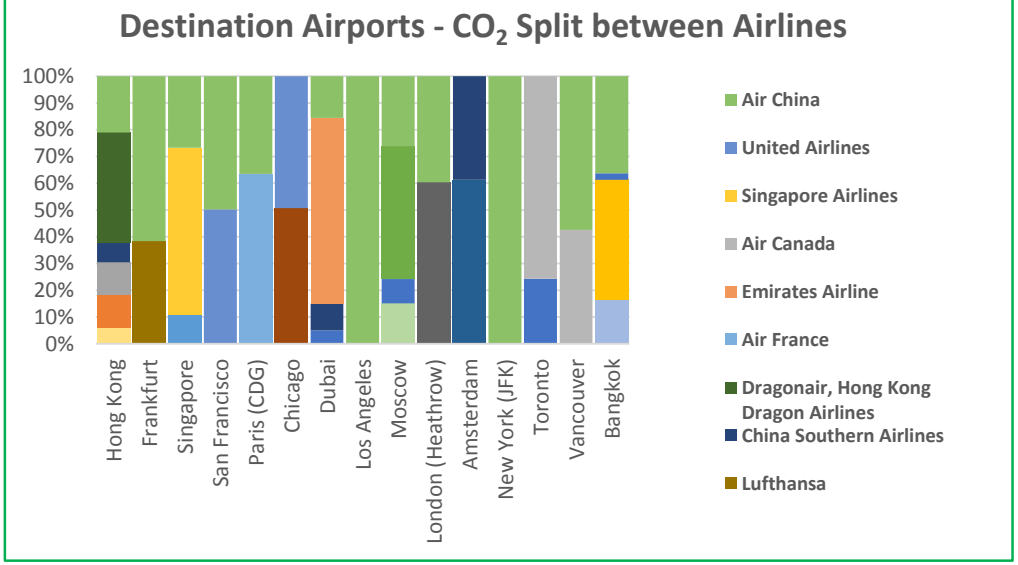




Destination Airports	CO_2 (kt)
Hong Kong	292
Frankfurt	256
Singapore	256
San Francisco	247
Paris (CDG)	196
Chicago	193
Dubai	182
Los Angeles	168
Moscow	166
London (Heathrow)	163
Amsterdam	159
New York (JFK)	146
Toronto	130
Vancouver	124
Bangkok	109
Other Airports	2,285
Total	**5,074**

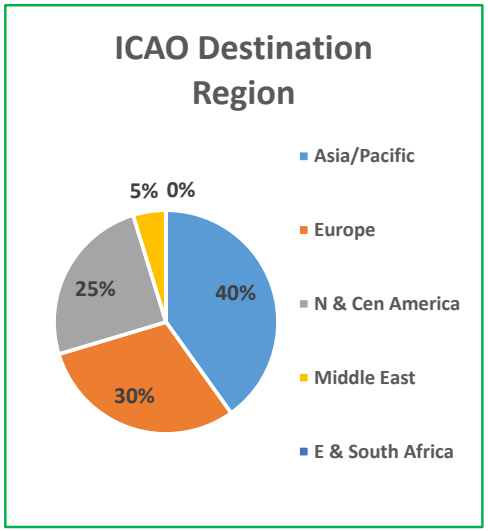
Airlines	CO_2 (kt)
Air China	1,575
United Airlines	396
Hainan Airlines	250
Singapore Airlines	159
Lufthansa	154
Air Canada	151
Emirates Airline	126
Air France	124
Delta Air Lines	121
Dragonair, Hong Kong Dragon	120
China Southern Airlines	119
British Airways	98
American Airlines	98
KLM Royal Dutch Airlines	97
Aeroflot Russian Airlines	83
Other Airlines	1,403
Total	**5,074**

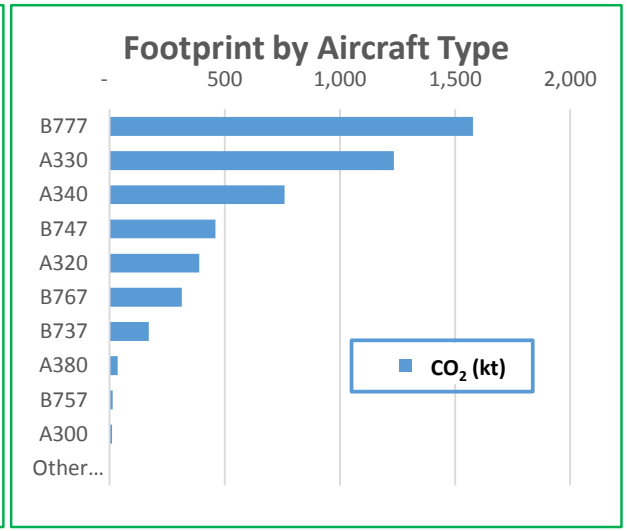




Shanghai

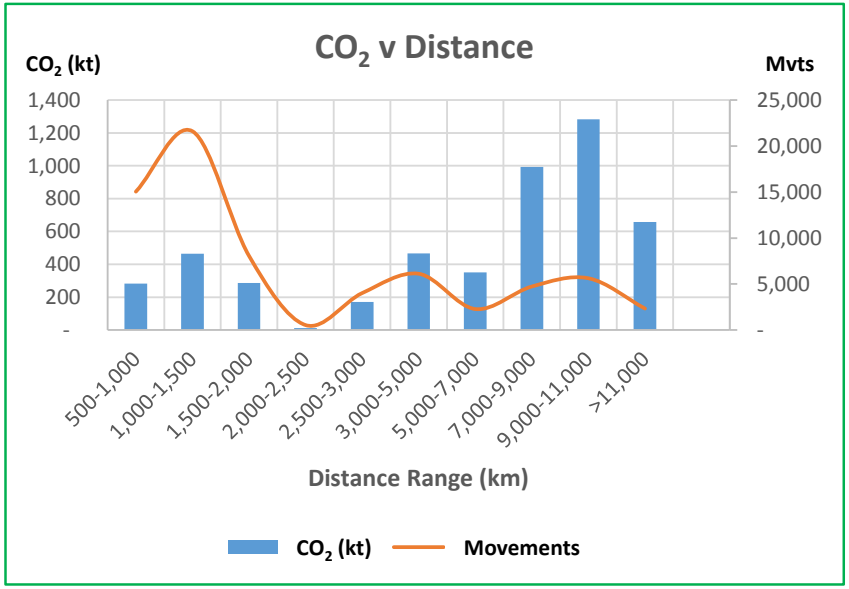
Total Footprint = 4,965 kt CO_2

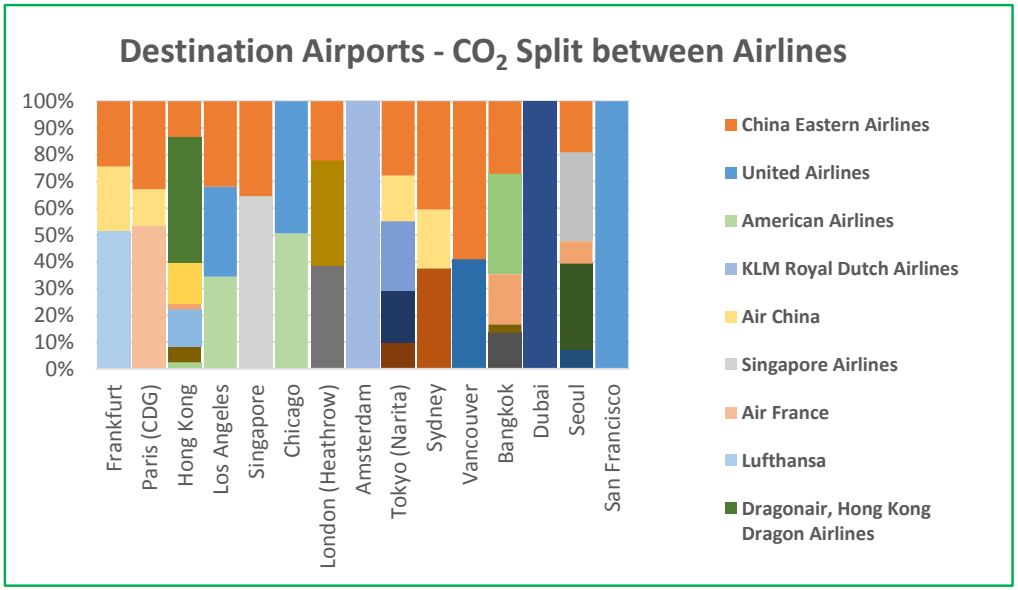




Destination Airports	CO_2 (kt)
Frankfurt	289
Paris (CDG)	289
Hong Kong	285
Los Angeles	281
Singapore	253
Chicago	207
London (Heathrow)	189
Amsterdam	188
Tokyo (Narita)	171
Sydney	157
Vancouver	136
Bangkok	130
Dubai	127
Seoul	123
San Francisco	114
Other Airports	2,026
Total	**4,965**

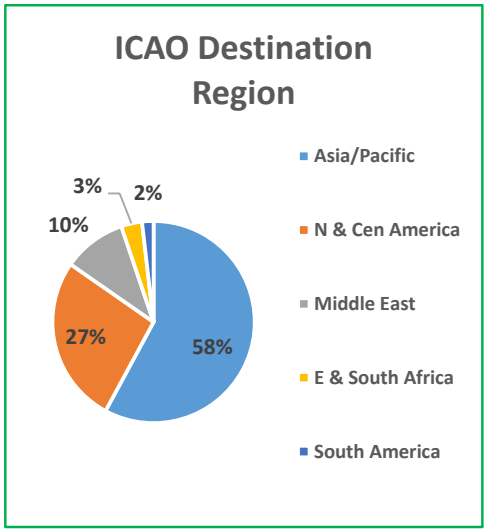
Airlines	CO_2 (kt)
China Eastern Airlines	1,151
United Airlines	392
Air China	321
Lufthansa	220
American Airlines	201
KLM Royal Dutch Airlines	188
Air Canada	162
Singapore Airlines	162
Air France	154
Dragonair, Hong Kong Dragon	134
Delta Air Lines	129
Emirates Airline	127
Shanghai Airlines	112
Aeroflot Russian Airlines	92
All Nippon Airways	88
Other Airlines	1,331
Total	**4,965**

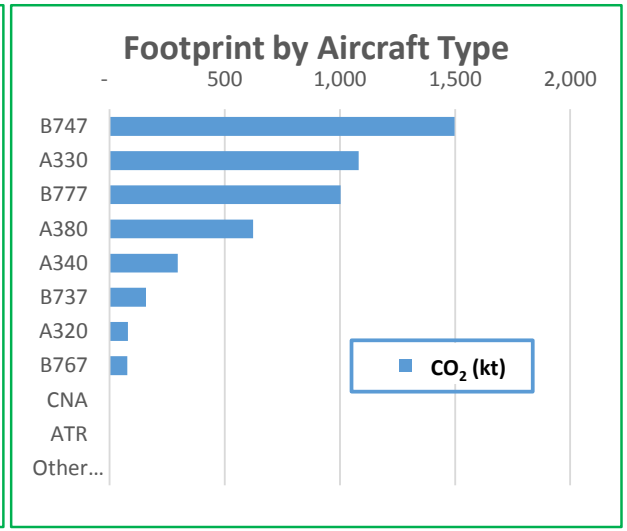




Sydney

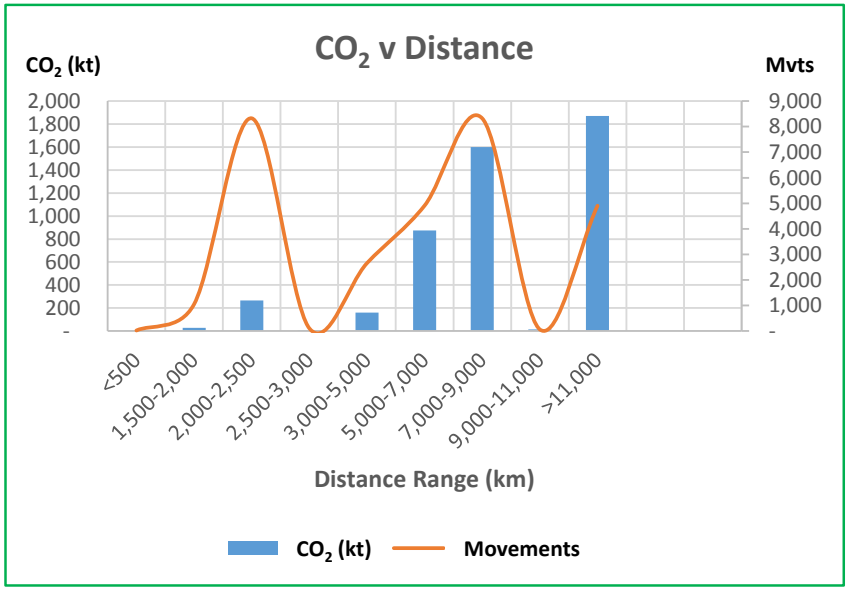
Total Footprint = 4,817 kt CO_2

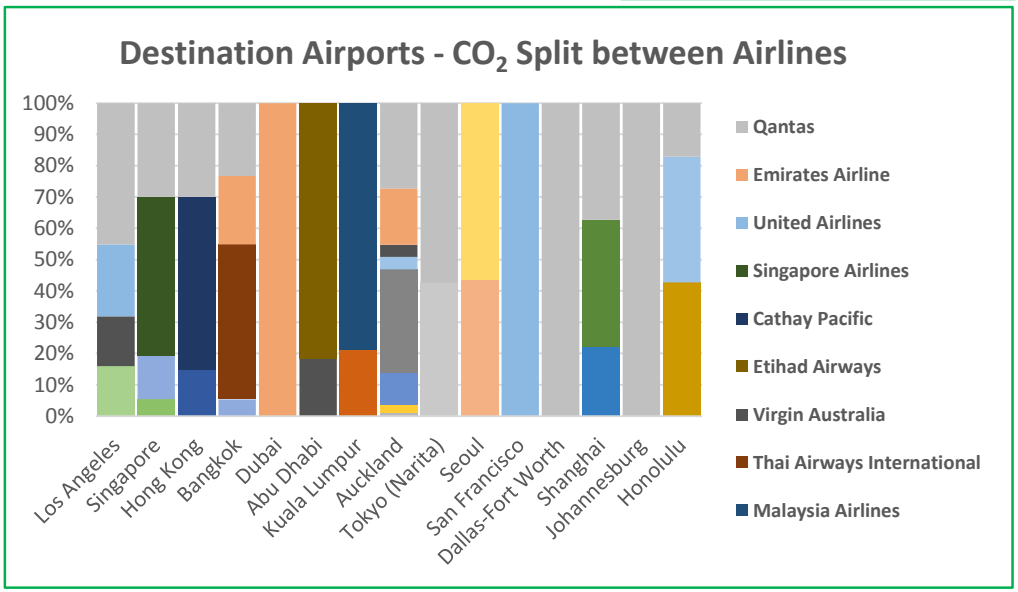




Destination Airports	CO_2 (kt)
Los Angeles	707
Singapore	530
Hong Kong	418
Bangkok	314
Dubai	277
Abu Dhabi	212
Kuala Lumpur	181
Auckland	170
Tokyo (Narita)	168
Seoul	160
San Francisco	160
Dallas-Fort Worth	160
Shanghai	158
Johannesburg	147
Honolulu	144
Other Airports	911
Total	**4,817**

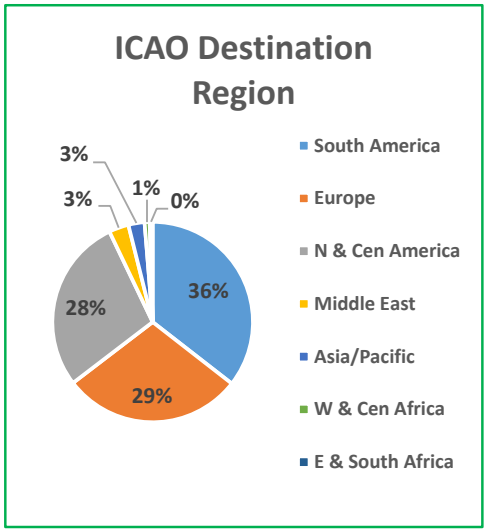
Airlines	CO_2 (kt)
Qantas	1,358
Emirates Airline	398
United Airlines	322
Singapore Airlines	268
Cathay Pacific	231
Virgin Australia	208
Etihad Airways	173
Thai Airways International	155
Malaysia Airlines	142
Jetstar Airways	137
Air Canada	119
Delta Air Lines	113
China Southern Airlines	113
Air New Zealand	95
Air China	94
Other Airlines	890
Total	**4,817**

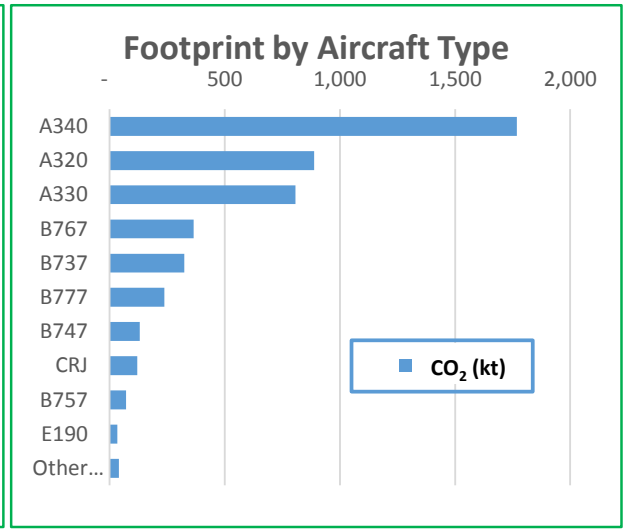




Madrid

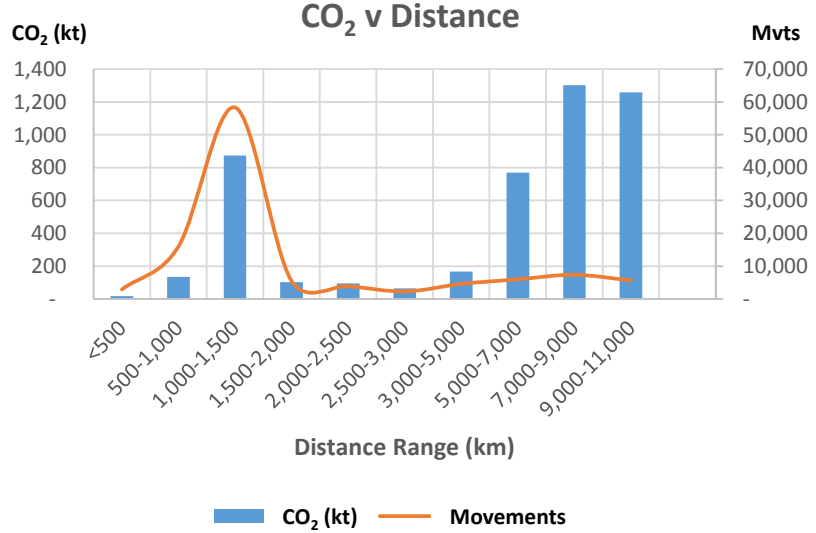
Total Footprint = 4,788 kt CO_2

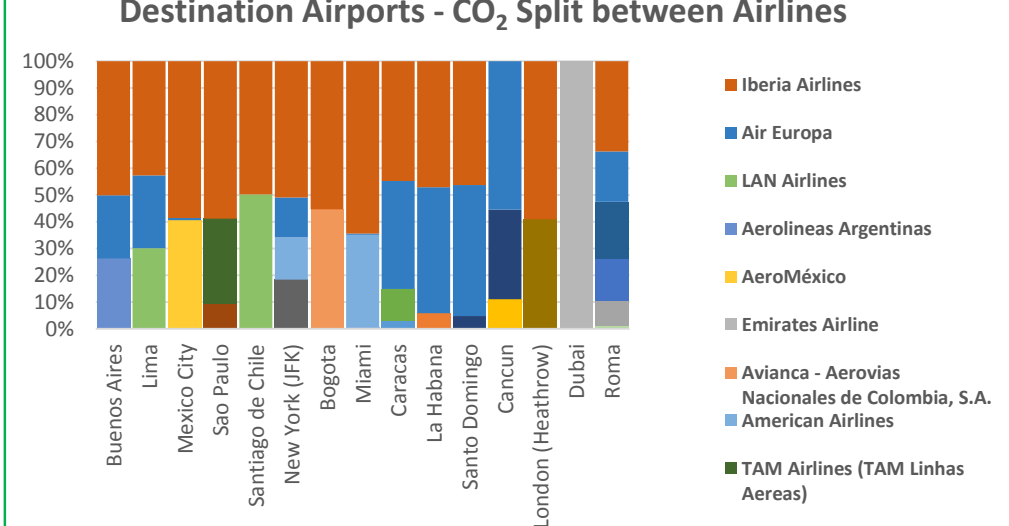




Destination Airports	CO_2 (kt)
Buenos Aires	340
Lima	236
Mexico City	214
Sao Paulo	209
Santiago de Chile	184
New York (JFK)	175
Bogota	172
Miami	131
Caracas	130
La Habana	115
Santo Domingo	104
Cancun	89
London (Heathrow)	81
Dubai	77
Roma	74
Other Airports	2,457
Total	**4,788**

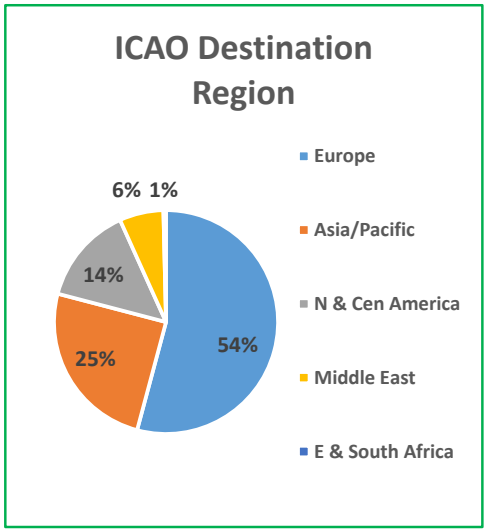
Airlines	CO_2 (kt)
Iberia Airlines	2,129
Air Europa	522
LAN Airlines	242
Easyjet	147
Avianca - Aerovias Nacionales	146
Ryanair	145
American Airlines	124
Aerolineas Argentinas	89
AeroMéxico	87
Emirates Airline	77
Delta Air Lines	71
TAM Airlines (TAM Linhas Aere	67
Air China	63
Lufthansa	60
US Airways	58
Other Airlines	760
Total	**4,788**

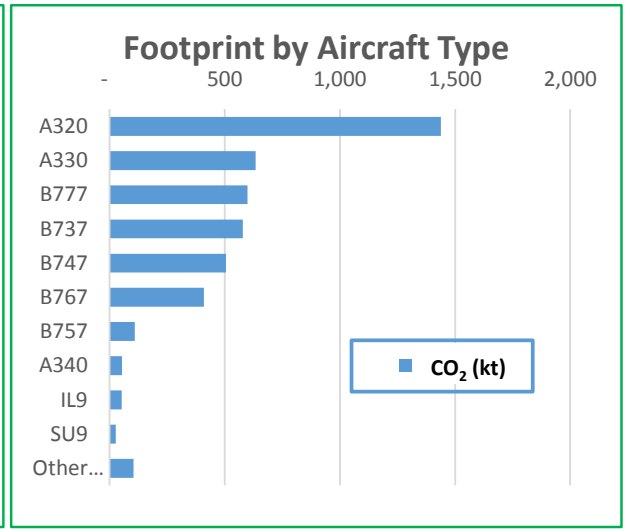




Moscow

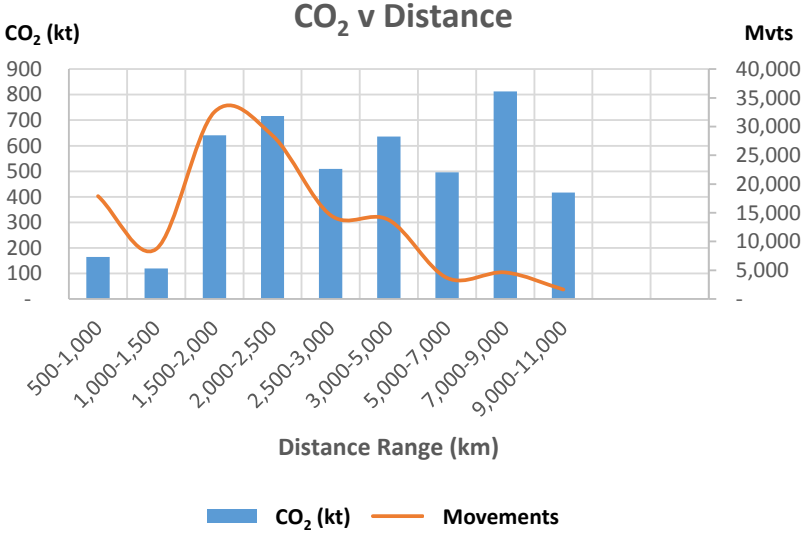
Total Footprint = 4,512 kt CO_2

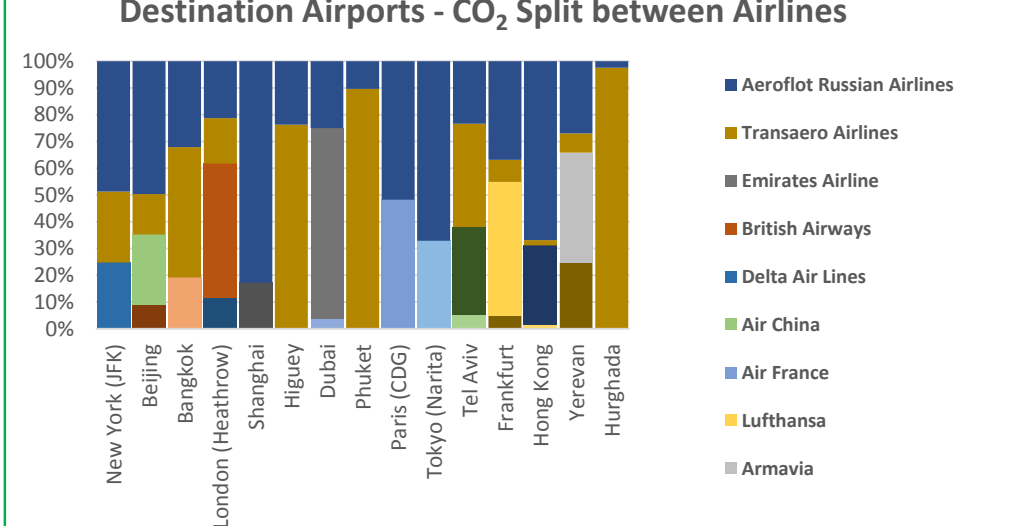




Destination Airports	CO_2 (kt)
New York (JFK)	193
Beijing	166
Bangkok	155
London (Heathrow)	125
Shanghai	111
Higuey	107
Dubai	93
Phuket	92
Paris (CDG)	90
Tokyo (Narita)	89
Tel Aviv	85
Frankfurt	84
Hong Kong	82
Yerevan	80
Hurghada	78
Other Airports	2,882
Total	**4,512**

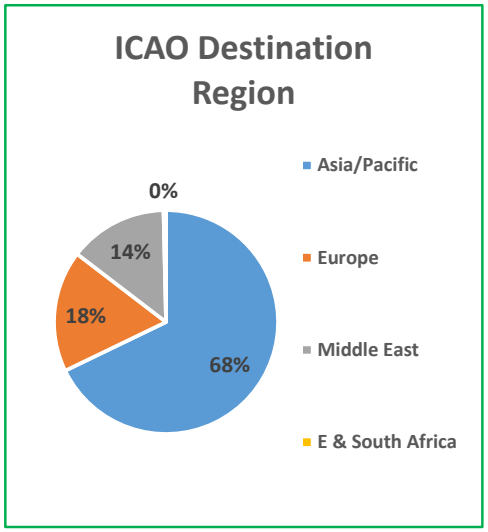
Airlines	CO_2 (kt)
Aeroflot Russian Airlines	1,581
Transaero Airlines	987
S7 Airlines (Siberia Airlines)	151
Singapore Airlines	122
Lufthansa	89
UTair Aviation	85
Uzbekistan Airways	69
Emirates Airline	66
British Airways	63
Vietnam Airlines	58
Air France	49
Delta Air Lines	48
VIM Airlines	45
Air China	43
Turkish Airlines	41
Other Airlines	1,016
Total	**4,512**

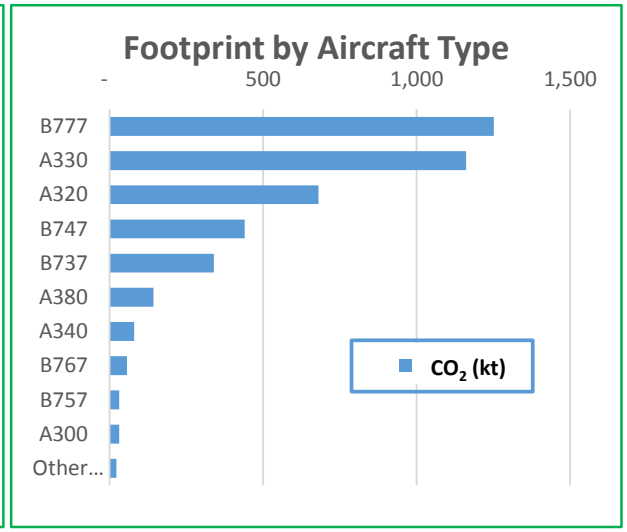




Kuala Lumpur

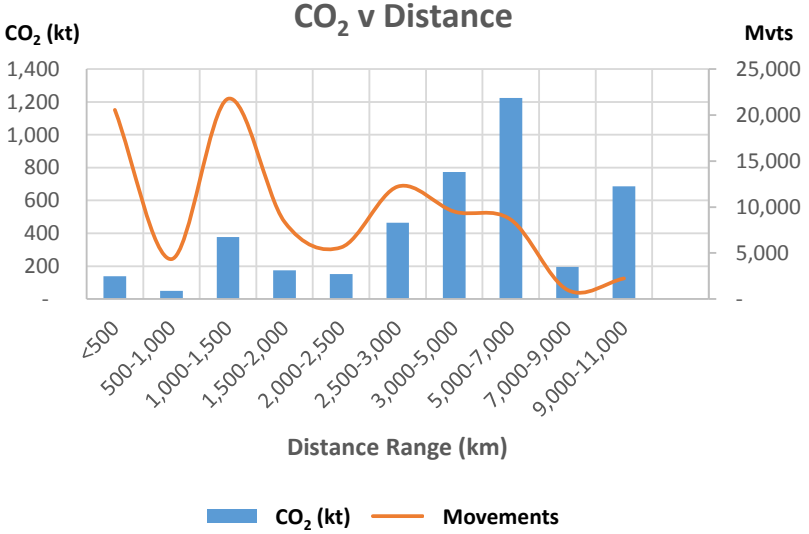
Total Footprint = 4,237 kt CO_2

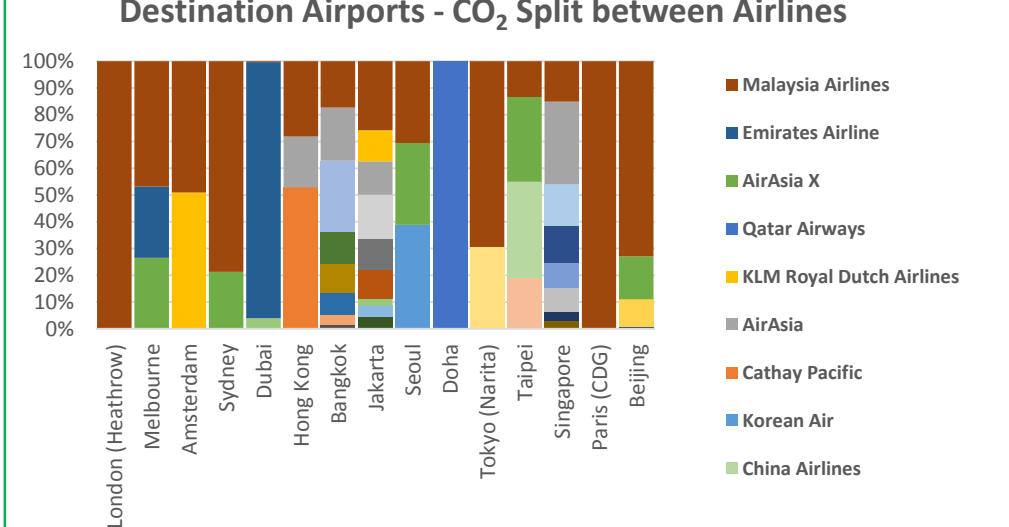




Destination Airports	CO_2 (kt)
London (Heathrow)	282
Melbourne	215
Amsterdam	206
Sydney	181
Dubai	180
Hong Kong	166
Bangkok	136
Jakarta	124
Seoul	121
Doha	119
Tokyo (Narita)	111
Taipei	108
Singapore	106
Paris (CDG)	96
Beijing	94
Other Airports	1,990
Total	**4,237**

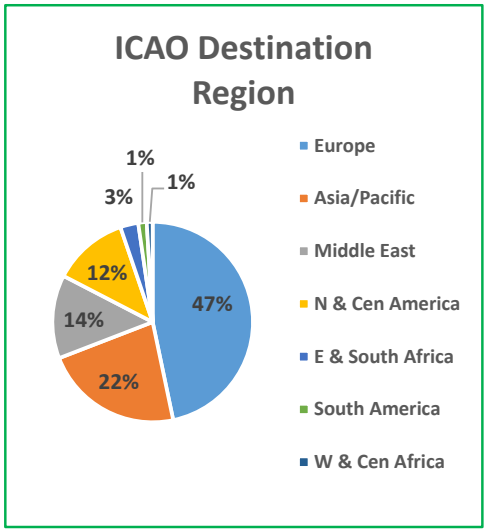
Airlines	CO_2 (kt)
Malaysia Airlines	1,818
AirAsia X	457
AirAsia	452
Emirates Airline	230
Qatar Airways	129
KLM Royal Dutch Airlines	119
Cathay Pacific	88
Indonesia AirAsia	77
Saudi Arabian Airlines	71
Iran Air	57
Etihad Airways	49
Korean Air	47
Oman Air	42
China Airlines	42
Thai Airways International	36
Other Airlines	523
Total	**4,237**

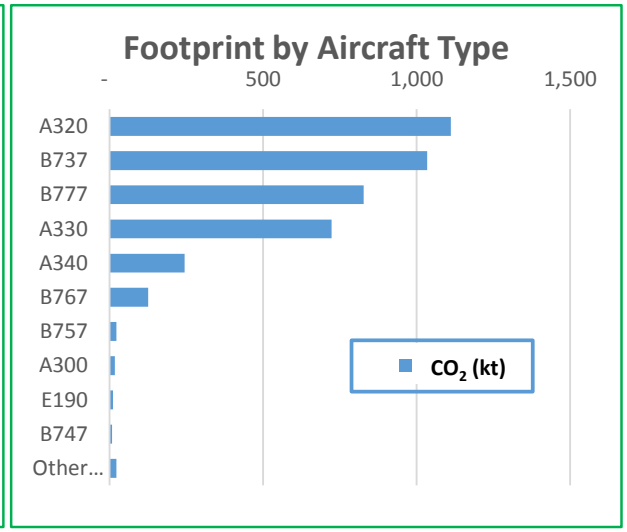




Istanbul

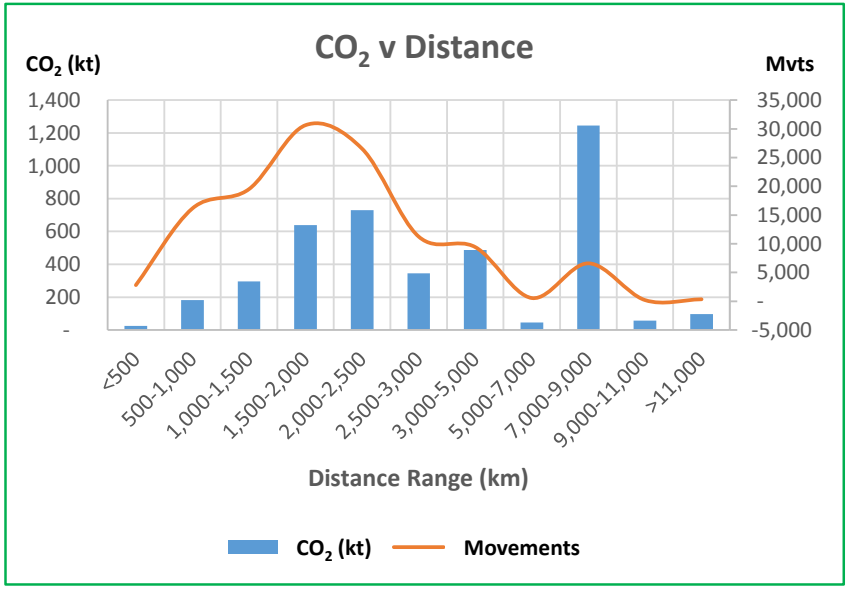
Total Footprint = 4,146 kt CO_2

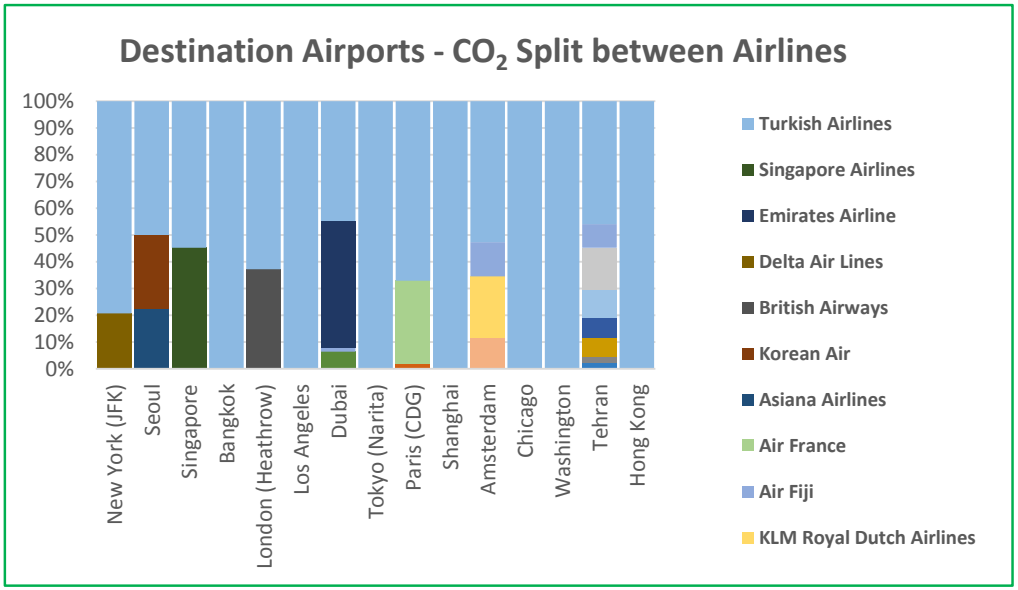




Destination Airports	CO_2 (kt)
New York (JFK)	201
Seoul	134
Singapore	126
Bangkok	107
London (Heathrow)	100
Los Angeles	97
Dubai	95
Tokyo (Narita)	80
Paris (CDG)	79
Shanghai	73
Amsterdam	73
Chicago	71
Washington	68
Tehran	68
Hong Kong	64
Other Airports	2,711
Total	**4,146**

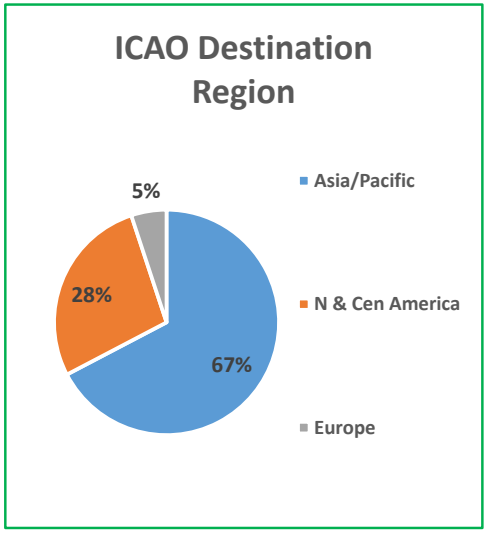
Airlines	CO_2 (kt)
Turkish Airlines	2,960
Pegasus Airlines	210
Singapore Airlines	58
SunExpress	46
Emirates Airline	45
Delta Air Lines	42
Lufthansa	42
British Airways	37
Korean Air	37
Malaysia Airlines	33
Atlasjet	32
Air France	31
Saudi Arabian Airlines	30
Azerbaijan Airlines	30
Asiana Airlines	30
Other Airlines	484
Total	**4,146**

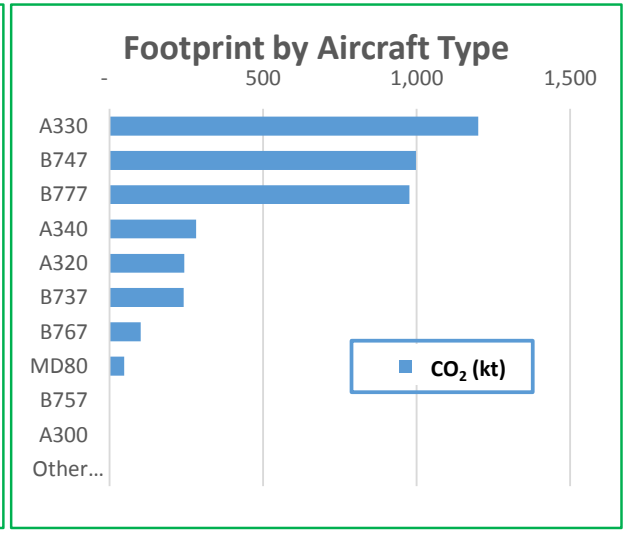




Taipei

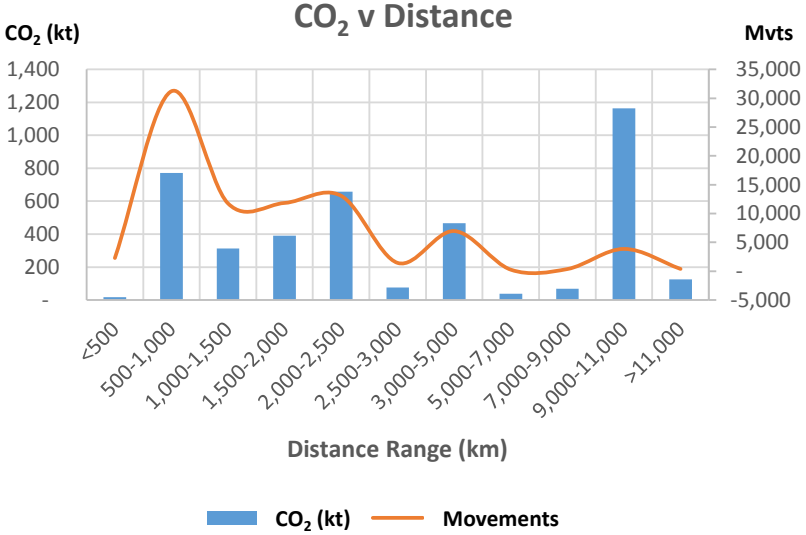
Total Footprint = 4,090 kt CO_2

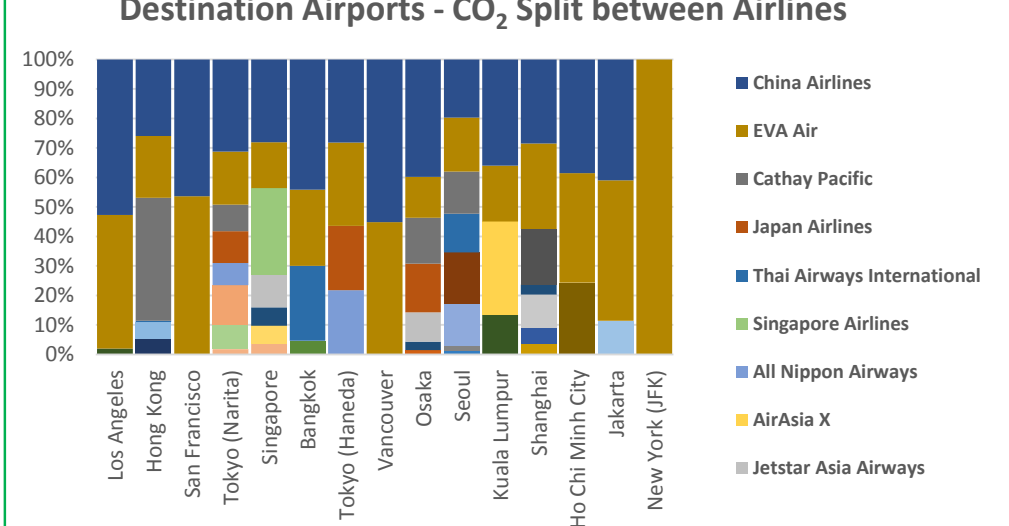




Destination Airports	CO_2 (kt)
Los Angeles	503
Hong Kong	450
San Francisco	288
Tokyo (Narita)	215
Singapore	194
Bangkok	170
Tokyo (Haneda)	133
Vancouver	124
Osaka	120
Seoul	110
Kuala Lumpur	108
Shanghai	103
Ho Chi Minh City	83
Jakarta	79
New York (JFK)	76
Other Airports	1,333
Total	**4,090**

Airlines	CO_2 (kt)
China Airlines	1,456
EVA Air	1,327
Cathay Pacific	274
KLM Royal Dutch Airlines	86
Japan Airlines	80
Thai Airways International	59
TransAsia Airways	59
Singapore Airlines	57
China Eastern Airlines	52
Air China	52
All Nippon Airways	45
Uni Air	45
China Southern Airlines	44
AirAsia X	34
Jetstar Asia Airways	34
Other Airlines	385
Total	**4,090**





Profile F4

Airline Footprint Profiles

Profile F4 contains carbon footprint profiles for the 15 airlines listed at the bottom of the figure to the right. The top 20 airlines capture about 50% of the global carbon footprint for scheduled international passenger flights in 2012.

The profiles for the top five airlines (dark orange colour in the figure), are contained in Chapter 6.

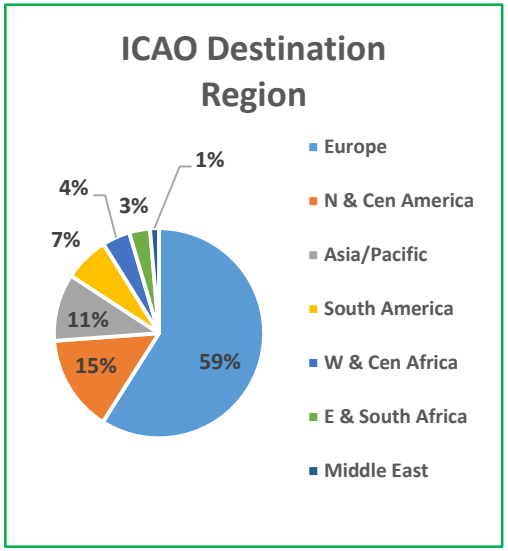
The Innovata database identifies 492 separate airlines that operated scheduled international passenger flights in 2012.

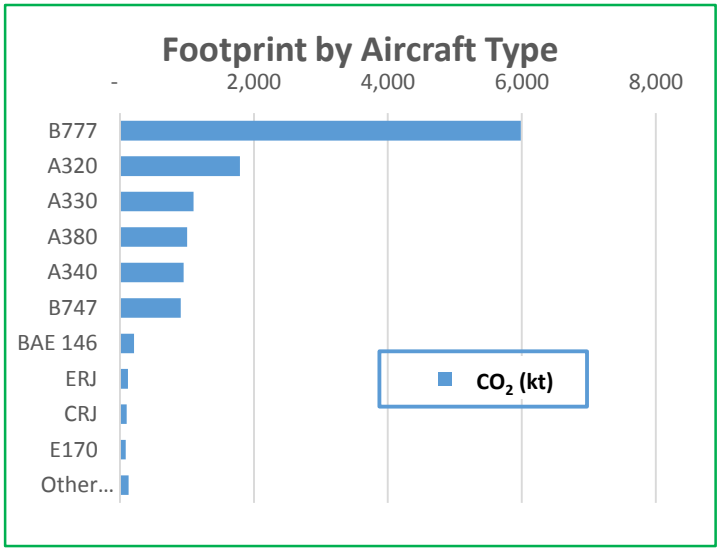
The profiles are ordered by descending weight of CO_2.

Airline	CO_2 (kt)	Cumulative %
Emirates Airline	17,333	4.8
British Airways	15,808	9.2
Lufthansa	15,344	13.4
United Airlines	14,828	17.5
Delta Air Lines	12,743	21.1
Air France	12,389	24.5
Singapore Airlines	10,498	27.4
Cathay Pacific	10,135	30.2
American Airlines	10,030	33.0
KLM Royal Dutch Airlines	9,079	35.5
Korean Air	7,982	37.7
Qatar Airways	7,330	39.8
Ryanair	6,803	41.7
Thai Airways International	6,311	43.4
Air Canada	6,179	45.1
Turkish Airlines	6,123	46.8
Qantas	5,181	48.2
Etihad Airways	4,779	49.6
Easyjet	4,645	50.9
Iberia Airlines	4,302	52.0
Other Airlines	173,033	100.0
Total	**360,857**	

Air France

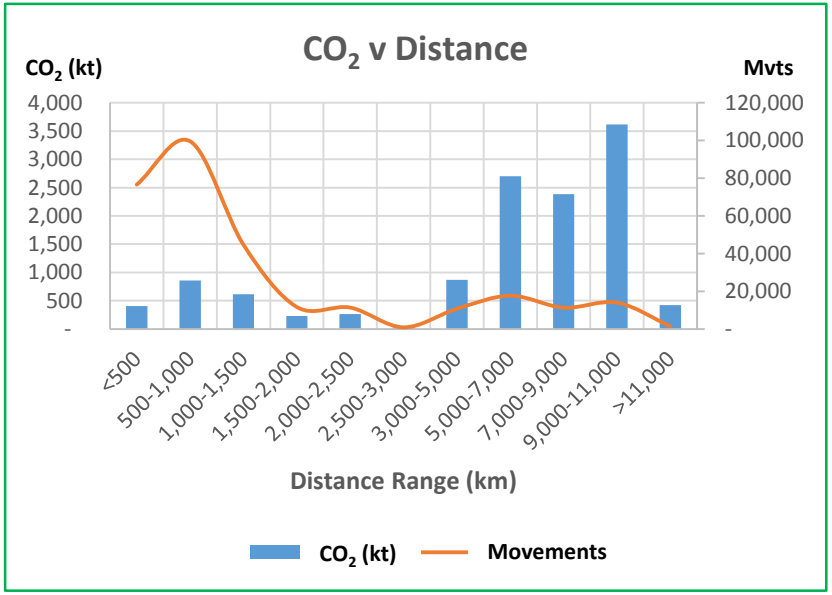
Total Footprint = 12,389 kt CO_2





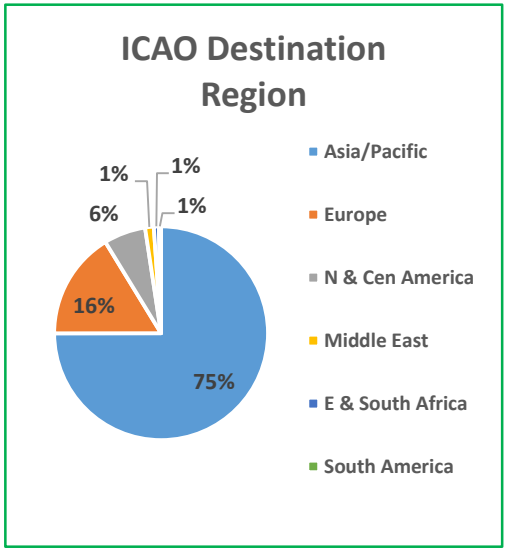
City-Pair Hierarchy	CO_2 (kt)
Paris (CDG)-New York (JFK)	249
New York (JFK)-Paris (CDG)	249
Tokyo (Narita)-Paris (CDG)	205
Paris (CDG)-Tokyo (Narita)	205
Los Angeles-Paris (CDG)	188
Paris (CDG)-Los Angeles	188
Paris (CDG)-Rio de Janeiro	174
Rio de Janeiro-Paris (CDG)	174
Sao Paulo-Paris (CDG)	170
Paris (CDG)-Sao Paulo	170
Paris (CDG)-Shanghai	154
Shanghai-Paris (CDG)	154
Hong Kong-Paris (CDG)	142
Paris (CDG)-Hong Kong	142
Mexico City-Paris (CDG)	131
Paris (CDG)-Mexico City	131
Paris (Orly)-St-Denis de la Reunion	130
St-Denis de la Reunion-Paris (Orly)	130
San Francisco-Paris (CDG)	127
Paris (CDG)-San Francisco	127
Paris (CDG)-Beijing	125
Beijing-Paris (CDG)	124
Paris (CDG)-Montreal	123
Montreal-Paris (CDG)	123
Atlanta-Paris (CDG)	114
Paris (CDG)-Atlanta	114
Singapore-Paris (CDG)	113
Paris (CDG)-Singapore	113
Paris (CDG)-Johannesburg	111
Johannesburg-Paris (CDG)	111
Other Routes	7,879
Total	**12,389**

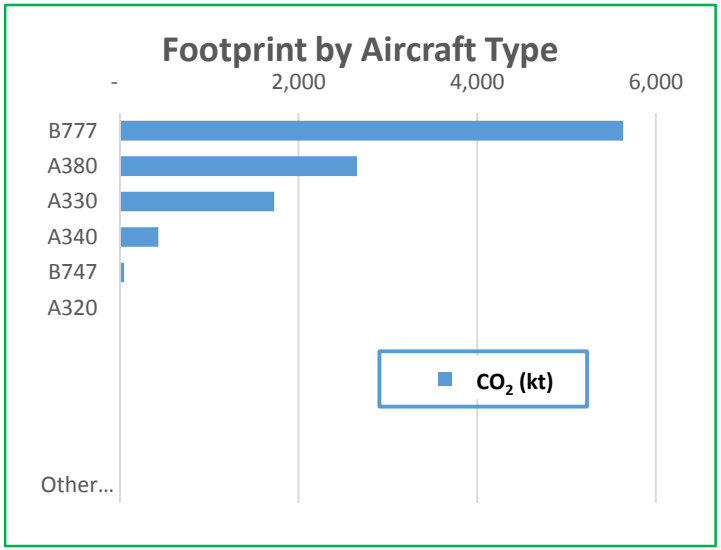
Origin Airports	CO_2 (kt)
Paris (CDG)	5,539
Paris (Orly)	385
New York (JFK)	249
Los Angeles	214
Tokyo (Narita)	205
Rio de Janeiro	174
Sao Paulo	170
Shanghai	154
Hong Kong	142
Mexico City	131
St-Denis de la Reunic	130
San Francisco	127
Beijing	124
Montreal	123
Pointe-a-Pitre	116
Other Airports	4,406
Total	**12,389**



Singapore Airlines

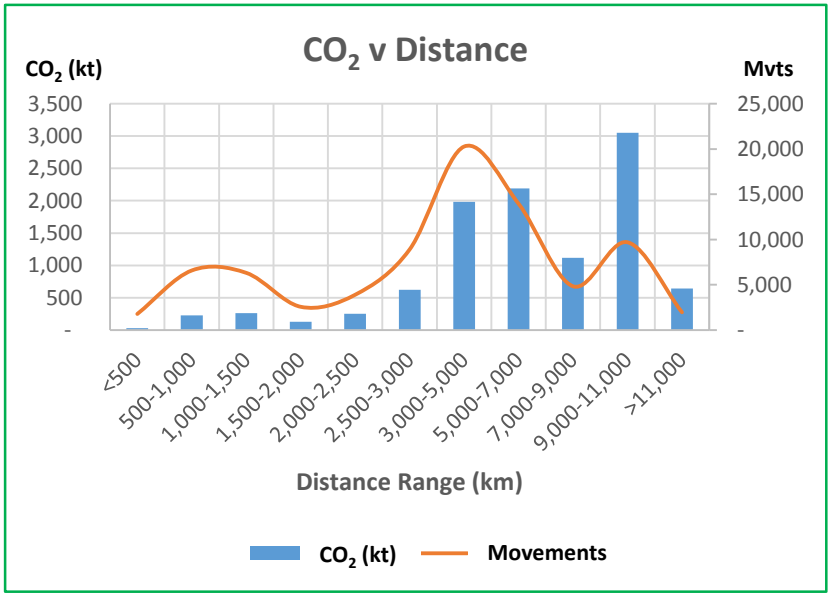
Total Footprint = 10,498 kt CO_2





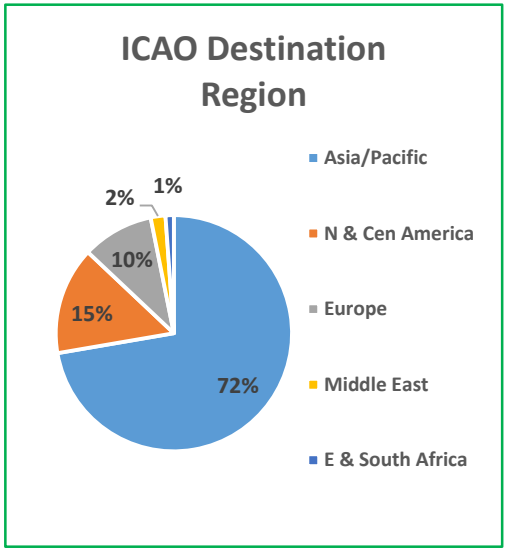
City-Pair Hierarchy	CO_2 (kt)
Singapore-London (Heathrow)	444
London (Heathrow)-Singapore	444
Singapore-Sydney	268
Sydney-Singapore	268
Singapore-Frankfurt	233
Frankfurt-Singapore	233
Singapore-Melbourne	195
Melbourne-Singapore	195
Singapore-Hong Kong	184
Hong Kong-Singapore	184
Shanghai-Singapore	162
Singapore-Shanghai	162
Beijing-Singapore	159
Singapore-Beijing	159
Brisbane-Singapore	148
Singapore-Brisbane	148
Singapore-Seoul	145
Paris (CDG)-Singapore	145
Singapore-Paris (CDG)	145
Seoul-Singapore	145
Singapore-Zurich	138
Zurich-Singapore	138
Auckland-Singapore	137
Singapore-Auckland	137
Singapore-Newark	130
Newark-Singapore	130
Singapore-Tokyo (Narita)	117
Tokyo (Narita)-Singapore	117
Los Angeles-Tokyo (Narita)	115
Tokyo (Narita)-Los Angeles	115
Other Routes	5,055
Total	**10,498**

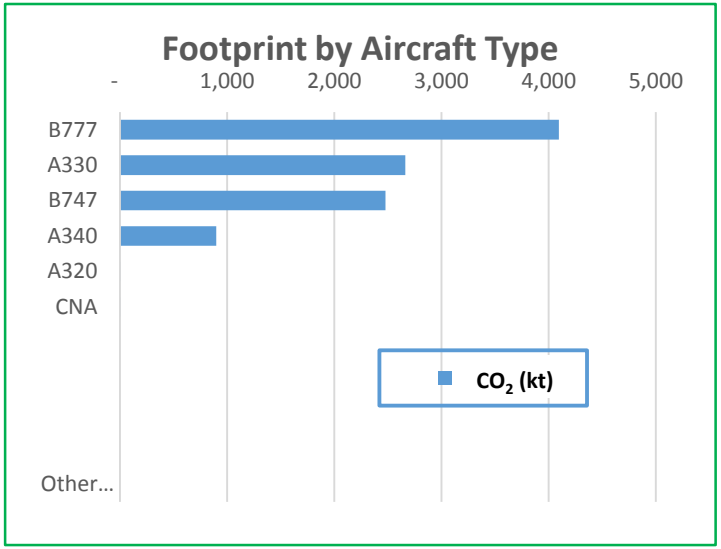
Origin Airports	CO_2 (kt)
Singapore	4,726
London (Heathrow)	444
Frankfurt	312
Hong Kong	288
Sydney	268
Tokyo (Narita)	232
Seoul	229
Los Angeles	201
Melbourne	195
San Francisco	189
Shanghai	162
Beijing	159
Brisbane	148
Paris (CDG)	145
Zurich	138
Other Airports	2,660
Total	**10,498**



Cathay Pacific

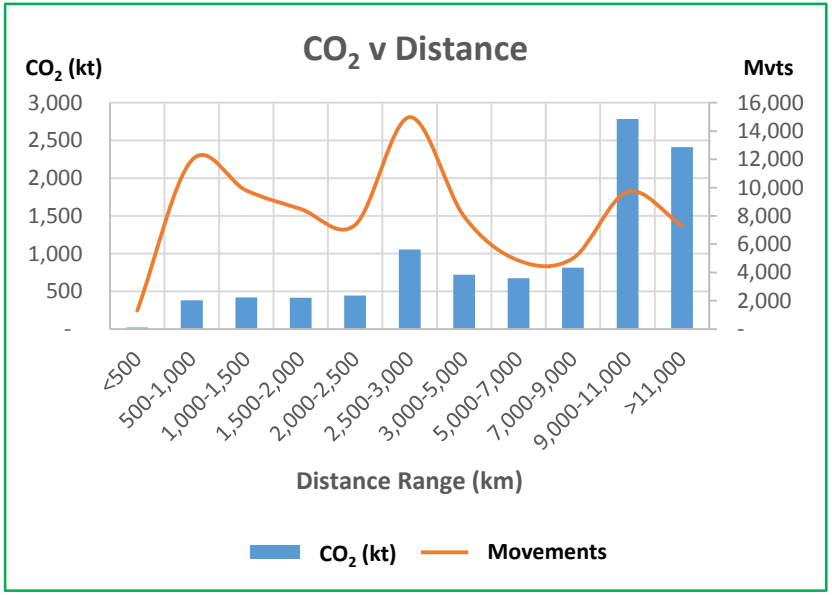
Total Footprint = 10,135 kt CO_2





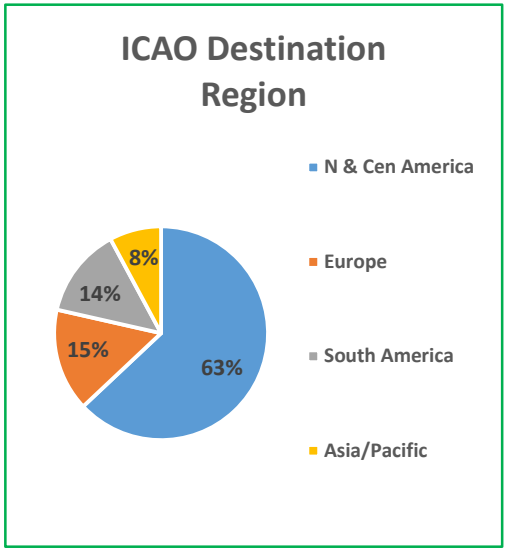
City-Pair Hierarchy	CO_2 (kt)
London (Heathrow)-Hong Kong	432
Hong Kong-London (Heathrow)	431
New York (JFK)-Hong Kong	348
Hong Kong-New York (JFK)	348
Hong Kong-Los Angeles	297
Los Angeles-Hong Kong	297
San Francisco-Hong Kong	270
Hong Kong-San Francisco	270
Hong Kong-Sydney	231
Sydney-Hong Kong	231
Hong Kong-Vancouver	216
Vancouver-Hong Kong	216
Hong Kong-Singapore	192
Singapore-Hong Kong	192
Taipei-Hong Kong	188
Hong Kong-Taipei	188
Melbourne-Hong Kong	178
Hong Kong-Toronto	173
Toronto-Hong Kong	173
Paris (CDG)-Hong Kong	149
Hong Kong-Paris (CDG)	148
Hong Kong-Melbourne	124
Hong Kong-Frankfurt	118
Frankfurt-Hong Kong	118
Chicago-Hong Kong	117
Hong Kong-Chicago	117
Johannesburg-Hong Kong	116
Hong Kong-Johannesburg	115
Hong Kong-Amsterdam	108
Amsterdam-Hong Kong	108
Other Routes	3,926
Total	**10,135**

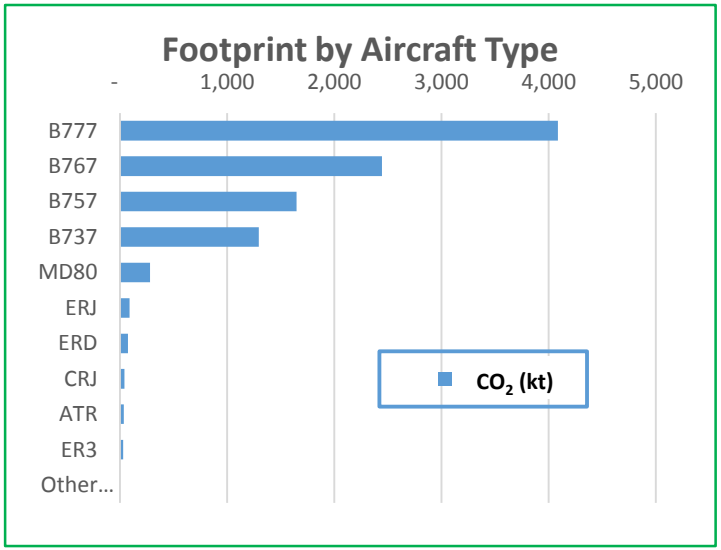
Origin Airports	CO_2 (kt)
Hong Kong	4,824
London (Heathrow)	432
New York (JFK)	384
Los Angeles	297
Taipei	274
San Francisco	270
Vancouver	252
Sydney	231
Singapore	223
Melbourne	178
Bangkok	178
Toronto	173
Paris (CDG)	154
Tokyo (Narita)	122
Frankfurt	118
Other Airports	2,025
Total	**10,135**



American Airlines

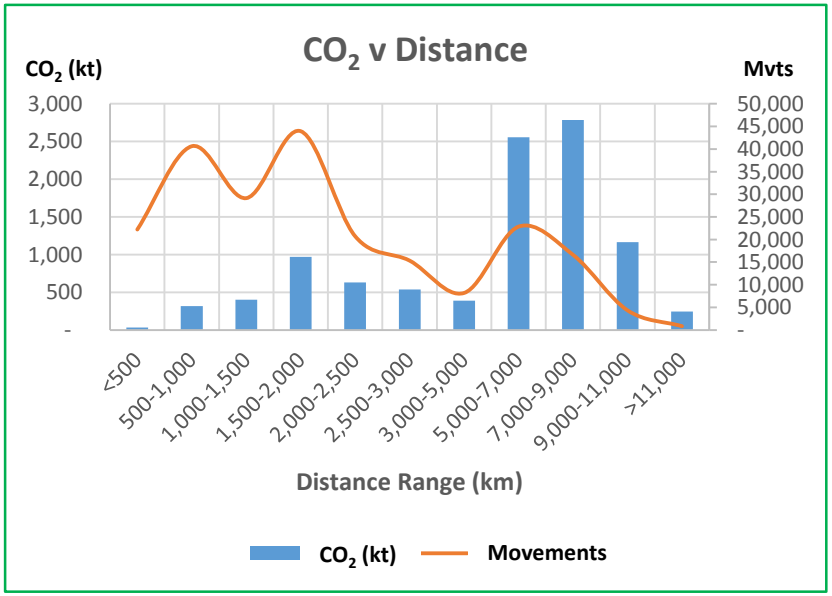
Total Footprint = 10,030 kt CO_2





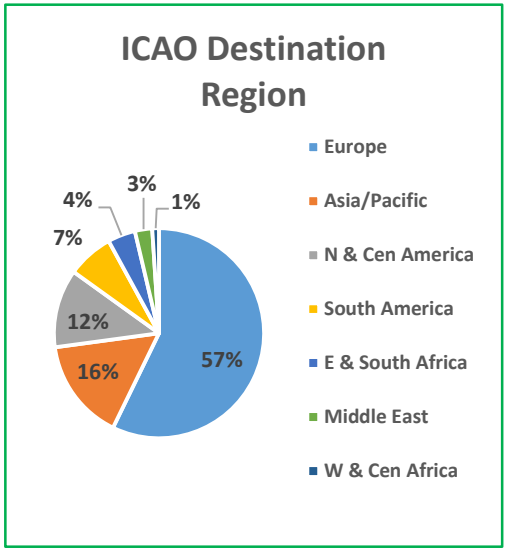
City-Pair Hierarchy	CO_2 (kt)
New York (JFK)-London (Heathrow)	237
London (Heathrow)-New York (JFK)	236
Dallas-Fort Worth-Tokyo (Narita)	193
Tokyo (Narita)-Dallas-Fort Worth	193
London (Heathrow)-Dallas-Fort Wort	179
Dallas-Fort Worth-London (Heathrov	179
Miami-Sao Paulo	179
Sao Paulo-Miami	179
Chicago-London (Heathrow)	174
London (Heathrow)-Chicago	173
Miami-Buenos Aires	150
Buenos Aires-Miami	150
Shanghai-Chicago	105
Chicago-Shanghai	105
Chicago-Beijing	98
Beijing-Chicago	98
Los Angeles-Shanghai	96
Shanghai-Los Angeles	96
Chicago-Tokyo (Narita)	93
Tokyo (Narita)-Chicago	93
New York (JFK)-Sao Paulo	88
Sao Paulo-New York (JFK)	88
Sao Paulo-Dallas-Fort Worth	88
Dallas-Fort Worth-Sao Paulo	88
London (Heathrow)-Miami	85
Miami-London (Heathrow)	85
Los Angeles-Tokyo (Narita)	81
Tokyo (Narita)-Los Angeles	81
London (Heathrow)-Los Angeles	79
Los Angeles-London (Heathrow)	79
Other Routes	6,182
Total	**10,030**

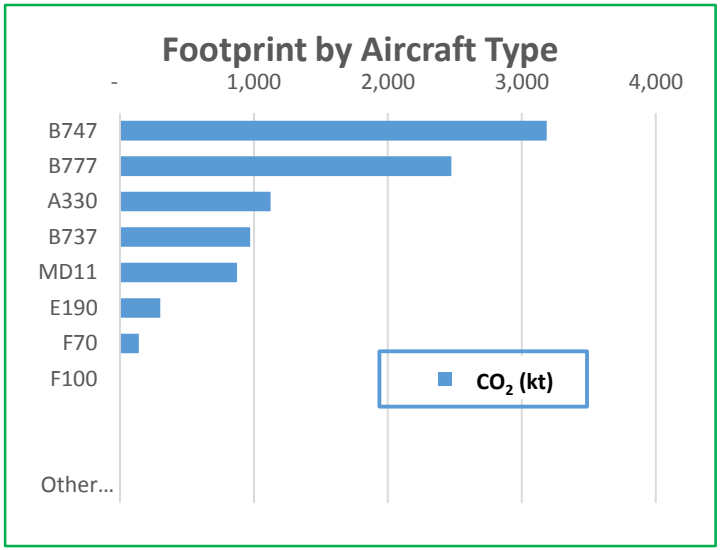
Origin Airports	CO_2 (kt)
Miami	1,695
Dallas-Fort Worth	1,121
New York (JFK)	1,040
London (Heathrow)	849
Chicago	716
Tokyo (Narita)	410
Sao Paulo	354
Buenos Aires	295
Los Angeles	286
Paris (CDG)	213
Shanghai	201
San Juan	179
Rio de Janeiro	133
Madrid	124
Santiago de Chile	104
Other Airports	2,309
Total	**10,030**



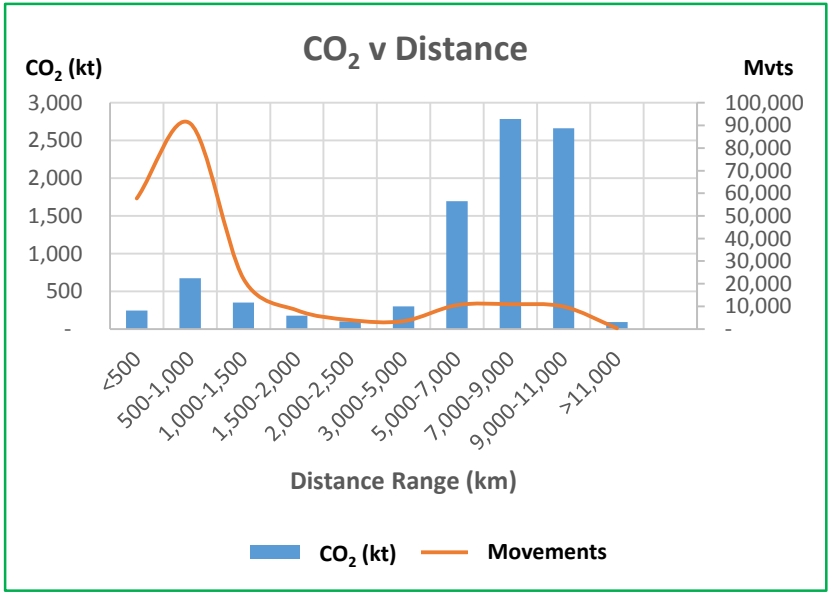
KLM Royal Dutch Airlines

Total Footprint = 9,079 kt CO_2





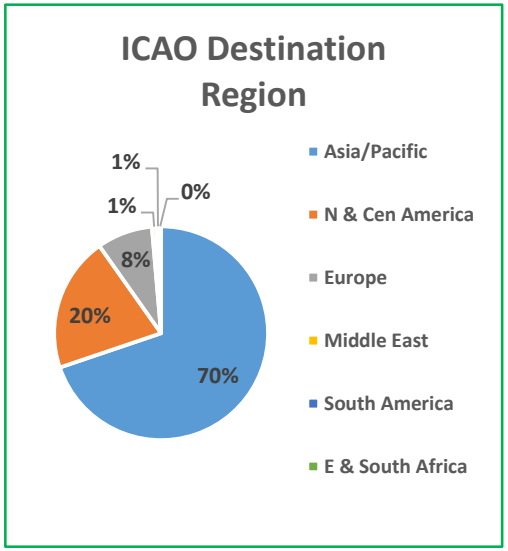
Origin Airports	CO_2 (kt)
Amsterdam	4,458
Shanghai	188
Tokyo (Narita)	150
Los Angeles	126
New York (JFK)	123
Mexico City	120
Hong Kong	120
Kuala Lumpur	119
Singapore	115
Seoul	106
Houston	104
Curacao	101
Bangkok	101
Lima	98
Beijing	97
Other Airports	2,952
Total	**9,079**

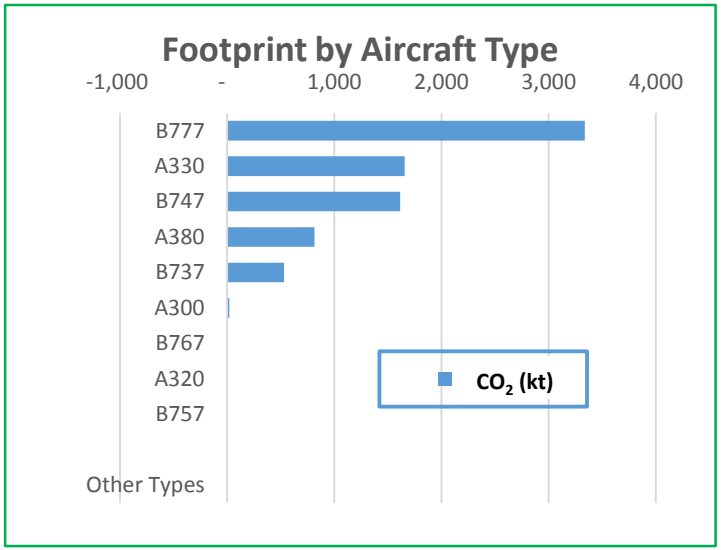


City-Pair Hierarchy	CO_2 (kt)
Shanghai-Amsterdam	188
Amsterdam-Shanghai	188
Amsterdam-Tokyo (Narita)	150
Tokyo (Narita)-Amsterdam	150
Los Angeles-Amsterdam	126
Amsterdam-Los Angeles	126
New York (JFK)-Amsterdam	123
Amsterdam-New York (JFK)	123
Mexico City-Amsterdam	120
Amsterdam-Mexico City	120
Amsterdam-Hong Kong	120
Hong Kong-Amsterdam	120
Seoul-Amsterdam	106
Amsterdam-Seoul	106
Amsterdam-Kuala Lumpur	105
Kuala Lumpur-Amsterdam	105
Houston-Amsterdam	104
Amsterdam-Houston	104
Curacao-Amsterdam	101
Amsterdam-Singapore	98
Amsterdam-Lima	98
Lima-Amsterdam	98
Singapore-Amsterdam	98
Amsterdam-Beijing	97
Beijing-Amsterdam	97
Toronto-Amsterdam	96
Amsterdam-Toronto	96
Amsterdam-San Francisco	96
San Francisco-Amsterdam	96
Panama City-Amsterdam	94
Other Routes	5,629
Total	**9,079**

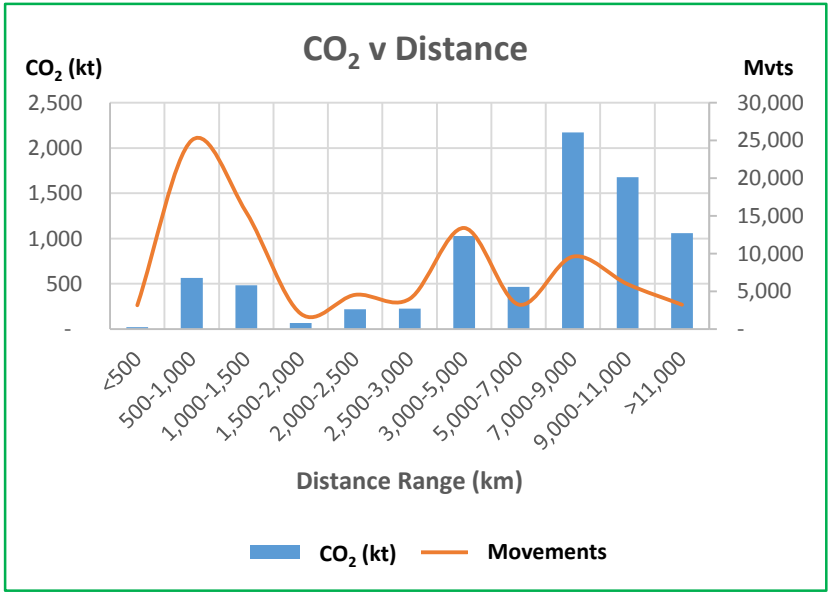
Korean Air

Total Footprint = 7,982 kt CO_2





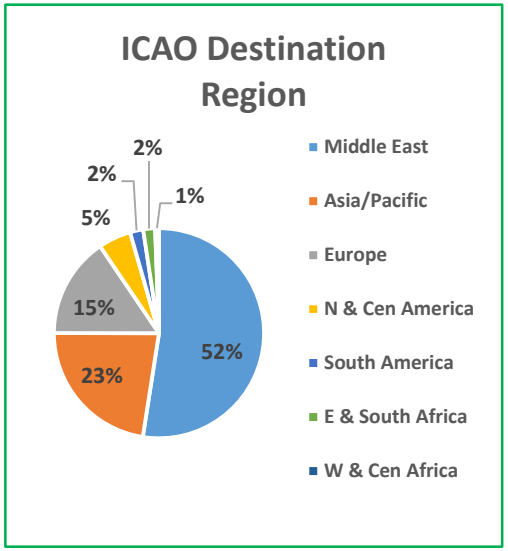
Origin Airports	CO_2 (kt)
Seoul	3,736
Los Angeles	404
New York (JFK)	262
Atlanta	164
Honolulu	153
Tokyo (Narita)	151
Bangkok	130
Paris (CDG)	113
Chicago	106
London (Heathrow)	106
Washington	104
Busan	99
Hong Kong	91
Frankfurt	91
Sydney	90
Other Airports	2,183
Total	**7,982**

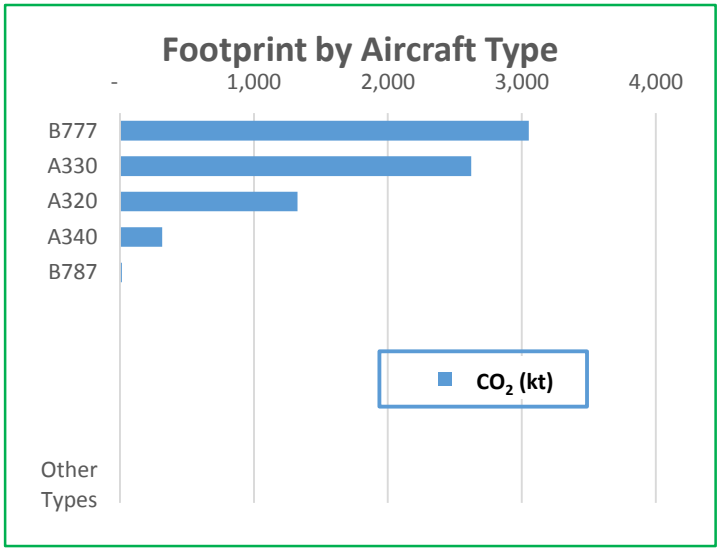


City-Pair Hierarchy	CO_2 (kt)
Seoul-Los Angeles	294
Los Angeles-Seoul	294
Seoul-New York (JFK)	262
New York (JFK)-Seoul	262
Atlanta-Seoul	164
Seoul-Atlanta	163
Seoul-Honolulu	153
Honolulu-Seoul	153
Seoul-Paris (CDG)	113
Paris (CDG)-Seoul	113
Chicago-Seoul	106
Seoul-Chicago	106
London (Heathrow)-Seoul	106
Seoul-London (Heathrow)	106
Washington-Seoul	104
Seoul-Washington	104
Bangkok-Seoul	98
Seoul-Bangkok	98
Frankfurt-Seoul	91
Seoul-Frankfurt	91
Seoul-Sydney	90
Sydney-Seoul	90
Seoul-Auckland	87
Auckland-Seoul	87
Seoul-Singapore	84
Singapore-Seoul	84
Seoul-San Francisco	84
San Francisco-Seoul	84
Hong Kong-Seoul	81
Seoul-Hong Kong	81
Other Routes	4,147
Total	**7,982**

Qatar Airways

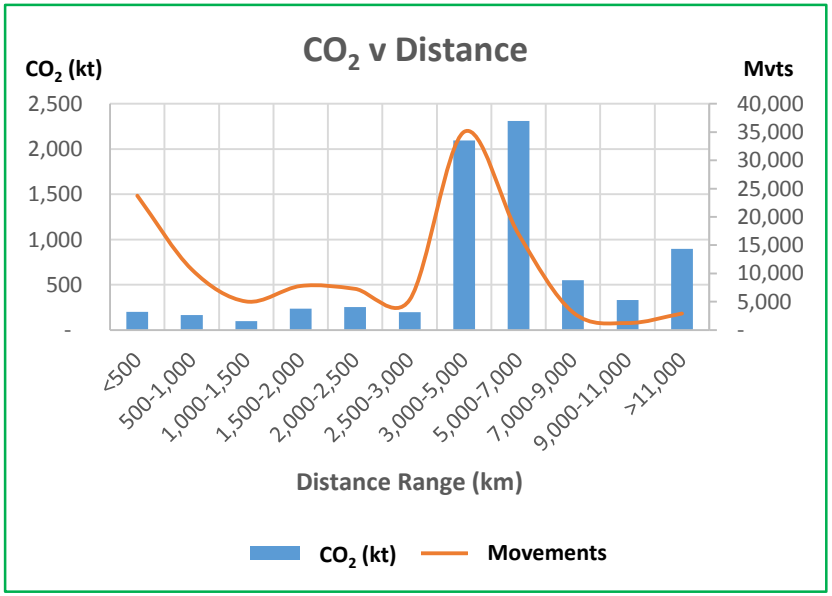
Total Footprint = 7,330 kt CO_2





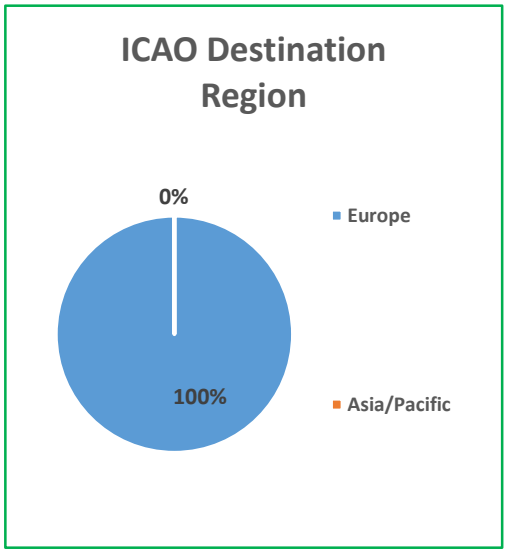
City-Pair Hierarchy	CO_2 (kt)
London (Heathrow)-Doha	212
Doha-London (Heathrow)	212
Doha-Bangkok	144
Bangkok-Doha	144
Manila-Doha	126
Doha-Manila	126
Doha-Houston	121
Houston-Doha	121
Doha-Kuala Lumpur	119
Kuala Lumpur-Doha	119
Doha-Singapore	113
Singapore-Doha	113
Melbourne-Doha	112
Doha-Melbourne	112
Doha-Sao Paulo	111
Sao Paulo-Doha	111
Doha-Washington	104
Washington-Doha	104
New York (JFK)-Doha	101
Doha-New York (JFK)	101
Paris (CDG)-Doha	95
Doha-Paris (CDG)	95
Doha-Hong Kong	86
Hong Kong-Doha	86
Doha-Frankfurt	74
Frankfurt-Doha	74
Doha-Jakarta	73
Jakarta-Doha	73
Osaka-Doha	71
Doha-Osaka	71
Other Routes	4,006
Total	**7,330**

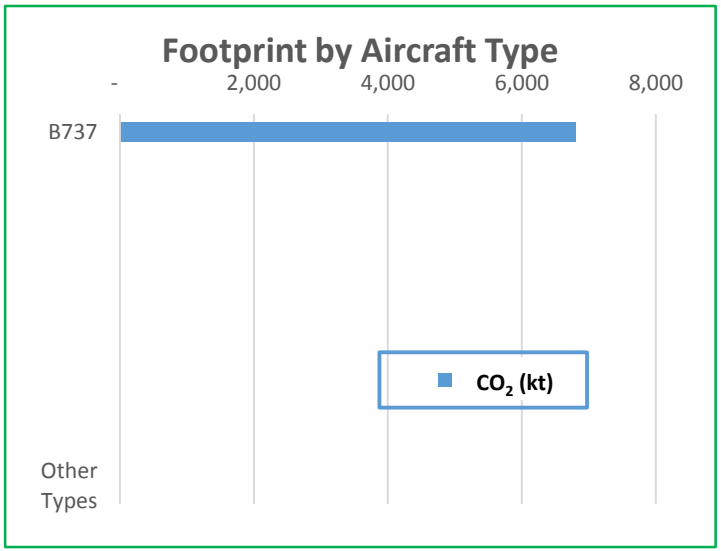
Origin Airports	CO_2 (kt)
Doha	3,560
London (Heathrow)	212
Bangkok	169
Singapore	131
Sao Paulo	130
Kuala Lumpur	129
Manila	126
Houston	121
Melbourne	112
Washington	104
New York (JFK)	101
Paris (CDG)	95
Hong Kong	86
Frankfurt	74
Jakarta	73
Other Airports	2,108
Total	**7,330**



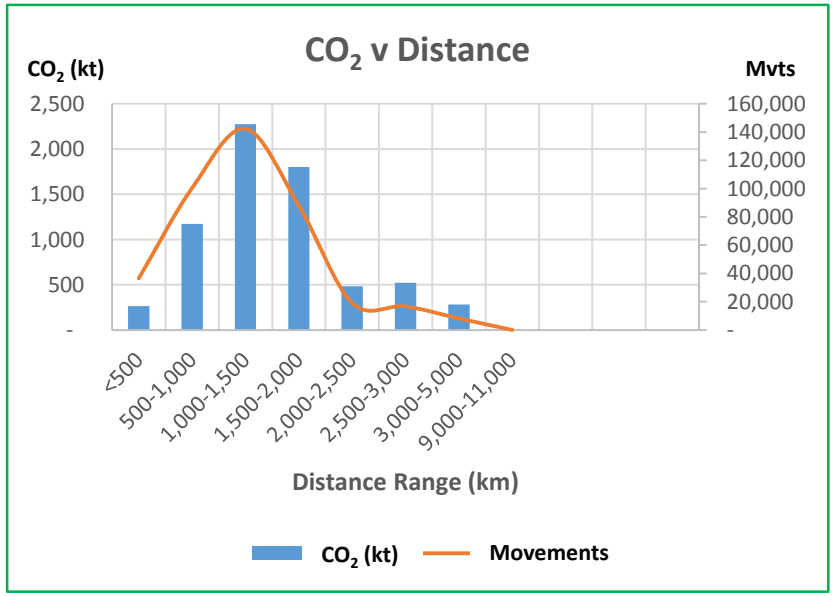
Ryanair

Total Footprint = 6,803 kt CO_2





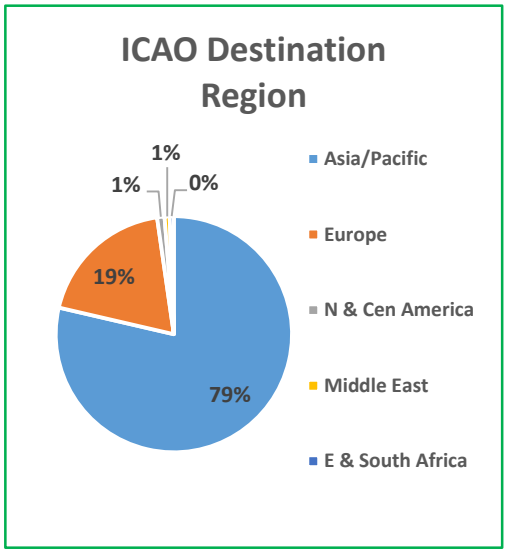
Origin Airports	CO_2 (kt)
London (Stansted)	615
Dublin	324
Charleroi	284
Bergamo	229
Roma	179
Malaga	162
Beauvais	161
Madrid	145
Hahn	143
Stockholm	141
Alicante	134
Barcelona	130
Niederrhein	129
Girona	124
Palma de Mallorca	119
Other Airports	3,784
Total	**6,803**

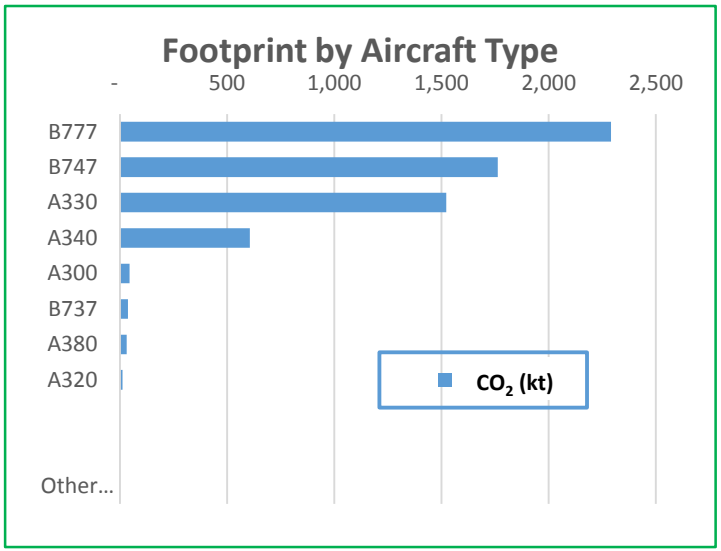


City-Pair Hierarchy	CO_2 (kt)
London (Stansted)-Roma	20
Roma-London (Stansted)	20
Dublin-London (Stansted)	20
London (Stansted)-Dublin	20
Madrid-Charleroi	16
Charleroi-Madrid	16
London (Stansted)-Stockholm	16
Stockholm-London (Stansted)	16
Bergamo-London (Stansted)	15
London (Stansted)-Bergamo	15
Barcelona-Charleroi	15
Charleroi-Barcelona	15
Pisa-London (Stansted)	14
London (Stansted)-Pisa	14
Roma-Charleroi	14
Charleroi-Roma	14
Dublin-London (Gatwick)	13
London (Gatwick)-Dublin	13
Malaga-London (Stansted)	13
London (Stansted)-Malaga	13
London (Stansted)-Krakow	13
Krakow-London (Stansted)	13
Roma-Barcelona	13
Barcelona-Roma	13
Bergamo-Barcelona	12
Barcelona-Bergamo	12
Roma-Madrid	12
Madrid-Roma	12
London (Stansted)-Madrid	12
Madrid-London (Stansted)	12
Other Routes	6,372
Total	**6,803**

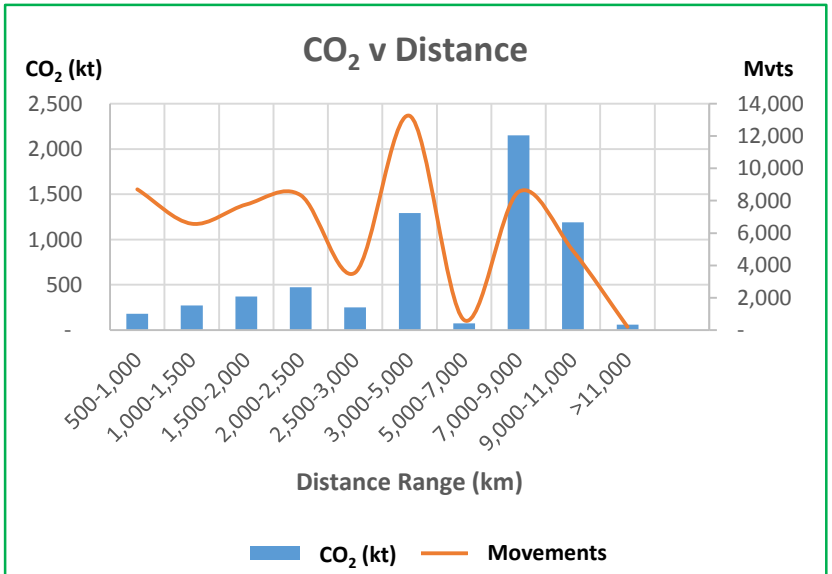
Thai Airways International

Total Footprint = 6,311 kt CO_2





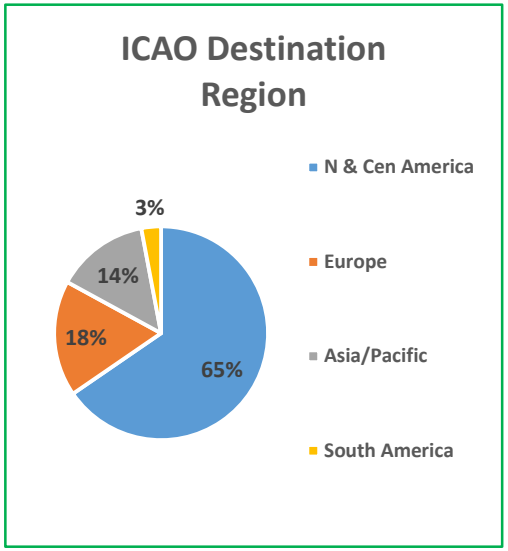
Origin Airports	CO_2 (kt)
Bangkok	3,033
Frankfurt	197
London (Heathrow)	174
Seoul	170
Sydney	155
Hong Kong	143
Tokyo (Narita)	139
Copenhagen	125
Melbourne	121
Paris (CDG)	118
Munich	114
Stockholm	108
Osaka	85
Zurich	78
Singapore	77
Other Airports	1,473
Total	**6,311**

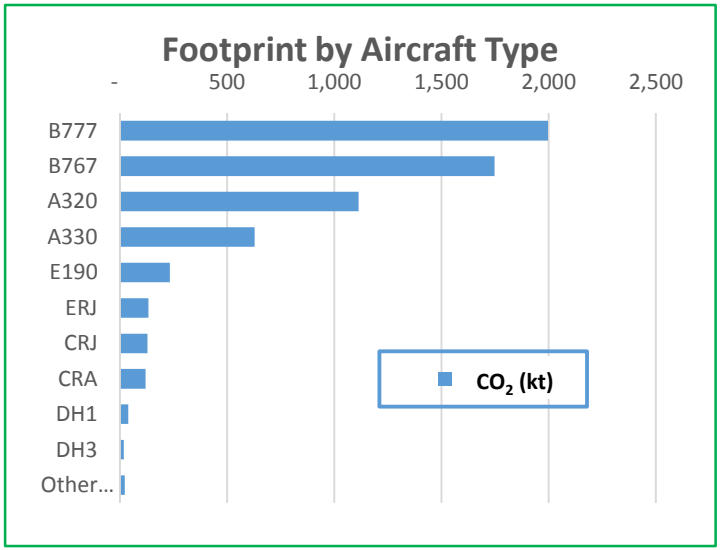


City-Pair Hierarchy	CO_2 (kt)
Bangkok-Frankfurt	197
Frankfurt-Bangkok	197
London (Heathrow)-Bangkok	174
Bangkok-London (Heathrow)	174
Sydney-Bangkok	155
Bangkok-Sydney	155
Tokyo (Narita)-Bangkok	139
Bangkok-Tokyo (Narita)	139
Bangkok-Copenhagen	124
Bangkok-Melbourne	121
Melbourne-Bangkok	121
Paris (CDG)-Bangkok	118
Bangkok-Paris (CDG)	118
Bangkok-Munich	114
Munich-Bangkok	114
Bangkok-Stockholm	108
Copenhagen-Bangkok	108
Stockholm-Bangkok	103
Hong Kong-Bangkok	100
Bangkok-Hong Kong	100
Bangkok-Osaka	85
Osaka-Bangkok	85
Seoul-Bangkok	82
Bangkok-Seoul	81
Zurich-Bangkok	78
Bangkok-Zurich	78
Bangkok-Singapore	77
Singapore-Bangkok	77
Oslo-Bangkok	66
Bangkok-Oslo	66
Other Routes	2,857
Total	**6,311**

Air Canada

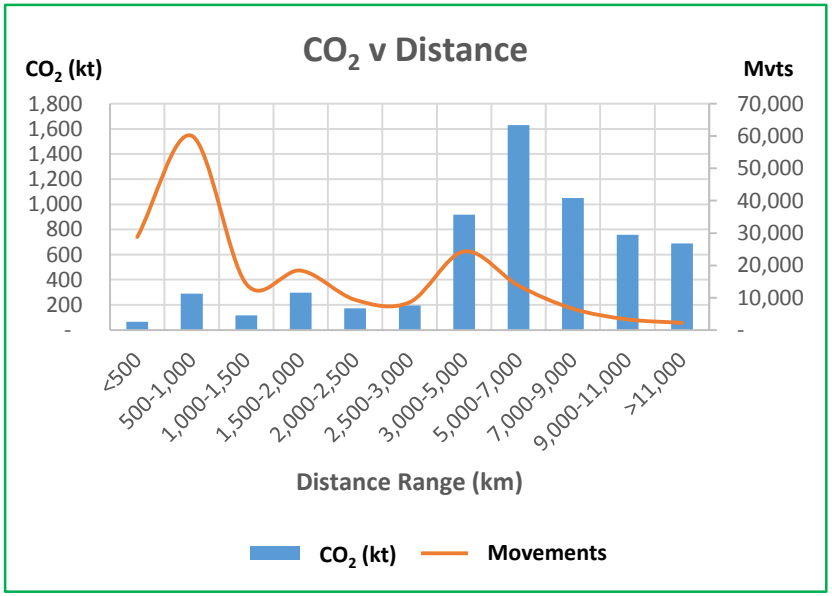
Total Footprint = 6,179 kt CO_2





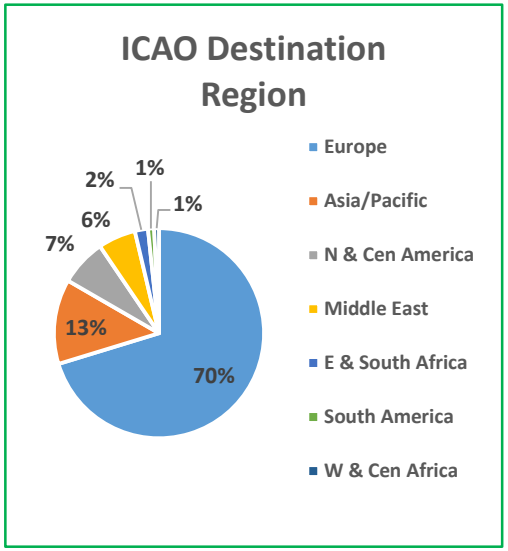
City-Pair Hierarchy	CO_2 (kt)
London (Heathrow)-Toronto	176
Toronto-London (Heathrow)	176
Vancouver-Sydney	120
Sydney-Vancouver	119
Hong Kong-Toronto	117
Toronto-Hong Kong	117
Toronto-Frankfurt	107
Toronto-Shanghai	107
Shanghai-Toronto	107
Frankfurt-Toronto	107
Toronto-Beijing	99
Beijing-Toronto	99
Tokyo (Narita)-Toronto	96
Toronto-Tokyo (Narita)	96
Vancouver-Hong Kong	89
Hong Kong-Vancouver	89
Vancouver-London (Heathrow)	66
London (Heathrow)-Vancouver	65
Toronto-Sao Paulo	61
Sao Paulo-Toronto	61
Toronto-Los Angeles	60
Los Angeles-Toronto	60
Frankfurt-Calgary	58
Calgary-Frankfurt	58
Tokyo (Narita)-Vancouver	58
Vancouver-Tokyo (Narita)	58
Santiago de Chile-Toronto	57
Toronto-Santiago de Chile	57
Vancouver-Shanghai	55
Shanghai-Vancouver	55
Other Routes	3,527
Total	**6,179**

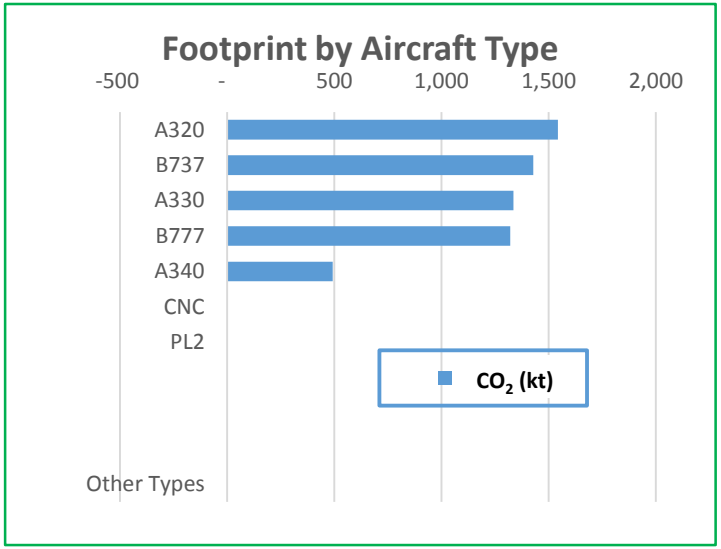
Origin Airports	CO_2 (kt)
Toronto	1,732
Vancouver	611
London (Heathrow)	431
Montreal	380
Frankfurt	249
Hong Kong	207
Calgary	204
Tokyo (Narita)	177
Shanghai	162
Beijing	151
Sydney	119
Los Angeles	115
Paris (CDG)	98
Ottawa	81
San Francisco	70
Other Airports	1,391
Total	**6,179**



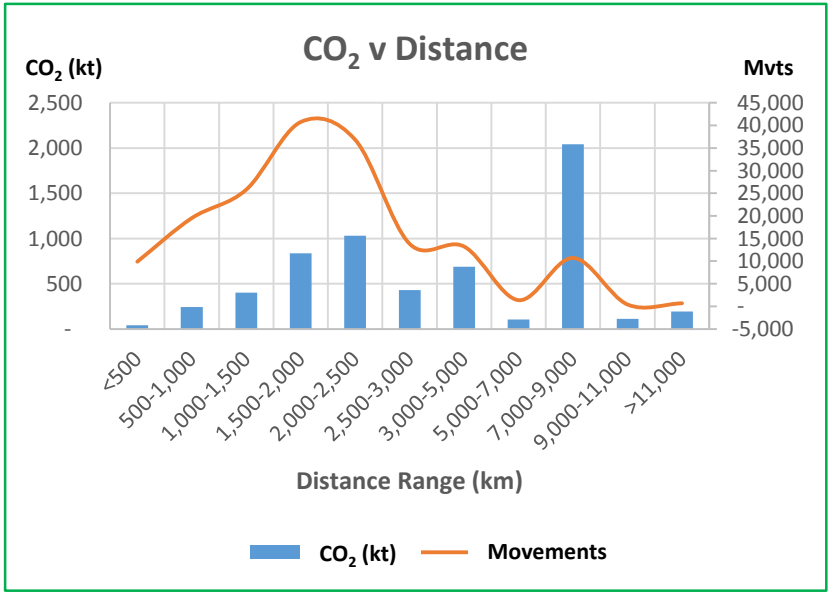
Turkish Airlines

Total Footprint = 6,123 kt CO_2





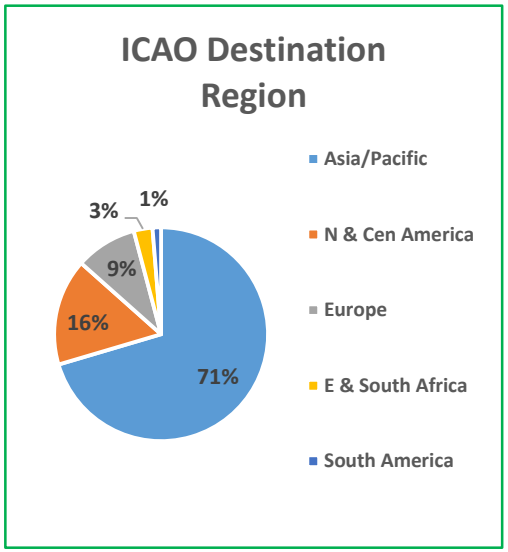
Origin Airports	CO_2 (kt)
Istanbul	2,960
New York (JFK)	159
Bangkok	117
Los Angeles	97
Tokyo (Narita)	80
Singapore	80
Shanghai	73
Chicago	70
Washington	68
Seoul	67
Hong Kong	65
Beijing	64
London (Heathrow)	62
Osaka	62
Johannesburg	60
Other Airports	2,040
Total	**6,123**

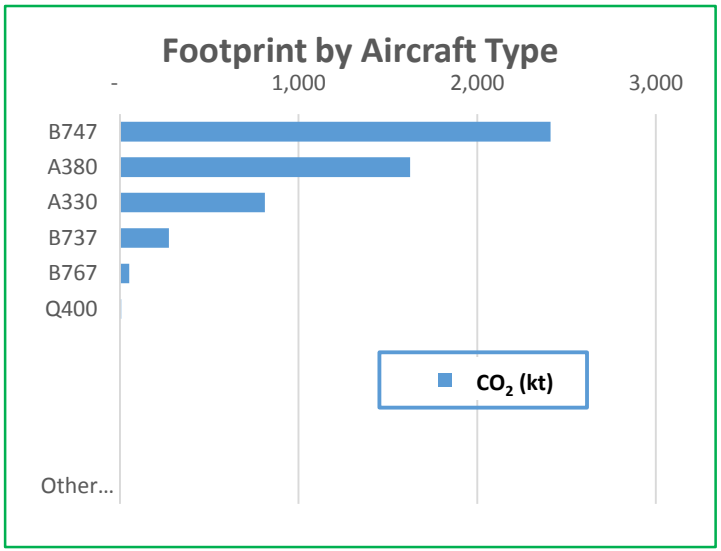


City-Pair Hierarchy	CO_2 (kt)
Istanbul-New York (JFK)	159
New York (JFK)-Istanbul	159
Bangkok-Istanbul	107
Istanbul-Bangkok	107
Los Angeles-Istanbul	97
Istanbul-Los Angeles	97
Istanbul-Tokyo (Narita)	80
Tokyo (Narita)-Istanbul	80
Shanghai-Istanbul	73
Istanbul-Shanghai	73
Istanbul-Chicago	71
Chicago-Istanbul	70
Istanbul-Singapore	69
Singapore-Istanbul	69
Washington-Istanbul	68
Istanbul-Washington	68
Seoul-Istanbul	67
Istanbul-Seoul	67
Hong Kong-Istanbul	65
Istanbul-Hong Kong	64
Istanbul-Beijing	64
Beijing-Istanbul	64
Istanbul-London (Heathrow)	63
London (Heathrow)-Istanbul	62
Osaka-Istanbul	62
Istanbul-Osaka	61
Johannesburg-Istanbul	60
Istanbul-Johannesburg	60
Sao Paulo-Istanbul	56
Istanbul-Sao Paulo	56
Other Routes	3,805
Total	**6,123**

Qantas

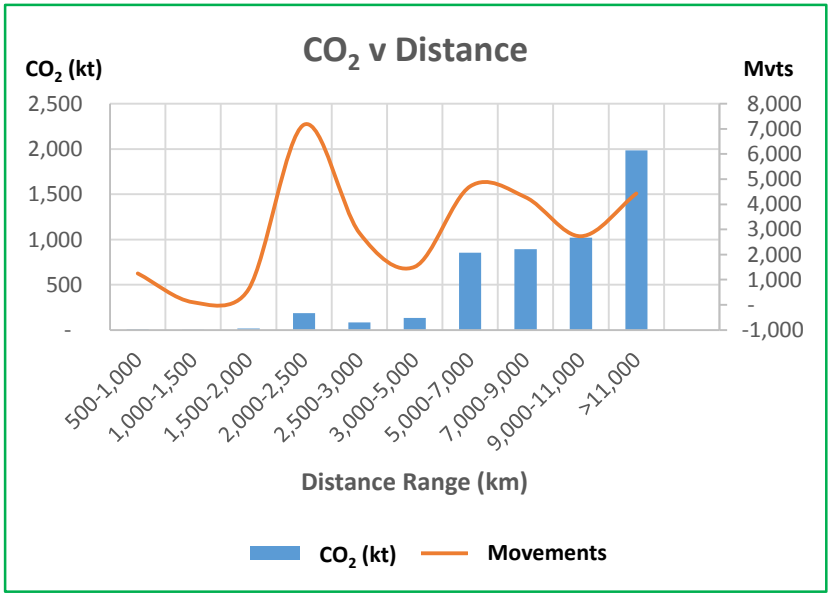
Total Footprint = 5,181 kt CO_2





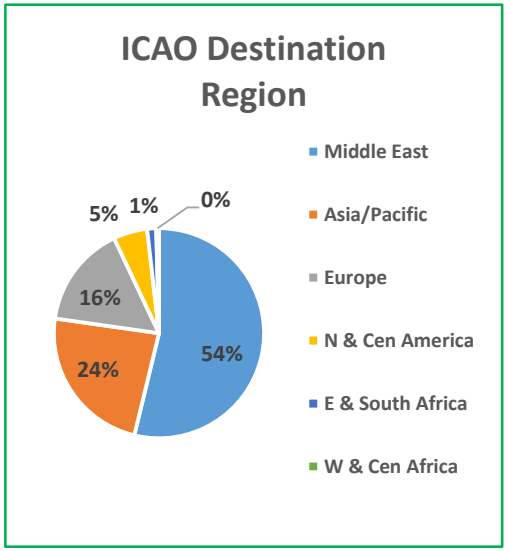
City-Pair Hierarchy	CO_2 (kt)
Sydney-Los Angeles	320
Los Angeles-Sydney	317
Singapore-London (Heathrow)	295
London (Heathrow)-Singapore	295
Los Angeles-Melbourne	174
Melbourne-Los Angeles	174
Sydney-Dallas-Fort Worth	160
Sydney-Singapore	159
Singapore-Sydney	158
Dallas-Fort Worth-Brisbane	155
Sydney-Johannesburg	147
Johannesburg-Sydney	147
Singapore-Frankfurt	134
Frankfurt-Singapore	133
Brisbane-Los Angeles	130
Los Angeles-Brisbane	130
Hong Kong-Sydney	126
Sydney-Hong Kong	125
Sydney-Tokyo (Narita)	97
Tokyo (Narita)-Sydney	97
Melbourne-Singapore	77
Singapore-Melbourne	77
Bangkok-Sydney	73
Sydney-Bangkok	73
Brisbane-Singapore	70
Singapore-Brisbane	70
Melbourne-Hong Kong	67
Hong Kong-Melbourne	67
Singapore-Perth	62
Perth-Singapore	61
Other Routes	1,012
Total	**5,181**

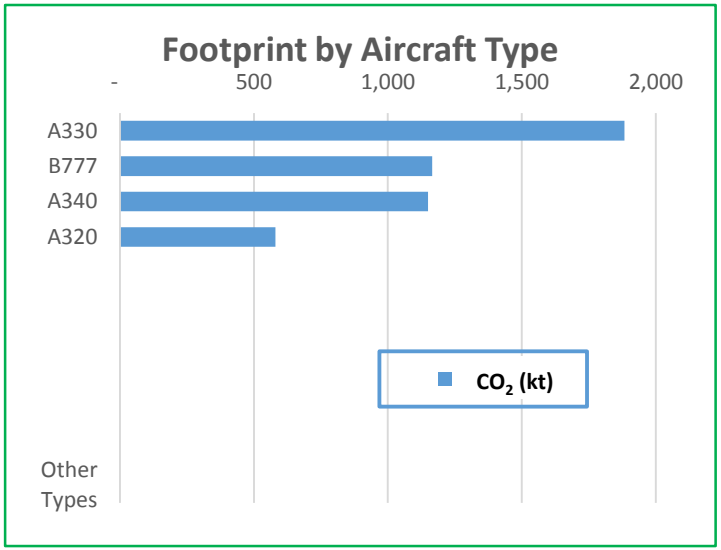
Origin Airports	CO_2 (kt)
Sydney	1,358
Singapore	818
Los Angeles	650
Melbourne	360
London (Heathrow)	348
Hong Kong	270
Brisbane	258
Dallas-Fort Worth	155
Johannesburg	147
Frankfurt	133
Auckland	125
Bangkok	101
Tokyo (Narita)	97
Perth	81
Shanghai	59
Other Airports	221
Total	**5,181**



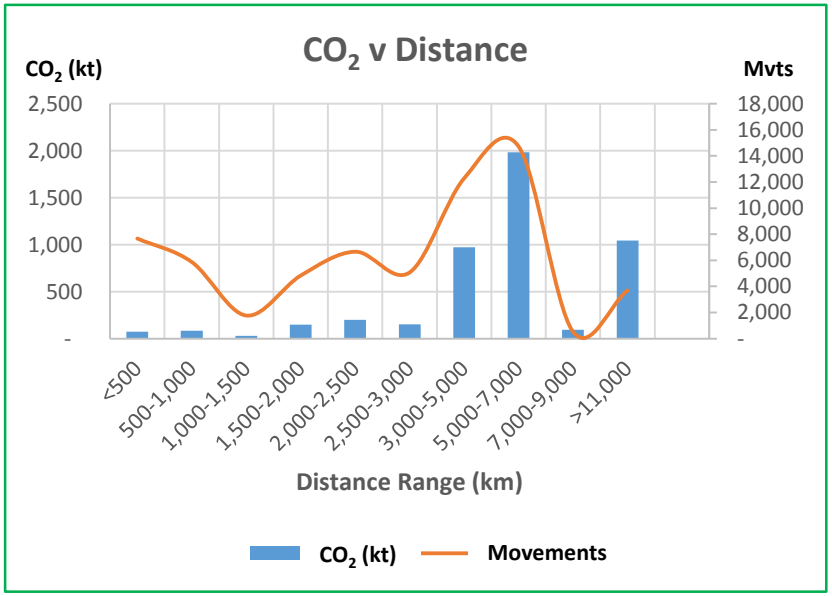
Etihad Airways

Total Footprint = 4,779 kt CO_2





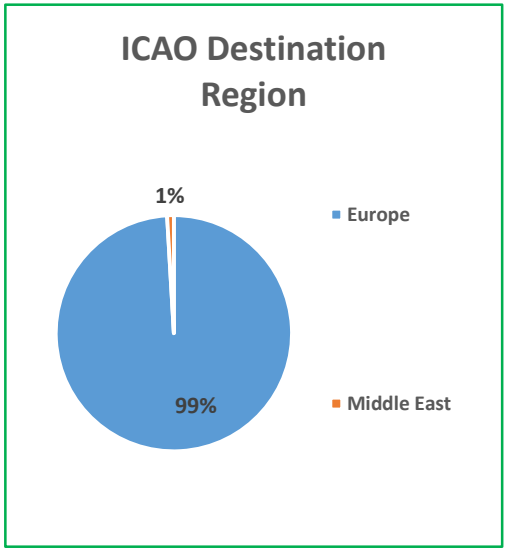
Origin Airports	CO_2 (kt)
Abu Dhabi	2,356
Sydney	173
London (Heathrow)	139
Manila	126
Bangkok	123
Chicago	110
Melbourne	101
New York (JFK)	95
Manchester	91
Paris (CDG)	86
Frankfurt	79
Dublin	68
Beijing	60
Jakarta	58
Seoul	55
Other Airports	1,061
Total	**4,779**

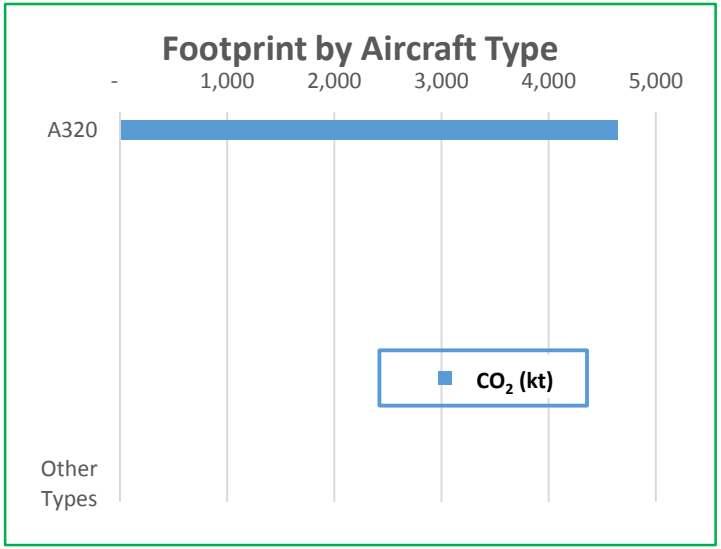


City-Pair Hierarchy	CO_2 (kt)
Sydney-Abu Dhabi	173
Abu Dhabi-Sydney	172
London (Heathrow)-Abu Dhabi	139
Abu Dhabi-London (Heathrow)	139
Abu Dhabi-Manila	126
Manila-Abu Dhabi	126
Bangkok-Abu Dhabi	123
Abu Dhabi-Bangkok	123
Abu Dhabi-Chicago	110
Chicago-Abu Dhabi	110
Abu Dhabi-Melbourne	101
Melbourne-Abu Dhabi	101
New York (JFK)-Abu Dhabi	95
Abu Dhabi-New York (JFK)	95
Manchester-Abu Dhabi	91
Abu Dhabi-Manchester	91
Paris (CDG)-Abu Dhabi	86
Abu Dhabi-Paris (CDG)	86
Frankfurt-Abu Dhabi	79
Abu Dhabi-Frankfurt	79
Abu Dhabi-Dublin	68
Dublin-Abu Dhabi	68
Jakarta-Abu Dhabi	58
Abu Dhabi-Jakarta	58
Abu Dhabi-Seoul	55
Seoul-Abu Dhabi	55
Johannesburg-Abu Dhabi	50
Abu Dhabi-Johannesburg	50
Abu Dhabi-Kuala Lumpur	49
Kuala Lumpur-Abu Dhabi	49
Other Routes	1,975
Total	**4,779**

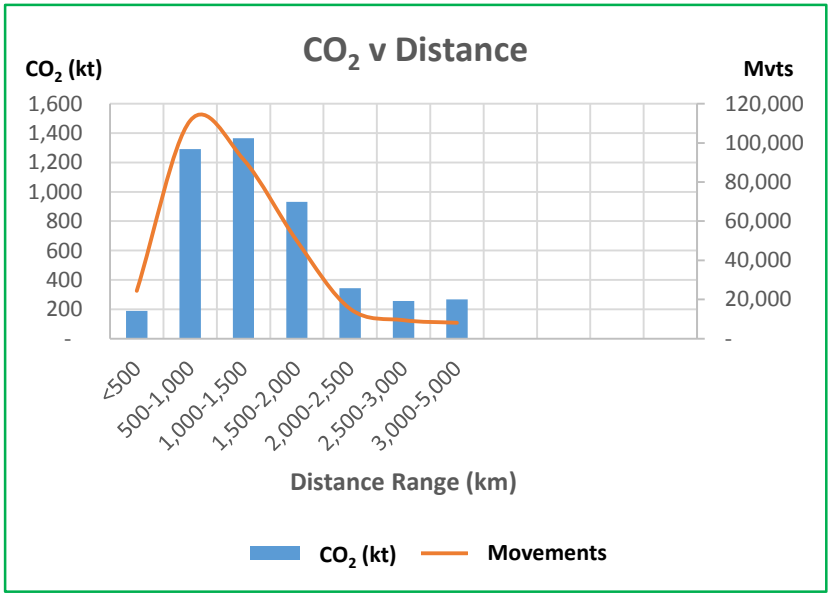
Easyjet

Total Footprint = 4,645 kt CO_2





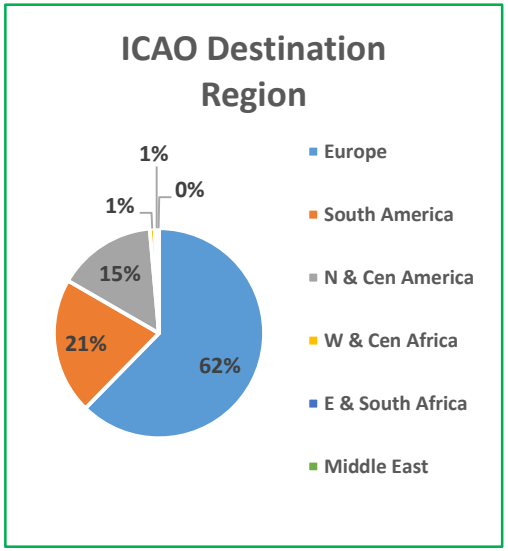
Origin Airports	CO_2 (kt)
London (Gatwick)	665
Geneva	203
Milano	194
Berlin	185
London (Luton)	180
Paris (CDG)	165
Madrid	147
Barcelona	146
Bristol	126
Amsterdam	124
London (Stansted)	120
Malaga	114
Liverpool	112
Roma	105
Basel	105
Other Airports	1,953
Total	**4,645**

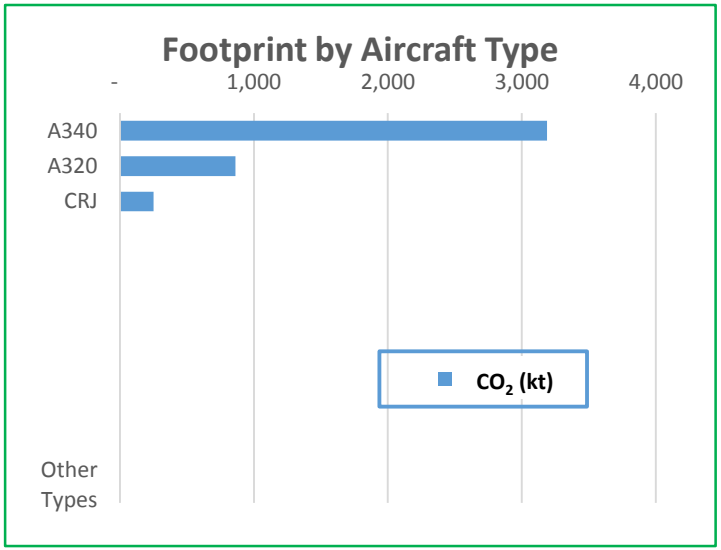


City-Pair Hierarchy	CO_2 (kt)
London (Gatwick)-Barcelona	29
Barcelona-London (Gatwick)	29
Milano-London (Gatwick)	28
London (Gatwick)-Milano	28
Malaga-London (Gatwick)	27
London (Gatwick)-Malaga	27
Madrid-London (Gatwick)	23
London (Gatwick)-Madrid	23
Milano-Paris (CDG)	21
Paris (CDG)-Milano	21
Faro-London (Gatwick)	21
London (Gatwick)-Faro	21
Geneva-London (Gatwick)	20
London (Gatwick)-Geneva	20
London (Gatwick)-Roma	20
Roma-London (Gatwick)	20
Paphos-London (Gatwick)	18
London (Gatwick)-Paphos	18
Paris (Orly)-Roma	18
Roma-Paris (Orly)	18
London (Gatwick)-Alicante	17
Alicante-London (Gatwick)	17
Paris (CDG)-Barcelona	16
Barcelona-Paris (CDG)	16
Palma de Mallorca-London (Gatwick	15
London (Gatwick)-Palma de Mallorca	15
Paris (CDG)-Madrid	15
Madrid-Paris (CDG)	15
London (Gatwick)-Nice	15
Nice-London (Gatwick)	15
Other Routes	4,035
Total	**4,645**

Iberia Airlines

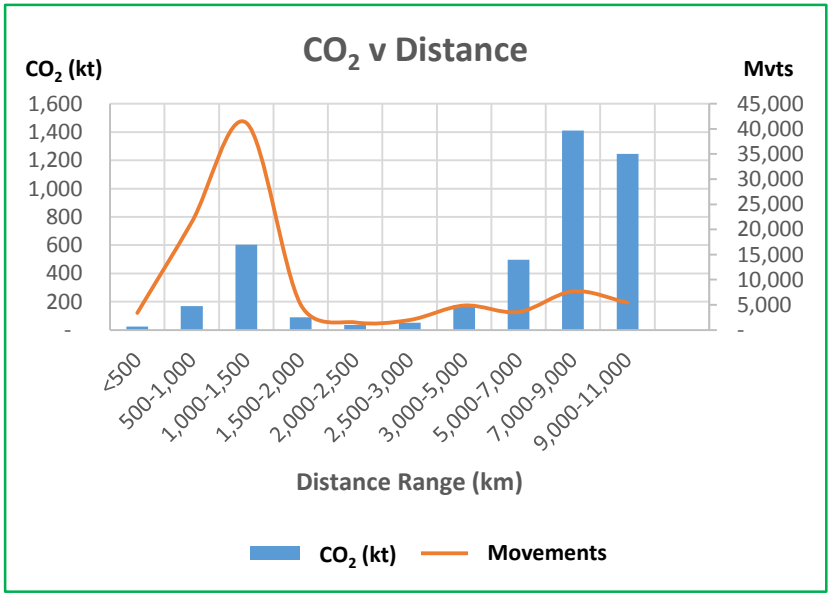
Total Footprint = 4,302 kt CO_2





City-Pair Hierarchy	CO_2 (kt)
Madrid-Buenos Aires	170
Buenos Aires-Madrid	170
Mexico City-Madrid	126
Madrid-Mexico City	126
Sao Paulo-Madrid	123
Madrid-Sao Paulo	123
Lima-Madrid	101
Madrid-Lima	101
Madrid-Bogota	96
Bogota-Madrid	95
Santiago de Chile-Madrid	92
Madrid-Santiago de Chile	92
New York (JFK)-Madrid	89
Madrid-New York (JFK)	89
Miami-Madrid	84
Madrid-Miami	84
Guayaquil-Madrid	76
Madrid-Quito	74
Madrid-San Jose	72
San Jose-Madrid	72
Madrid-Montevideo	63
Montevideo-Madrid	63
Madrid-Rio de Janeiro	62
Rio de Janeiro-Madrid	62
Madrid-Caracas	58
Caracas-Madrid	58
La Habana-Madrid	54
Madrid-La Habana	54
Chicago-Madrid	52
Madrid-Chicago	52
Other Routes	1,668
Total	**4,302**

Origin Airports	CO_2 (kt)
Madrid	2,129
Buenos Aires	170
Sao Paulo	140
Mexico City	126
Lima	101
Bogota	95
Santiago de Chile	92
Miami	90
New York (JFK)	89
Guayaquil	76
San Jose	72
Montevideo	63
Rio de Janeiro	62
Caracas	58
La Habana	54
Other Airports	885
Total	**4,302**



Profile F5

Route Footprints

Profile F5 lists carbon footprint information for the top 1,000 city-pair routes categorised by the size of the carbon footprint.

The information for each route is split into the component legs (eg information is shown both for London (Heathrow)-New York (JFK) and for New York (JFK)-London (Heathrow)) to enable easier access to the data. The information is listed alphabetically so that the reader can readily access data for any given airport.

There are approximately 25,000 city pairs in the Innovata dataset.

The top 1,000 routes listed capture about 45% of the global carbon footprint for scheduled international passenger flights in 2012.

The column headed 'CO_2 (kt)' contains the total computed amount of CO_2 generated by scheduled international passenger flights on each of the routes in 2012.

City Pair	CO_2 (kt)	CO_2/PAX (kg)
Abu Dhabi-Bangkok	123	553
Abu Dhabi-Chicago	110	1,340
Abu Dhabi-Frankfurt	116	484
Abu Dhabi-London (Heathrow)	189	504
Abu Dhabi-Manchester	91	635
Abu Dhabi-Manila	126	778
Abu Dhabi-Melbourne	101	1,030
Abu Dhabi-New York (JFK)	95	1,012
Abu Dhabi-Paris (CDG)	91	436
Abu Dhabi-Sydney	212	1,047
Agana-Manila	88	275
Agana-Tokyo (Narita)	125	241
Amsterdam-Atlanta	173	728
Amsterdam-Bangkok	228	1,053
Amsterdam-Beijing	159	1,094
Amsterdam-Chicago	112	811
Amsterdam-Curacao	100	820
Amsterdam-Detroit	177	608
Amsterdam-Dubai	145	551
Amsterdam-Hong Kong	228	1,242
Amsterdam-Houston	155	958
Amsterdam-Johannesburg	83	1,019
Amsterdam-Kuala Lumpur	207	1,183
Amsterdam-Lima	98	1,205
Amsterdam-Los Angeles	126	1,341
Amsterdam-Mexico City	120	1,563
Amsterdam-Minneapolis	129	618
Amsterdam-Nairobi	135	711
Amsterdam-New York (JFK)	165	675
Amsterdam-Osaka	84	1,053
Amsterdam-Panama City	94	1,119
Amsterdam-San Francisco	96	1,017
Amsterdam-Sao Paulo	91	1,114
Amsterdam-Seoul	137	1,257
Amsterdam-Shanghai	188	1,426
Amsterdam-Singapore	197	1,204
Amsterdam-Tokyo (Narita)	150	1,320
Amsterdam-Toronto	109	690
Amsterdam-Washington	82	626
Amsterdam-Zanderij	90	849
Atlanta-Amsterdam	173	728
Atlanta-Dubai	115	1,350
Atlanta-Frankfurt	106	634
Atlanta-Johannesburg	127	1,492
Atlanta-London (Heathrow)	146	581
Atlanta-Paris (CDG)	172	690
Atlanta-Seoul	164	1,314
Atlanta-Tokyo (Narita)	128	1,243
Auckland-Brisbane	99	238
Auckland-Hong Kong	190	982
Auckland-Los Angeles	217	1,069
Auckland-Melbourne	120	256
Auckland-San Francisco	109	1,181
Auckland-Seoul	87	1,085
Auckland-Singapore	178	944
Auckland-Sydney	170	212
Bahrain-London (Heathrow)	126	568
Bahrain-Manila	81	798
Bangalore-Frankfurt	92	840
Bangalore-London (Heathrow)	85	891
Bangkok-Abu Dhabi	123	553
Bangkok-Amsterdam	228	1,053
Bangkok-Beijing	110	365
Bangkok-Copenhagen	190	921
Bangkok-Delhi	121	275
Bangkok-Doha	144	586
Bangkok-Dubai	237	503
Bangkok-Frankfurt	306	944
Bangkok-Guangzhou	96	177
Bangkok-Helsinki	89	876
Bangkok-Hong Kong	322	202
Bangkok-Istanbul	107	801
Bangkok-Kuala Lumpur	136	144
Bangkok-London (Heathrow)	402	932
Bangkok-Manila	87	234
Bangkok-Melbourne	146	770
Bangkok-Moscow	154	706
Bangkok-Mumbai	114	270
Bangkok-Munich	114	965
Bangkok-Osaka	111	402
Bangkok-Paris (CDG)	174	973
Bangkok-Seoul	315	356
Bangkok-Shanghai	130	288
Bangkok-Singapore	264	170
Bangkok-Stockholm	108	911
Bangkok-Sydney	314	799
Bangkok-Taipei	169	283
Bangkok-Tokyo (Haneda)	100	388
Bangkok-Tokyo (Narita)	350	451
Bangkok-Wien	107	948
Bangkok-Zurich	155	809
Beijing-Amsterdam	159	1,094
Beijing-Bangkok	109	365
Beijing-Chicago	193	1,210
Beijing-Dubai	182	587
Beijing-Frankfurt	256	784
Beijing-Hong Kong	292	211
Beijing-Kuala Lumpur	94	463
Beijing-London (Heathrow)	163	893
Beijing-Los Angeles	168	1,028
Beijing-Moscow	166	572
Beijing-Munich	103	728

City Pair	CO_2 (kt)	CO_2/PAX (kg)
Beijing-New York (JFK)	146	1,243
Beijing-Newark	100	1,257
Beijing-Paris (CDG)	196	881
Beijing-Roma	107	906
Beijing-San Francisco	247	1,055
Beijing-Seattle	90	794
Beijing-Seoul	96	122
Beijing-Singapore	256	458
Beijing-Tokyo (Narita)	92	196
Beijing-Toronto	130	1,215
Beijing-Vancouver	124	834
Beijing-Washington	101	1,274
Beirut-Paris (CDG)	92	367
Birmingham-Dubai	102	625
Bogota-Madrid	172	757
Boston-Frankfurt	97	614
Boston-London (Heathrow)	299	495
Boston-Paris (CDG)	86	565
Bridgetown-London (Gatwick)	162	732
Brisbane-Auckland	99	238
Brisbane-Dubai	112	1,374
Brisbane-Hong Kong	87	672
Brisbane-Los Angeles	192	1,313
Brisbane-Singapore	295	624
Brussels-New York (JFK)	120	524
Brussels-Newark	98	640
Buenos Aires-Frankfurt	152	1,305
Buenos Aires-Lima	100	261
Buenos Aires-London (Heathrow)	104	1,277
Buenos Aires-Madrid	340	934
Buenos Aires-Miami	265	734
Buenos Aires-Paris (CDG)	102	1,272
Buenos Aires-Rio de Janeiro	92	216
Buenos Aires-Roma	160	1,273
Buenos Aires-Santiago de Chile	93	133
Buenos Aires-Sao Paulo	164	178
Cairo-Dubai	99	272
Cairo-Jeddah	154	165
Cairo-London (Heathrow)	92	351
Calgary-London (Heathrow)	99	599
Cancun-Madrid	89	878
Cape Town-Dubai	118	805
Cape Town-London (Heathrow)	259	1,028
Caracas-Madrid	129	646
Caracas-Miami	87	202
Cayenne-Paris (Orly)	85	711
Chennai/Madras-Dubai	100	303
Chennai/Madras-Singapore	86	267
Chicago-Abu Dhabi	110	1,340
Chicago-Amsterdam	112	811
Chicago-Beijing	193	1,210
Chicago-Delhi	112	1,379

City Pair	CO_2 (kt)	CO_2/PAX (kg)
Chicago-Frankfurt	255	754
Chicago-Hong Kong	280	1,414
Chicago-London (Heathrow)	442	607
Chicago-Munich	114	678
Chicago-Paris (CDG)	124	588
Chicago-Seoul	163	1,202
Chicago-Shanghai	207	1,299
Chicago-Tokyo (Narita)	414	1,106
Colombo-Dubai	108	333
Colombo-London (Heathrow)	85	929
Colombo-Singapore	98	283
Copenhagen-Bangkok	173	918
Curacao-Amsterdam	133	800
Dallas-Fort Worth-Brisbane	155	1,521
Dallas-Fort Worth-Dubai	111	1,419
Dallas-Fort Worth-Frankfurt	114	746
Dallas-Fort Worth-London (Heathr	276	805
Dallas-Fort Worth-Sao Paulo	88	893
Dallas-Fort Worth-Tokyo (Narita)	193	1,182
Delhi-Bangkok	121	275
Delhi-Chicago	112	1,379
Delhi-Dubai	130	238
Delhi-Frankfurt	128	687
Delhi-Hong Kong	104	402
Delhi-London (Heathrow)	352	711
Delhi-New York (JFK)	91	1,348
Delhi-Newark	109	1,349
Delhi-Paris (CDG)	119	700
Delhi-Singapore	140	416
Denpasar-Hong Kong	100	355
Denpasar-Perth	90	225
Denpasar-Seoul	89	508
Denpasar-Singapore	135	198
Denpasar-Sydney	83	479
Detroit-Amsterdam	177	608
Detroit-Frankfurt	93	563
Detroit-Nagoya	115	1,182
Detroit-Seoul	89	1,214
Detroit-Shanghai	111	1,302
Detroit-Tokyo (Narita)	136	1,149
Dhaka-Dubai	103	383
Doha-Bangkok	144	586
Doha-Dubai	107	76
Doha-Frankfurt	109	473
Doha-Hong Kong	86	698
Doha-Houston	121	1,420
Doha-Kuala Lumpur	119	602
Doha-London (Heathrow)	212	507
Doha-Manila	126	779
Doha-Melbourne	112	1,313
Doha-New York (JFK)	101	1,234
Doha-Paris (CDG)	95	381

City Pair	CO_2 (kt)	CO_2/PAX (kg)	City Pair	CO_2 (kt)	CO_2/PAX (kg)
Doha-Sao Paulo	111	1,301	Dubai-Seattle	93	1,309
Doha-Singapore	113	682	Dubai-Seoul	124	691
Doha-Washington	104	1,275	Dubai-Shanghai	127	685
Dubai-Amsterdam	142	554	Dubai-Singapore	234	623
Dubai-Atlanta	115	1,350	Dubai-Sydney	277	1,288
Dubai-Bangkok	238	503	Dubai-Tokyo (Narita)	89	823
Dubai-Beijing	183	588	Dubai-Washington	139	1,288
Dubai-Birmingham	102	625	Dubai-Wien	100	404
Dubai-Brisbane	112	1,374	Dubai-Zurich	125	506
Dubai-Cairo	99	272	Dublin-New York (JFK)	107	513
Dubai-Cape Town	118	803	Dusseldorf-Dubai	91	521
Dubai-Chennai/Madras	100	303	Fort de France-Paris (Orly)	236	724
Dubai-Colombo	107	333	Frankfurt-Abu Dhabi	116	484
Dubai-Dallas-Fort Worth	111	1,419	Frankfurt-Atlanta	106	634
Dubai-Delhi	130	238	Frankfurt-Bangalore	92	840
Dubai-Dhaka	97	386	Frankfurt-Bangkok	306	944
Dubai-Doha	108	76	Frankfurt-Beijing	257	784
Dubai-Dusseldorf	91	521	Frankfurt-Boston	97	614
Dubai-Frankfurt	176	490	Frankfurt-Buenos Aires	152	1,305
Dubai-Glasgow	81	623	Frankfurt-Chicago	255	754
Dubai-Guangzhou	106	649	Frankfurt-Dallas-Fort Worth	114	746
Dubai-Hamburg	89	543	Frankfurt-Delhi	128	687
Dubai-Hong Kong	203	602	Frankfurt-Detroit	93	563
Dubai-Houston	134	1,490	Frankfurt-Doha	109	473
Dubai-Hyderabad	95	255	Frankfurt-Dubai	176	490
Dubai-Istanbul	95	325	Frankfurt-Hong Kong	235	1,008
Dubai-Jakarta	157	727	Frankfurt-Houston	160	776
Dubai-Jeddah	139	182	Frankfurt-Johannesburg	186	777
Dubai-Johannesburg	181	700	Frankfurt-Los Angeles	166	1,035
Dubai-Karachi	93	162	Frankfurt-Mexico City	123	1,057
Dubai-Kuala Lumpur	180	571	Frankfurt-Miami	100	803
Dubai-Kuwait City	115	119	Frankfurt-Moscow	84	189
Dubai-Lagos	100	606	Frankfurt-New York (JFK)	248	565
Dubai-London (Gatwick)	149	603	Frankfurt-Newark	164	630
Dubai-London (Heathrow)	542	543	Frankfurt-Osaka	119	1,021
Dubai-Los Angeles	199	1,498	Frankfurt-Philadelphia	115	622
Dubai-Manchester	172	587	Frankfurt-Rio de Janeiro	114	1,001
Dubai-Manila	126	769	Frankfurt-San Francisco	282	977
Dubai-Melbourne	122	1,284	Frankfurt-Sao Paulo	218	1,036
Dubai-Milano	108	475	Frankfurt-Seoul	270	831
Dubai-Moscow	93	355	Frankfurt-Shanghai	289	973
Dubai-Mumbai	155	214	Frankfurt-Singapore	502	1,092
Dubai-Munich	135	433	Frankfurt-Tokyo (Narita)	298	964
Dubai-Nairobi	87	351	Frankfurt-Toronto	169	606
Dubai-New York (JFK)	253	1,174	Frankfurt-Vancouver	83	695
Dubai-Paris (CDG)	188	539	Frankfurt-Washington	256	693
Dubai-Perth	173	1,000	Glasgow-Dubai	81	623
Dubai-Rio de Janeiro	111	1,357	Guangzhou-Bangkok	96	177
Dubai-Riyadh	89	125	Guangzhou-Dubai	106	649
Dubai-Roma	93	447	Guangzhou-Los Angeles	120	1,286
Dubai-San Francisco	122	1,494	Guangzhou-Melbourne	95	840
Dubai-Sao Paulo	115	1,401	Guangzhou-Paris (CDG)	128	1,060

City Pair	CO_2 (kt)	CO_2/PAX (kg)
Guangzhou-Singapore	95	241
Guangzhou-Sydney	113	770
Guayaquil-Madrid	132	899
Hamburg-Dubai	89	543
Helsinki-Bangkok	89	876
Higuey-Moscow	107	1,027
Ho Chi Minh City-Paris (CDG)	94	1,156
Ho Chi Minh City-Seoul	128	340
Ho Chi Minh City-Taipei	82	252
Ho Chi Minh City-Tokyo (Narita)	100	375
Hong Kong-Amsterdam	228	1,242
Hong Kong-Auckland	190	982
Hong Kong-Bangkok	323	202
Hong Kong-Beijing	292	211
Hong Kong-Brisbane	95	672
Hong Kong-Chicago	280	1,414
Hong Kong-Delhi	104	402
Hong Kong-Denpasar	100	355
Hong Kong-Doha	86	698
Hong Kong-Dubai	203	602
Hong Kong-Frankfurt	235	1,008
Hong Kong-Jakarta	160	333
Hong Kong-Johannesburg	207	1,134
Hong Kong-Kuala Lumpur	166	268
Hong Kong-London (Heathrow)	843	1,034
Hong Kong-Los Angeles	297	1,309
Hong Kong-Manila	163	152
Hong Kong-Melbourne	191	731
Hong Kong-Milano	87	1,035
Hong Kong-Moscow	82	707
Hong Kong-Mumbai	91	459
Hong Kong-New York (JFK)	348	1,451
Hong Kong-Newark	118	1,487
Hong Kong-Osaka	112	255
Hong Kong-Paris (CDG)	290	1,070
Hong Kong-Perth	87	589
Hong Kong-San Francisco	524	1,262
Hong Kong-Seoul	280	229
Hong Kong-Shanghai	285	147
Hong Kong-Singapore	451	275
Hong Kong-Sydney	419	704
Hong Kong-Taipei	450	129
Hong Kong-Tokyo (Haneda)	121	333
Hong Kong-Tokyo (Narita)	212	283
Hong Kong-Toronto	290	1,388
Hong Kong-Vancouver	305	1,160
Honolulu-Nagoya	82	483
Honolulu-Osaka	165	622
Honolulu-Seoul	224	723
Honolulu-Sydney	144	834
Honolulu-Tokyo (Haneda)	145	632
Honolulu-Tokyo (Narita)	464	566

City Pair	CO_2 (kt)	CO_2/PAX (kg)
Houston-Amsterdam	155	958
Houston-Doha	121	1,420
Houston-Dubai	134	1,490
Houston-Frankfurt	160	776
Houston-Lagos	82	1,199
Houston-London (Heathrow)	292	863
Houston-Paris (CDG)	110	800
Houston-Tokyo (Narita)	100	1,222
Hyderabad-Dubai	95	255
Istanbul-Bangkok	107	801
Istanbul-Dubai	95	325
Istanbul-London (Heathrow)	100	223
Istanbul-Los Angeles	97	1,265
Istanbul-New York (JFK)	201	818
Istanbul-Seoul	134	842
Istanbul-Singapore	126	969
Jakarta-Dubai	156	727
Jakarta-Hong Kong	160	334
Jakarta-Jeddah	297	880
Jakarta-Kuala Lumpur	124	126
Jakarta-Seoul	110	576
Jakarta-Singapore	242	119
Jakarta-Tokyo (Narita)	137	566
Jeddah-Cairo	154	165
Jeddah-Dubai	139	182
Jeddah-Jakarta	331	879
Johannesburg-Amsterdam	83	1,019
Johannesburg-Atlanta	127	1,492
Johannesburg-Dubai	181	700
Johannesburg-Frankfurt	186	777
Johannesburg-Hong Kong	208	1,135
Johannesburg-London (Heathrow)	484	929
Johannesburg-New York (JFK)	109	1,028
Johannesburg-Paris (CDG)	111	864
Johannesburg-Sao Paulo	89	769
Johannesburg-Sydney	147	1,248
Karachi-Dubai	92	162
Kuala Lumpur-Amsterdam	206	1,183
Kuala Lumpur-Bangkok	136	144
Kuala Lumpur-Beijing	94	463
Kuala Lumpur-Doha	119	602
Kuala Lumpur-Dubai	180	571
Kuala Lumpur-Hong Kong	166	268
Kuala Lumpur-Jakarta	124	125
Kuala Lumpur-London (Heathrow)	282	1,158
Kuala Lumpur-Melbourne	215	653
Kuala Lumpur-Paris (CDG)	96	1,196
Kuala Lumpur-Perth	86	432
Kuala Lumpur-Seoul	121	503
Kuala Lumpur-Shanghai	85	380
Kuala Lumpur-Singapore	106	59
Kuala Lumpur-Sydney	181	719

City Pair	CO_2 (kt)	CO_2/PAX (kg)	City Pair	CO_2 (kt)	CO_2/PAX (kg)
Kuala Lumpur-Taipei	108	352	London (Heathrow)-Miami	411	743
Kuala Lumpur-Tokyo (Narita)	111	518	London (Heathrow)-Montreal	82	495
Kuwait City-Dubai	115	119	London (Heathrow)-Moscow	125	215
Kuwait City-London (Heathrow)	87	502	London (Heathrow)-Mumbai	354	796
Kuwait City-Washington	99	1,210	London (Heathrow)-Nairobi	167	741
La Habana-Madrid	122	774	London (Heathrow)-New York (JFK)	1,000	556
La Habana-Paris (CDG)	82	857	London (Heathrow)-Newark	390	527
Lagos-Dubai	100	606	London (Heathrow)-Philadelphia	134	561
Lagos-Houston	82	1,199	London (Heathrow)-Phoenix	92	923
Lagos-London (Heathrow)	144	462	London (Heathrow)-Rio de Janeiro	104	1,041
Las Vegas-London (Gatwick)	108	921	London (Heathrow)-Riyadh	111	548
Las Vegas-London (Heathrow)	105	915	London (Heathrow)-San Francisco	476	940
Lima-Amsterdam	98	1,205	London (Heathrow)-Sao Paulo	210	996
Lima-Buenos Aires	97	261	London (Heathrow)-Seattle	97	833
Lima-Madrid	226	851	London (Heathrow)-Seoul	193	985
Lima-Miami	119	352	London (Heathrow)-Shanghai	189	890
Lima-Santiago de Chile	111	223	London (Heathrow)-Singapore	1,015	1,149
Lisboa-Luanda	129	598	London (Heathrow)-Tel Aviv	110	352
Lisboa-Rio de Janeiro	98	828	London (Heathrow)-Tokyo (Narita)	347	970
Lisboa-Sao Paulo	101	849	London (Heathrow)-Toronto	278	535
London (Gatwick)-Bridgetown	162	732	London (Heathrow)-Vancouver	205	806
London (Gatwick)-Dubai	149	603	London (Heathrow)-Washington	360	587
London (Gatwick)-Las Vegas	108	921	Los Angeles-Agana	137	1,078
London (Gatwick)-Orlando	227	742	Los Angeles-Amsterdam	132	1,298
London (Gatwick)-St. Lucia	91	747	Los Angeles-Auckland	217	1,068
London (Heathrow)-Abu Dhabi	189	504	Los Angeles-Beijing	168	1,028
London (Heathrow)-Atlanta	145	581	Los Angeles-Brisbane	192	1,313
London (Heathrow)-Bahrain	126	568	Los Angeles-Dubai	199	1,498
London (Heathrow)-Bangalore	85	891	Los Angeles-Frankfurt	166	1,035
London (Heathrow)-Bangkok	402	932	Los Angeles-Guangzhou	120	1,286
London (Heathrow)-Beijing	163	893	Los Angeles-Hong Kong	297	1,309
London (Heathrow)-Boston	299	495	Los Angeles-Istanbul	97	1,265
London (Heathrow)-Buenos Aires	104	1,277	Los Angeles-London (Heathrow)	664	902
London (Heathrow)-Cairo	92	351	Los Angeles-Melbourne	225	1,338
London (Heathrow)-Calgary	99	599	Los Angeles-Mexico City	82	241
London (Heathrow)-Cape Town	260	1,028	Los Angeles-Papeete	102	673
London (Heathrow)-Chicago	442	606	Los Angeles-Paris (CDG)	238	966
London (Heathrow)-Colombo	85	930	Los Angeles-Seoul	541	1,046
London (Heathrow)-Dallas-Fort Wo	276	805	Los Angeles-Shanghai	281	1,048
London (Heathrow)-Delhi	352	711	Los Angeles-Singapore	86	1,373
London (Heathrow)-Doha	212	507	Los Angeles-Sydney	705	1,335
London (Heathrow)-Dubai	542	543	Los Angeles-Taipei	503	1,243
London (Heathrow)-Hong Kong	843	1,034	Los Angeles-Tokyo (Haneda)	151	987
London (Heathrow)-Houston	292	863	Los Angeles-Tokyo (Narita)	628	938
London (Heathrow)-Istanbul	100	223	Luanda-Lisboa	123	595
London (Heathrow)-Johannesburg	483	929	Madrid-Bogota	172	757
London (Heathrow)-Kuala Lumpur	282	1,158	Madrid-Buenos Aires	340	934
London (Heathrow)-Kuwait City	89	503	Madrid-Cancun	89	878
London (Heathrow)-Lagos	144	461	Madrid-Caracas	130	647
London (Heathrow)-Las Vegas	105	915	Madrid-La Habana	115	782
London (Heathrow)-Los Angeles	664	902	Madrid-Lima	236	849
London (Heathrow)-Madrid	81	118	Madrid-London (Heathrow)	81	118

City Pair	CO_2 (kt)	CO_2/PAX (kg)
Madrid-Mexico City	214	860
Madrid-Miami	131	604
Madrid-New York (JFK)	175	493
Madrid-Santiago de Chile	184	1,055
Madrid-Santo Domingo	104	742
Madrid-Sao Paulo	209	847
Manchester-Abu Dhabi	91	635
Manchester-Dubai	172	587
Manchester-Orlando	104	672
Manila-Abu Dhabi	126	778
Manila-Bahrain	81	798
Manila-Bangkok	87	234
Manila-Doha	126	779
Manila-Dubai	126	769
Manila-Hong Kong	163	152
Manila-Los Angeles	164	1,318
Manila-San Francisco	148	1,270
Manila-Seoul	165	258
Manila-Singapore	222	243
Manila-Tokyo (Narita)	134	279
Manila-Vancouver	91	1,072
Mauritius-Paris (CDG)	171	1,002
Melbourne-Abu Dhabi	101	1,029
Melbourne-Auckland	120	255
Melbourne-Bangkok	146	770
Melbourne-Doha	112	1,313
Melbourne-Dubai	122	1,284
Melbourne-Guangzhou	95	840
Melbourne-Hong Kong	244	728
Melbourne-Kuala Lumpur	215	653
Melbourne-Los Angeles	225	1,338
Melbourne-Shanghai	96	764
Melbourne-Singapore	376	613
Mexico City-Amsterdam	120	1,563
Mexico City-Frankfurt	123	1,057
Mexico City-Los Angeles	82	241
Mexico City-Madrid	214	860
Mexico City-Paris (CDG)	190	937
Mexico City-Sao Paulo	129	827
Miami-Buenos Aires	265	735
Miami-Caracas	86	202
Miami-Frankfurt	100	803
Miami-Lima	117	352
Miami-London (Heathrow)	410	743
Miami-Madrid	130	604
Miami-Paris (CDG)	121	721
Miami-Rio de Janeiro	97	566
Miami-Santiago de Chile	126	555
Miami-Sao Paulo	286	693
Milano-Dubai	108	475
Milano-Hong Kong	87	1,035
Milano-New York (JFK)	115	553
Milano-Singapore	92	1,181
Minneapolis-Amsterdam	129	618
Minneapolis-Tokyo (Narita)	89	1,057
Montreal-London (Heathrow)	82	494
Montreal-Paris (CDG)	230	587
Moscow-Bangkok	155	707
Moscow-Beijing	166	572
Moscow-Dubai	93	355
Moscow-Frankfurt	84	189
Moscow-Higuey	107	1,027
Moscow-Hong Kong	82	707
Moscow-London (Heathrow)	125	215
Moscow-New York (JFK)	193	692
Moscow-Paris (CDG)	90	212
Moscow-Phuket	92	799
Moscow-Shanghai	111	594
Moscow-Tel Aviv	85	244
Moscow-Tokyo (Narita)	89	775
Mumbai-Bangkok	114	270
Mumbai-Dubai	155	214
Mumbai-Frankfurt	81	703
Mumbai-Hong Kong	91	459
Mumbai-London (Heathrow)	354	796
Mumbai-Newark	217	1,409
Mumbai-Singapore	166	422
Munich-Bangkok	114	965
Munich-Beijing	103	728
Munich-Chicago	114	678
Munich-Dubai	135	433
Munich-Newark	94	537
Munich-Sao Paulo	82	909
Munich-Singapore	143	1,104
Munich-Tokyo (Narita)	162	893
Munich-Washington	106	701
Nagoya-Detroit	115	1,182
Nagoya-Honolulu	82	484
Nairobi-Amsterdam	135	711
Nairobi-Dubai	90	349
Nairobi-London (Heathrow)	167	741
New York (JFK)-Abu Dhabi	95	1,012
New York (JFK)-Amsterdam	165	675
New York (JFK)-Beijing	146	1,243
New York (JFK)-Brussels	120	524
New York (JFK)-Delhi	91	1,348
New York (JFK)-Doha	101	1,234
New York (JFK)-Dubai	253	1,174
New York (JFK)-Dublin	107	513
New York (JFK)-Frankfurt	248	565
New York (JFK)-Hong Kong	348	1,451
New York (JFK)-Istanbul	201	818
New York (JFK)-Johannesburg	109	1,028
New York (JFK)-London (Heathrow)	1,000	556

City Pair	CO_2 (kt)	CO_2/PAX (kg)
New York (JFK)-Madrid	175	493
New York (JFK)-Milano	115	553
New York (JFK)-Moscow	193	692
New York (JFK)-Paris (CDG)	372	564
New York (JFK)-Rio de Janeiro	108	775
New York (JFK)-Roma	180	687
New York (JFK)-San Juan	136	228
New York (JFK)-Santiago de los Cab	84	210
New York (JFK)-Santo Domingo	82	224
New York (JFK)-Sao Paulo	260	778
New York (JFK)-Seoul	367	1,200
New York (JFK)-Shanghai	102	951
New York (JFK)-Tel Aviv	305	1,008
New York (JFK)-Tokyo (Narita)	408	1,190
New York (JFK)-Zurich	152	568
Newark-Beijing	100	1,257
Newark-Brussels	98	640
Newark-Delhi	109	1,349
Newark-Frankfurt	164	629
Newark-Hong Kong	117	1,487
Newark-London (Heathrow)	390	527
Newark-Mumbai	217	1,409
Newark-Munich	94	537
Newark-Shanghai	108	1,360
Newark-Singapore	130	1,495
Newark-Tel Aviv	243	1,031
Newark-Tokyo (Narita)	100	1,239
Newark-Zurich	83	569
Orlando-London (Gatwick)	227	741
Orlando-Manchester	104	672
Orlando-Sao Paulo	110	764
Osaka-Amsterdam	84	1,053
Osaka-Bangkok	111	402
Osaka-Frankfurt	120	1,021
Osaka-Hong Kong	112	255
Osaka-Honolulu	165	622
Osaka-Paris (CDG)	86	1,095
Osaka-Seoul	131	116
Osaka-Taipei	120	187
Panama City-Amsterdam	94	1,119
Papeete-Los Angeles	102	673
Paris (CDG)-Abu Dhabi	91	436
Paris (CDG)-Atlanta	172	690
Paris (CDG)-Bangkok	174	973
Paris (CDG)-Beijing	196	881
Paris (CDG)-Beirut	92	368
Paris (CDG)-Boston	86	565
Paris (CDG)-Buenos Aires	102	1,272
Paris (CDG)-Chicago	124	588
Paris (CDG)-Delhi	119	701
Paris (CDG)-Doha	95	381
Paris (CDG)-Dubai	188	539

City Pair	CO_2 (kt)	CO_2/PAX (kg)
Paris (CDG)-Guangzhou	128	1,060
Paris (CDG)-Ho Chi Minh City	94	1,156
Paris (CDG)-Hong Kong	290	1,070
Paris (CDG)-Houston	110	800
Paris (CDG)-Johannesburg	111	864
Paris (CDG)-Kuala Lumpur	96	1,196
Paris (CDG)-La Habana	82	857
Paris (CDG)-Los Angeles	238	966
Paris (CDG)-Mauritius	171	1,002
Paris (CDG)-Mexico City	190	937
Paris (CDG)-Miami	121	721
Paris (CDG)-Montreal	232	587
Paris (CDG)-Moscow	90	212
Paris (CDG)-New York (JFK)	373	564
Paris (CDG)-Osaka	86	1,095
Paris (CDG)-Rio de Janeiro	227	1,020
Paris (CDG)-San Francisco	132	983
Paris (CDG)-Santiago de Chile	109	1,338
Paris (CDG)-Sao Paulo	245	1,060
Paris (CDG)-Seoul	230	996
Paris (CDG)-Shanghai	289	1,044
Paris (CDG)-Singapore	258	1,123
Paris (CDG)-St-Denis de la Reunior	98	1,050
Paris (CDG)-Tel Aviv	89	298
Paris (CDG)-Tokyo (Haneda)	90	1,105
Paris (CDG)-Tokyo (Narita)	386	1,038
Paris (CDG)-Toronto	107	623
Paris (CDG)-Washington	149	593
Paris (Orly)-Cayenne	83	710
Paris (Orly)-Fort de France	233	725
Paris (Orly)-Pointe-a-Pitre	248	710
Paris (Orly)-St-Denis de la Reunior	249	1,046
Perth-Denpasar	90	225
Perth-Dubai	173	1,000
Perth-Hong Kong	88	589
Perth-Kuala Lumpur	87	432
Perth-Singapore	198	396
Philadelphia-Frankfurt	115	622
Philadelphia-London (Heathrow)	134	561
Phoenix-London (Heathrow)	92	923
Phuket-Moscow	92	799
Phuket-Seoul	97	390
Pointe-a-Pitre-Paris (Orly)	246	710
Rio de Janeiro-Buenos Aires	92	216
Rio de Janeiro-Dubai	110	1,358
Rio de Janeiro-Frankfurt	114	1,001
Rio de Janeiro-Lisboa	98	828
Rio de Janeiro-London (Heathrow)	104	1,041
Rio de Janeiro-Miami	97	566
Rio de Janeiro-New York (JFK)	108	775
Rio de Janeiro-Paris (CDG)	227	1,020
Riyadh-Dubai	91	125

City Pair	CO_2 (kt)	CO_2/PAX (kg)
Riyadh-London (Heathrow)	111	548
Roma-Beijing	107	906
Roma-Buenos Aires	159	1,273
Roma-Dubai	93	447
Roma-New York (JFK)	180	687
Roma-Sao Paulo	98	1,070
Roma-Tokyo (Narita)	122	1,130
Roma-Toronto	97	649
Roma-Washington	104	736
San Francisco-Agana	115	1,029
San Francisco-Amsterdam	96	1,017
San Francisco-Auckland	109	1,181
San Francisco-Beijing	247	1,055
San Francisco-Dubai	122	1,494
San Francisco-Frankfurt	282	977
San Francisco-Hong Kong	524	1,262
San Francisco-London (Heathrow)	476	940
San Francisco-Paris (CDG)	132	983
San Francisco-Seoul	368	1,016
San Francisco-Shanghai	114	1,108
San Francisco-Sydney	160	1,357
San Francisco-Taipei	288	1,176
San Francisco-Tokyo (Narita)	271	843
San Juan-New York (JFK)	136	228
Santiago de Chile-Buenos Aires	94	133
Santiago de Chile-Lima	111	223
Santiago de Chile-Madrid	185	1,055
Santiago de Chile-Miami	125	555
Santiago de Chile-Paris (CDG)	109	1,338
Santiago de Chile-Sao Paulo	97	242
Santiago de los Caballeros-New Yo	84	210
Santo Domingo-Madrid	105	740
Santo Domingo-New York (JFK)	82	224
Sao Paulo-Amsterdam	91	1,114
Sao Paulo-Buenos Aires	163	178
Sao Paulo-Dallas-Fort Worth	88	892
Sao Paulo-Doha	111	1,301
Sao Paulo-Dubai	115	1,401
Sao Paulo-Frankfurt	218	1,036
Sao Paulo-Johannesburg	89	769
Sao Paulo-Lisboa	101	849
Sao Paulo-London (Heathrow)	211	996
Sao Paulo-Madrid	209	847
Sao Paulo-Mexico City	129	827
Sao Paulo-Miami	286	692
Sao Paulo-Munich	82	908
Sao Paulo-New York (JFK)	260	778
Sao Paulo-Orlando	110	764
Sao Paulo-Paris (CDG)	245	1,060
Sao Paulo-Roma	98	1,070
Sao Paulo-Santiago de Chile	97	241
Sao Paulo-Zurich	82	981

City Pair	CO_2 (kt)	CO_2/PAX (kg)
Seattle-Beijing	90	794
Seattle-Dubai	93	1,309
Seattle-London (Heathrow)	97	833
Seattle-Seoul	106	864
Seattle-Tokyo (Narita)	161	809
Seoul-Amsterdam	126	1,293
Seoul-Atlanta	163	1,314
Seoul-Auckland	87	1,085
Seoul-Bangkok	315	356
Seoul-Beijing	96	122
Seoul-Chicago	163	1,202
Seoul-Denpasar	89	508
Seoul-Detroit	89	1,214
Seoul-Dubai	124	691
Seoul-Frankfurt	270	831
Seoul-Ho Chi Minh City	128	340
Seoul-Hong Kong	280	229
Seoul-Honolulu	224	723
Seoul-Istanbul	134	842
Seoul-Jakarta	110	576
Seoul-Kuala Lumpur	120	503
Seoul-London (Heathrow)	193	985
Seoul-Los Angeles	541	1,046
Seoul-Manila	164	258
Seoul-New York (JFK)	367	1,200
Seoul-Osaka	131	116
Seoul-Paris (CDG)	230	996
Seoul-Phuket	97	390
Seoul-San Francisco	368	1,016
Seoul-Seattle	106	864
Seoul-Shanghai	123	111
Seoul-Singapore	274	465
Seoul-Sydney	160	924
Seoul-Taipei	110	169
Seoul-Tokyo (Haneda)	183	149
Seoul-Tokyo (Narita)	177	154
Seoul-Vancouver	114	802
Seoul-Washington	104	1,281
Shanghai-Amsterdam	188	1,427
Shanghai-Bangkok	130	288
Shanghai-Chicago	207	1,299
Shanghai-Detroit	110	1,302
Shanghai-Dubai	127	685
Shanghai-Frankfurt	289	973
Shanghai-Hong Kong	285	147
Shanghai-Kuala Lumpur	85	380
Shanghai-London (Heathrow)	189	889
Shanghai-Los Angeles	281	1,048
Shanghai-Melbourne	96	764
Shanghai-Moscow	111	594
Shanghai-New York (JFK)	102	951
Shanghai-Newark	108	1,360

City Pair	CO_2 (kt)	CO_2/PAX (kg)	City Pair	CO_2 (kt)	CO_2/PAX (kg)
Shanghai-Paris (CDG)	289	1,044	Sydney-Dubai	277	1,288
Shanghai-San Francisco	114	1,108	Sydney-Guangzhou	113	770
Shanghai-Seoul	123	111	Sydney-Hong Kong	418	703
Shanghai-Singapore	253	392	Sydney-Honolulu	144	834
Shanghai-Sydney	157	789	Sydney-Johannesburg	147	1,248
Shanghai-Taipei	103	109	Sydney-Kuala Lumpur	181	719
Shanghai-Tokyo (Narita)	171	183	Sydney-Los Angeles	707	1,336
Shanghai-Toronto	107	1,262	Sydney-San Francisco	160	1,357
Shanghai-Vancouver	136	883	Sydney-Seoul	160	924
Singapore-Amsterdam	197	1,204	Sydney-Shanghai	158	789
Singapore-Auckland	173	944	Sydney-Singapore	530	629
Singapore-Bangkok	263	171	Sydney-Tokyo (Narita)	168	859
Singapore-Beijing	256	458	Sydney-Vancouver	119	1,372
Singapore-Brisbane	295	624	Taipei-Bangkok	170	283
Singapore-Chennai/Madras	86	267	Taipei-Ho Chi Minh City	83	250
Singapore-Colombo	86	279	Taipei-Hong Kong	450	129
Singapore-Delhi	140	416	Taipei-Kuala Lumpur	108	352
Singapore-Denpasar	134	199	Taipei-Los Angeles	503	1,243
Singapore-Doha	113	682	Taipei-Osaka	120	187
Singapore-Dubai	234	623	Taipei-Osaka	120	187
Singapore-Frankfurt	502	1,092	Taipei-San Francisco	288	1,176
Singapore-Guangzhou	95	241	Taipei-Seoul	110	169
Singapore-Hong Kong	451	274	Taipei-Shanghai	103	109
Singapore-Istanbul	125	969	Taipei-Singapore	194	315
Singapore-Jakarta	242	119	Taipei-Tokyo (Haneda)	133	205
Singapore-Kuala Lumpur	107	59	Taipei-Tokyo (Narita)	215	239
Singapore-London (Heathrow)	1,015	1,149	Taipei-Vancouver	124	1,015
Singapore-Los Angeles	86	1,373	Tel Aviv-London (Heathrow)	110	352
Singapore-Manila	222	243	Tel Aviv-Moscow	85	244
Singapore-Melbourne	376	613	Tel Aviv-New York (JFK)	305	1,007
Singapore-Milano	92	1,181	Tel Aviv-Newark	245	1,031
Singapore-Mumbai	166	422	Tel Aviv-Paris (CDG)	90	298
Singapore-Munich	143	1,104	Tokyo (Haneda)-Bangkok	100	388
Singapore-Newark	130	1,495	Tokyo (Haneda)-Hong Kong	121	333
Singapore-Paris (CDG)	258	1,123	Tokyo (Haneda)-Honolulu	145	632
Singapore-Perth	198	397	Tokyo (Haneda)-Los Angeles	151	987
Singapore-Seoul	274	465	Tokyo (Haneda)-Paris (CDG)	90	1,105
Singapore-Shanghai	253	392	Tokyo (Haneda)-Seoul	183	149
Singapore-Sydney	529	629	Tokyo (Haneda)-Singapore	164	488
Singapore-Taipei	194	315	Tokyo (Haneda)-Taipei	133	205
Singapore-Tokyo (Haneda)	164	488	Tokyo (Narita)-Agana	125	241
Singapore-Tokyo (Narita)	334	516	Tokyo (Narita)-Amsterdam	150	1,321
Singapore-Zurich	138	1,038	Tokyo (Narita)-Atlanta	128	1,243
St. Lucia-London (Gatwick)	91	747	Tokyo (Narita)-Bangkok	350	451
St-Denis de la Reunion-Paris (CDG)	99	1,050	Tokyo (Narita)-Beijing	92	196
St-Denis de la Reunion-Paris (Orly	249	1,046	Tokyo (Narita)-Chicago	414	1,106
Stockholm-Bangkok	103	911	Tokyo (Narita)-Dallas-Fort Worth	193	1,182
Sydney-Abu Dhabi	212	1,046	Tokyo (Narita)-Detroit	136	1,149
Sydney-Auckland	170	212	Tokyo (Narita)-Dubai	89	823
Sydney-Bangkok	314	798	Tokyo (Narita)-Frankfurt	298	964
Sydney-Dallas-Fort Worth	160	1,572	Tokyo (Narita)-Ho Chi Minh City	98	377
Sydney-Denpasar	84	479	Tokyo (Narita)-Hong Kong	211	284

City Pair	CO_2 (kt)	CO_2/PAX (kg)
Tokyo (Narita)-Honolulu	464	566
Tokyo (Narita)-Houston	100	1,222
Tokyo (Narita)-Jakarta	137	566
Tokyo (Narita)-Kuala Lumpur	111	518
Tokyo (Narita)-London (Heathrow)	347	970
Tokyo (Narita)-Los Angeles	626	939
Tokyo (Narita)-Manila	134	279
Tokyo (Narita)-Minneapolis	89	1,057
Tokyo (Narita)-Moscow	89	775
Tokyo (Narita)-Munich	162	893
Tokyo (Narita)-New York (JFK)	408	1,191
Tokyo (Narita)-Newark	100	1,239
Tokyo (Narita)-Paris (CDG)	386	1,038
Tokyo (Narita)-Roma	120	1,130
Tokyo (Narita)-San Francisco	272	843
Tokyo (Narita)-Seattle	160	810
Tokyo (Narita)-Seoul	177	154
Tokyo (Narita)-Shanghai	171	183
Tokyo (Narita)-Singapore	333	516
Tokyo (Narita)-Sydney	168	859
Tokyo (Narita)-Taipei	216	238
Tokyo (Narita)-Toronto	96	1,180
Tokyo (Narita)-Vancouver	106	647
Tokyo (Narita)-Washington	202	1,243
Tokyo (Narita)-Zurich	88	985
Toronto-Amsterdam	109	691
Toronto-Beijing	130	1,215
Toronto-Frankfurt	170	606
Toronto-Hong Kong	290	1,388
Toronto-London (Heathrow)	277	535
Toronto-Paris (CDG)	107	623
Toronto-Roma	90	643
Toronto-Shanghai	107	1,261
Toronto-Tokyo (Narita)	96	1,180
Vancouver-Beijing	124	834
Vancouver-Frankfurt	83	695
Vancouver-Hong Kong	305	1,160
Vancouver-London (Heathrow)	206	806
Vancouver-Manila	94	1,071
Vancouver-Seoul	114	802
Vancouver-Shanghai	136	883
Vancouver-Sydney	120	1,372
Vancouver-Taipei	124	1,015
Vancouver-Tokyo (Narita)	106	647
Washington-Addis Ababa	93	1,303
Washington-Amsterdam	82	626
Washington-Beijing	101	1,274
Washington-Doha	104	1,275
Washington-Dubai	139	1,288
Washington-Frankfurt	256	693
Washington-Kuwait City	99	1,210
Washington-London (Heathrow)	360	587
Washington-Munich	106	700
Washington-Paris (CDG)	149	593
Washington-Seoul	104	1,281
Washington-Tokyo (Narita)	201	1,243
Wien-Bangkok	107	948
Wien-Dubai	100	404
Zanderij-Amsterdam	90	849
Zurich-Bangkok	155	809
Zurich-Dubai	125	506
Zurich-New York (JFK)	152	568
Zurich-Newark	83	569
Zurich-Sao Paulo	82	981
Zurich-Singapore	138	1,038
Zurich-Tokyo (Narita)	88	985
Washington-Paris (CDG)	149	593
Washington-Seoul	104	1,281
Washington-Tokyo (Narita)	201	1,243
Wien-Bangkok	107	948
Wien-Dubai	100	404
Zanderij-Amsterdam	90	849
Zurich-Bangkok	155	809
Zurich-Dubai	125	506
Zurich-New York (JFK)	152	568
Zurich-Newark	83	569
Zurich-Sao Paulo	82	981
Zurich-Singapore	138	1,038
Zurich-Tokyo (Narita)	88	985

About the Author

Dave Southgate retired from the Australian Government Public Service in July 2012 after a 31 year career as an 'environmental bureaucrat'. After working in both State and Federal Government environmental agencies for 8 years he joined the aviation area of the Australian Government Transport Department in late 1989 and stayed there until he retired. Throughout his time in Transport he specialised in aircraft noise; in the latter years he also became involved in aviation climate change issues and developed a particular interest in carbon footprinting.

Dave has a longstanding interest in transparency and in facilitating public involvement in environmental decision-making through the development of 'simple' ways to describe patterns of pollution. As an outcome of working with representatives of the Sydney community his team developed innovative concepts for describing and assessing aircraft noise.[66] In 2008 Dave was awarded the Australian Government *Public Service Medal* (PSM) for his work in this area.[67]

From 2004 to 2012 Dave was the Australian Government representative on the United Nations International Civil Aviation Organization (ICAO) Committee on Aviation Environmental Protection (CAEP). He pursued his interest in carbon footprinting while on CAEP and was a member of the group that oversaw the development of the ICAO Carbon Calculator.[68]

In October 2012 he published *The Carbon Footprint of Aircraft Operations in Australia – 2011*.[69]

Dave has a science/engineering background and has degrees from the Universities of Liverpool, London (Imperial College) and Tasmania.

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[66] *Expanding Ways to Describe and Assess Aircraft Noise*, Dept of Transport and Regional Services, 2000. http://www.infrastructure.gov.au/aviation/environmental/transparent_noise/expanding/index.aspx

[67] http://www.itsanhonour.gov.au/honours/honour_roll/search.cfm?aus_award_id=1137899&search_type=quick&showInd=true

[68] ICAO Carbon Calculator: http://www.icao.int/environmental-protection/CarbonOffset/Pages/default.aspx

[69] *The carbon footprint of aircraft operations in Australia – 2011,* D Southgate, 2012: http://www.scribd.com/doc/110857161/The-Carbon-Footprint-of-Aircraft-Operations-in-Australia-2011