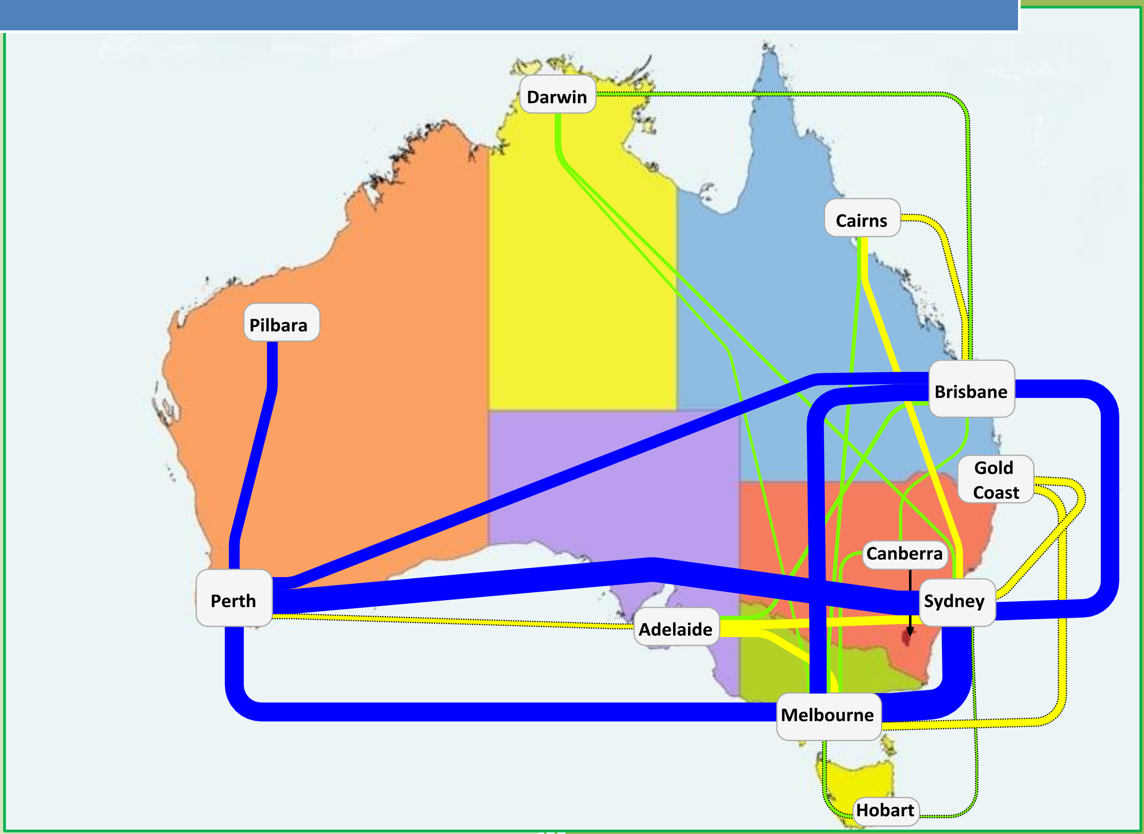
The Carbon Footprint of Aircraft Operations in Australia - 2011



This report provides a detailed breakdown of CO_2 *emissions from the Australian aviation network. The carbon footprints of scheduled domestic and international aircraft operations are examined from the perspective of both airlines and airports. The document also contains a disaggregated picture of the carbon costs associated with scheduled aircraft operations.*

Dave Southgate

October 2012

FOREWORD

This document is designed to provide the reader with a broad appreciation of the make-up of the carbon footprint of Australia's aircraft operations. In effect it is a carbon footprint atlas for aircraft operations in Australia in 2011.

The document does not suggest policy options for managing aviation's carbon footprint but rather is intended as a data resource to assist deliberations on the way forward. The monitoring and reporting of carbon footprints are fundamental components of any climate change management regime. A key aim of the document is to provide examples of concepts for generating carbon footprint pictures that are transparent and fully accessible to the non-expert.

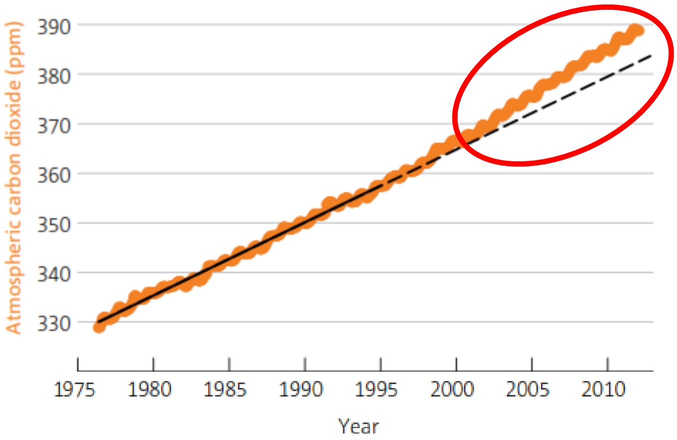
The information in the document has been generated from a publicly available dataset of scheduled aircraft operations and through the use of readily available software applications. Validation of the carbon footprint results indicates that reliable carbon footprint computations can be rapidly carried out across aviation networks using non-complex approaches.

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 as measured at Cape Grim in Tasmania since 1975.[1] It can be seen that over the period 1975-2010 the concentration of CO_2 grew at a rate of about 2-3 ppm per year. Over the past decade the rate of increase has risen above the linear trend line. The Cape Grim CO_2 measurements are consistent with readings taken elsewhere in the world.

Atmospheric CO_2

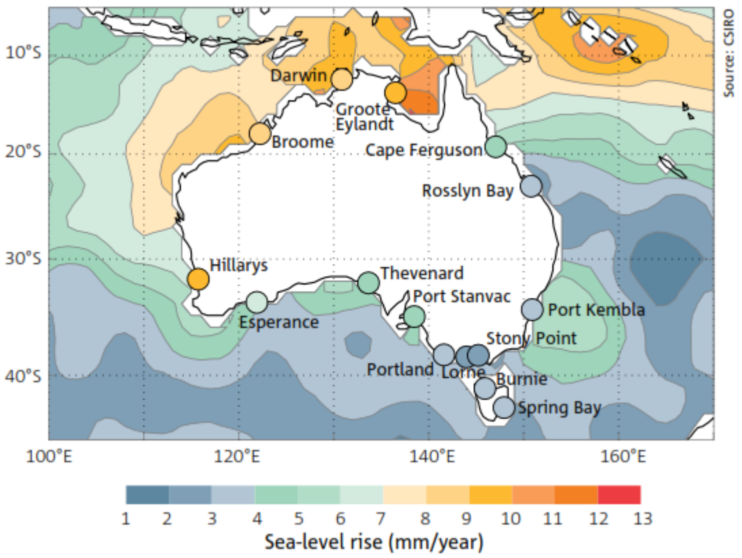


On a per capita basis, for countries with a population of over ten million, Australia is the highest CO_2 emitter in the world.[2]

This does not indicate that Australians are personally profligate but rather reflects the nature of our energy sources, our industries and the low density design of our cities.

Country	Personal Footprint (CO_2 tonnes/person)
Australia	19.04
US	18.84
Canada	16.63
Saudi Arabia	16.38
Netherlands	14.44
Belgium	13.77
Kazakhstan	12.92
Chinese Taipei	12.03
Russia	11.36
Czech Republic	11.30

The figure below, extracted from the *State of the Climate 2012* report[1], shows the sea-level rise around Australia as measured by coastal tide gauges (circles) and satellite observations (contours) from January 1993 to December 2011.



Since 1993, the rates of sea level rise to the north and northwest of Australia have been 7 to 11mm per year, two to three times the global average. Sea level rises on the central east and southern coasts have been similar to the global average.

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[1] *State of the Climate 2012,* CSIRO and Bureau of Meteorology. http://www.csiro.au/Outcomes/Climate/Understanding/State-of-the-Climate-2012.aspx

[2] *Transport Greenhouse Gas Emissions, Country Data 2010*, International Transport Forum. http://www.internationaltransportforum.org/Pub/pdf/10GHGcountry.pdf. Some smaller States such as Brunei and Luxembourg have higher per capita CO_2 footprints than Australia.

The Context

In 2010 transport generated 15% of Australia's total carbon footprint (*Figure 1*).[3] Domestic aviation constituted just over 1% of the total footprint. These contribution levels are typical for many other countries.[4]

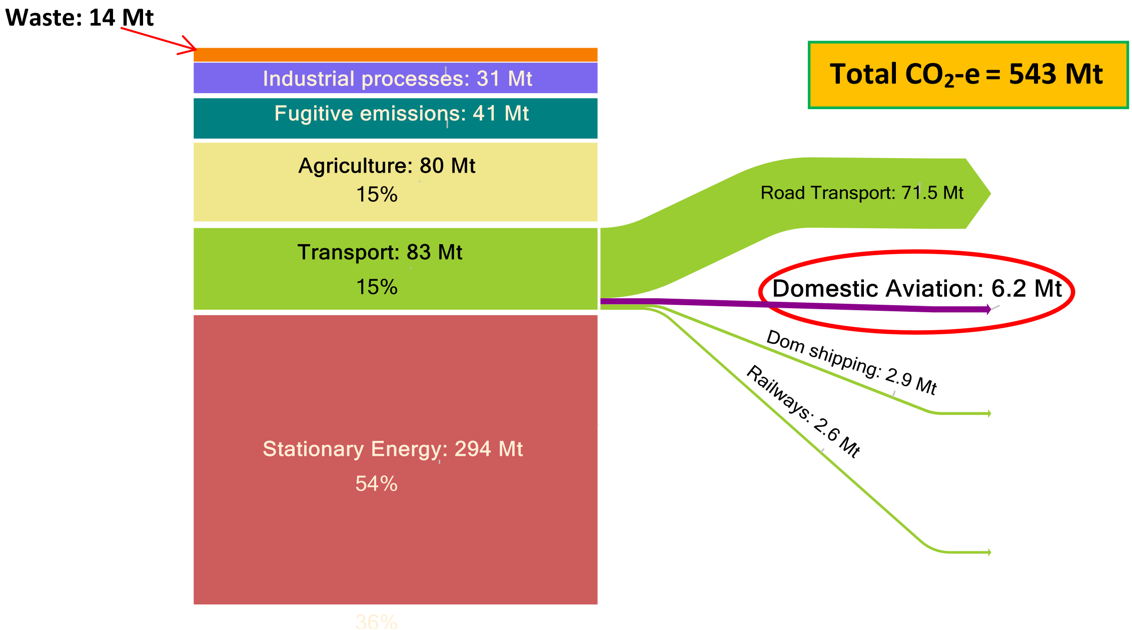
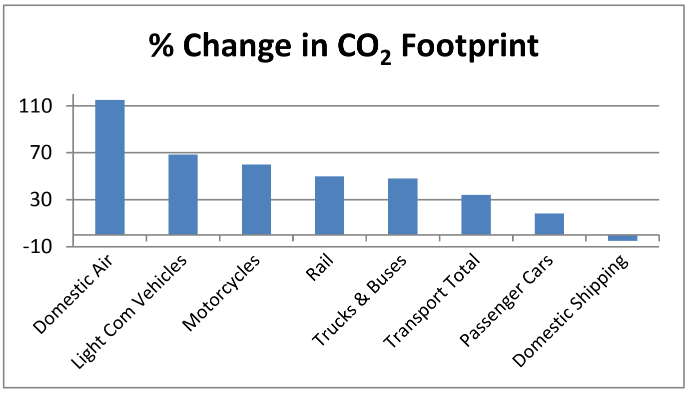


Figure 1: Domestic aviation contribution to Australia's carbon footprint in 2010

While the aviation contribution to the transport sector's carbon footprint is low compared to that from road transport, the Department of Climate Change and Energy Efficiency (DCCEE) has reported that over the past two decades Australia's domestic aviation carbon footprint has grown at a faster rate than that of other modes of transport (*Figure 2*).[5]

Figure 2: Change in CO_2 footprint by mode 1990-2010



[3] *Australian National Greenhouse Accounts, National Inventory Report 2010 – Vol 1*. Tables 2.1 & 3.1. Department of Climate Change and Energy Efficiency. April 2012. http://www.climatechange.gov.au/en/publications/greenhouse-acctg/~/media/publications/greenhouse-acctg/NationalInventoryReport-2010-Vol-1.pdf
[4] *Transport Greenhouse Gas Emissions, Country Data 2010*, International Transport Forum. http://www.internationaltransportforum.org/Pub/pdf/10GHGCountry.pdf
[5] See reference 3: Figure 3.4

In 2010 fuel uplifted in Australia for international aviation was the source of 10.3 Mt of CO_2-e.[6] Collectively domestic and international aviation generated 16.5 Mt of CO_2-e which constituted about 3% of Australia's carbon footprint.[7]

It can be seen from *Figure 3* that between 1990 and 2010 the annual carbon footprint of domestic aviation grew from around 3 million tonnes to around 6 million tonnes.[8] During this period international aviation grew more rapidly than domestic aviation (as demonstrated by the slopes of the linear trend lines).[9]

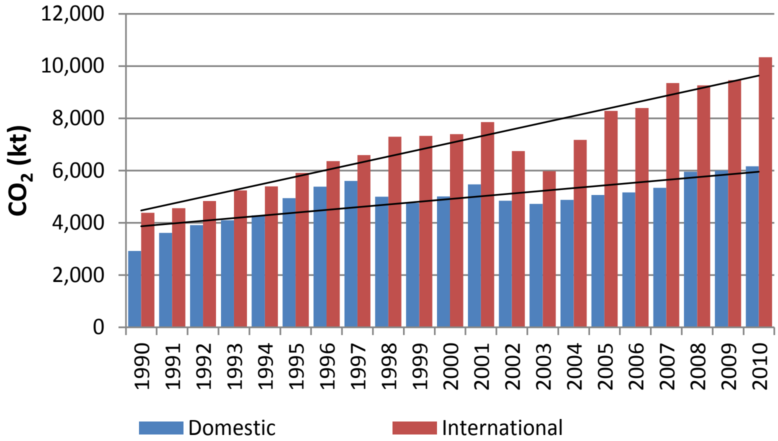


Figure 3: Aviation CO_2 footprint 1990-2010

The growth rates shown in the figure are around 4% per annum. This rate of growth in carbon footprints is broadly consistent with global growth in aviation emissions of around 3% per year.

[6] International aviation: http://ageis.climatechange.gov.au/Chart_KP.aspx?OD_ID=27152509190&TypeID=1
[7] From this point forward, carbon footprint data is presented in terms of 'CO_2' rather than 'CO_2-e'. This is standard practice for carbon footprinting aviation – see Section 1.2.
[8] Domestic aviation: http://ageis.climatechange.gov.au/Chart_KP.aspx?OD_ID=27152551629&TypeID=1
[9] International aviation: see reference 6.

Chapter 1

Introduction

Carbon footprinting underpins action on climate change. Without a solid understanding of the patterns of CO_2 generation in the aviation sector, it is unlikely that the optimum policies will be adopted to tackle aviation's contribution to climate change. Without routine on-going rigorous carbon footprinting of aviation it will not be possible to gauge whether climate change management actions are being effective. Public confidence in climate action relies on transparent reporting of carbon footprints.

At the present time there is a strong dichotomy in the carbon footprinting information that is available for aviation. On one hand, aggregated data on the total carbon footprint of aircraft operations originating in Australia has been available for a number of years through published information on jet fuel and aviation gasoline sales. At the other end of the scale, information on the average amount of carbon generated by single flights can readily be found by using one of the aviation carbon footprint calculators that have become accessible on the internet in recent years. However, as far as is known, to date no reports have been published which provide a comprehensive picture of the carbon footprint for the Australian aviation network in a disaggregated form. This report has been produced in an effort to fill that void. 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 aviation in Australia and is not aimed at discussing or promoting particular policy options for managing that footprint.

In addition to providing a data resource, the carbon footprinting exercise contained in this report has been carried out to test the robustness of 'simple' approaches to aviation carbon footprinting. All the data shown in this report has been derived from publicly available datasets of scheduled aircraft movements and the use of readily available 'non-expert' software applications which have been used on standard personal computers. The validation exercise described in Chapter 6 indicates that this approach produces carbon footprint results which are within about 5-10% of the best available published CO_2 emission figures (derived from data on actual fuel use).

The document relies heavily on the use of data visualisations to generate a picture of carbon footprints. In an effort to trial different presentational ideas no attempt has been made to achieve uniformity between graphics. It is hoped that this somewhat informal approach will generate an interest in communication concepts and encourage the reader to explore better ways to report aviation carbon footprints.

1.1 Report Structure

Within the aviation industry much of the attention on reducing the carbon footprint is through technological advances; for example, the introduction of new more efficient aircraft types, improved air traffic management (ATM) and the use of alternative fuels. At the government level, particularly in Australia, interest is focussed on using market based measures to drive change. By way of contrast, community activists, especially in Europe, often look to changes in personal behaviour as the key to reducing aviation's carbon footprint; for example, taking a train rather than flying; or avoiding unnecessary trips – so called 'frivolous flying'. When examining the potential efficiency of some of these options there is a need to use complex high fidelity carbon footprinting in order to examine very fine details of fuel use - this is particularly the case when optimising ATM procedures. However, when considering the application of other options less detailed, and more accessible, high level carbon footprinting approaches can provide very useful insights. This document provides an example of the type of picture that can be presented of an aviation system carbon footprint through the use of 'simple' great circle techniques.

Chapters 2 to 5 in this report progressively provide a picture of the carbon footprint for aircraft operations in Australia in 2011. Chapter 2 gives a disaggregated overview of the carbon footprint at the network level. Chapters 3 and 4 provide further insights by examining the data from perspective of the airports and then the airlines. In keeping with current interest both within Australia and the International Civil Aviation Organization (ICAO), Chapter 5 reports and discusses the carbon information in the early chapters in terms of dollar values. Chapter 6 describes the computational approach used to generate the information in Chapters 2 to 5 and assesses the robustness of the computations by comparison with a number of publicly available validation points. The Appendix provides an alphabetical listing of core carbon footprint data for all the airports and airlines included in the scheduled aircraft operations dataset that underpins this report.

1.2 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 scheduled aircraft operations carried out in Australia in 2011. 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.[10] The algorithms in this software tool are based on those contained in the ICAO Carbon Calculator.[11]

The reader is encouraged to examine Chapter 6 to learn about the methodology adopted to compute the numbers and to peruse the comparison of these numbers against the published validation points.

Input Data

All the CO_2 computations in this report are based on a publicly available database of 2011 scheduled aircraft movements for Australia. This database was sourced from Innovata, a provider of data for global aviation.[12] This dataset is discussed further in Chapter 6.

Scope

The carbon footprint computations relate only to the CO_2 generated by **scheduled** aircraft operations in year 2011. 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 are confined solely to aircraft take-offs to avoid double counting of carbon. All domestic operations have take-offs in Australia and therefore the carbon emissions for all domestic flights are captured by the CO_2 data in this report. The CO_2 emissions generated by aircraft departing from Australia to the first port of call overseas are also captured. However, the CO_2 generated by international arrivals is not computed. This methodology, which effectively computes all aviation fuel uplifted in Australia, is consistent with the UNFCCC carbon reporting regime.[13] Under the UNFCCC regime the carbon generated by an international arrival is counted

[10] TNIP Carbon Counter: http://www.infrastructure.gov.au/aviation/environmental/transparent_noise/tnip_CC.aspx
[11] ICAO Carbon Calculator: http://www.icao.int/environmental-protection/CarbonOffset/Pages/default.aspx
[12] Innovata: http://www.innovata-llc.com/
[13] *IPCC Guidelines for National Greenhouse Gas Inventories*, p1.6. http://www.ipcc-nggip.iges.or.jp/public/gl/guidelin/ch1ref1.pdf

under the inventory of the country from which the flight departed. This approach aligns with the reports on CO_2 generation that Australia submits to the UNFCCC in its Australian National Greenhouse Accounts (aviation CO_2 data is reported in two separate parts - domestic and international).[14]

Consistent with the approach of computing jet fuel uplift in Australia, the carbon computations for international departures only relate to the fuel used to reach the first port of call. For example, if a flight to London stops to re-fuel in Singapore the CO_2 is only computed for the Australia-Singapore leg of the journey.

The UNFCCC carbon accounting regime is based on computing the weight of six greenhouse gases.[15] 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 very small compared to the quantity of CO_2.[16]

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, 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.[17] This is the approach adopted in this document. Should the reader wish to incorporate a different RFI value into the results in this 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.[18]

Limitations

The limitations cited below should be read in conjunction with the discussion on validation in Chapter 6.

- The reported carbon data is based on computation. Ideally the figures would be based on actual fuel use data for every individual flight in 2011 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** movements dataset and does not contain information on unscheduled movements such as charter flights and aircraft carrying out aerial work such as training. This will tend to under report the quantum of CO_2.
- Information expressed in 'per passenger' metrics (eg CO_2/PAX, litres of jet fuel/RTK, etc) relies on assumptions relating to both load factors and seat configurations and is likely to have greater uncertainty than results solely reporting CO_2.

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[14] See reference 3.
[15] UNFCCC Fact Sheet: http://unfccc.int/files/press/backgrounders/application/pdf/press_factsh_mitigation.pdf
[16] See Table 3.1; reference 3.
[17] ICAO Carbon Calculator. FAQ No 1: http://www.icao.int/environmental-protection/CarbonOffset/Pages/FAQCarbonCalculator.aspx
[18] *Aviation and the Global Atmosphere*. IPCC. http://www.ipcc.ch/ipccreports/sres/aviation/index.php?idp=64

- This report only provides a one year snapshot of the carbon footprint of Australian aircraft movements. A larger database capturing data for a number of years would give a more comprehensive and reliable picture. Clearly the monitoring and reporting of CO_2 emission trends over time are fundamental components of a solid carbon footprinting regime.

1.3 Differentiating between Domestic and International Aviation

Conventionally domestic and international aviation are treated as separate entities. While domestic aviation is under the direct jurisdiction of the governments of individual countries, 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). This separation also applies under the United Nations Framework Convention on Climate Change (UNFCCC). Under the UNFCCC domestic aviation is reported as a component of country CO_2 emissions while the management of the climate change impacts of international aviation is being negotiated through ICAO. Accordingly, carbon footprints in this report have been divided into 'domestic' and 'international' components. As a further subdivision domestic aviation is reported by 'interstate' and 'intrastate' – this is an important administrative distinction in Australia since State governments have jurisdiction over certain aspects of intrastate aviation. In some States the rights to operate particular air routes are regulated and the rights to operate services are allocated to airlines. This occurs for example in Western Australia.[19]

As indicated in *Figure 3*, the growth in the CO_2 footprint for international aviation departing from Australia is outpacing the growth in the carbon footprint for domestic operations. This trend is much more marked at the global level. During the period 1900-2008 global domestic aviation grew by 6% while global international aviation grew by 76%.[20]

1.4 Transparency

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.

Access to data is not a straightforward issue. Clearly, providing people with data which they cannot understand is not transparency. Providing only partial data is not transparency. By the same token, information overload can hide key messages. Some form of balance needs to be struck and the 'CO_2 pictures' that are presented in this report simply reflect the author's first attempt to portray a transparent overview of Australia's aviation carbon footprint. Aviation carbon footprinting is still in its infancy and there are, as yet, no standard ways in which to provide aviation system footprints. The reader is encouraged to critically examine the information in this report with a view to improving current approaches.

Unfortunately, environmental data is often fiercely protected for reasons such as commercial confidentiality or commercial value. The protection of data is particularly sensitive when it relates to climate change since energy use, the core data, is one of the key indicators of an enterprise's technical performance. This is information that a company would not normally want to be divulged

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[19] *Western Australian State Aviation Strategy. Issues Paper.* March 2012: http://www.tourismcouncilwa.com.au/wp-content/uploads/Issues-Paper-FINAL-2.pdf

[20] See reference 2, p8.

to competitors. This constraint brings a level of uncertainty to carbon footprinting. However, derived data approaches such as the one used in this report, are able to be used and the results can be checked against a number of published validation points (see Chapter 6).

It is common for the tools used for analysing and reporting data to be complex and expensive and hence this is an area where it is difficult for members of the public to verify the work of 'experts'. While this arrangement may give comfort to the cognoscenti, it does little to build public confidence in environmental decisions and outcomes. Against this background, it is encouraging to note that in recent times the software tools for analysing and reporting data have become much more powerful, user friendly and less costly (eg Microsoft Excel). In response, a new field of endeavour – data journalism – has emerged in recent years where non-expert investigative journalists have become empowered to mine large datasets.[21,22] In a similar vein, the advent of e-books and self-publishing has facilitated the dissemination of information by private individuals. This document takes advantage of these advances in data accessibility.

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 6). The intention is to demonstrate that useful carbon footprinting can be carried out by interested members of the public and does not need to be in the domain of the expert. Ultimately public confidence in Government (and private/corporate) climate change decision making relies on members of the public being able to scrutinise what is happening.

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[21] *Facts are Sacred: The power of data.* The Guardian, January 2012. http://www.guardian.co.uk/news/datablog/2012/jan/06/facts-sacred-guardian-shorts-ebook

[22] ABC Radio National, Data Journalism, July 2012. http://www.abc.net.au/radionational/programs/mediareport/data-journalism/4128770

Chapter 2

The Network

2.1 Introduction

The carbon footprinting in this report is broken down into the three core levels of operations – international; interstate; and intrastate. This provides a good level of primary disaggregation for the CO_2 footprint of Australian aircraft operations. *Figure 4* shows the split of the carbon footprint between these components. The figure also illustrates the somewhat complex relationship between the number of aircraft movements and the carbon footprint – for example, it can be seen that international operations, which constituted about 10% of the scheduled departures within Australia in 2011, generated about 60% of the aircraft operations carbon footprint.

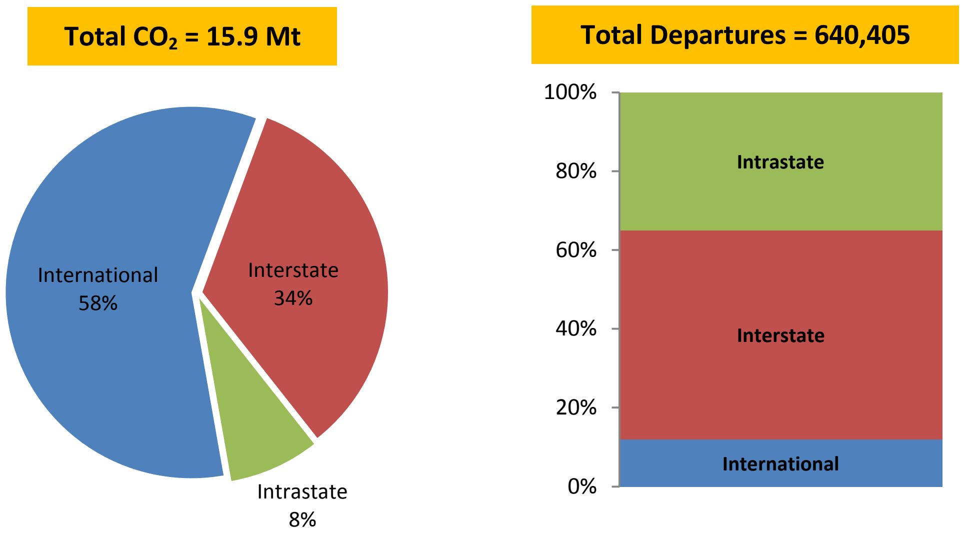


Figure 4: Primary components of the network CO_2 footprint

Within these three components the footprint is further disaggregated in the next three chapters into a number of discrete areas which provide different perspectives on the data: footprint by airports and airlines broken down into subdivisions such as city pairs and aircraft types.

In order to provide a comprehensive picture, but one which avoids information overload, the information is primarily provided using two core metrics – 'total CO_2' and 'CO_2/PAX' (CO_2 per passenger) for each element examined.

A key indicator of carbon footprinting interest is fuel (carbon) efficiency. At present this is reported in many ways in the literature – litres/RTK (revenue tonne kilometre), litres/RPK (revenue passenger kilometre), CO_2/PAX, etc. There are merits and weaknesses in any metric but for the purposes of this report efficiency is examined using the ICAO preferred metric of litres (of jet fuel)/RTK.

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 for short haul journeys (most notably rail and/or bus). This is discussed in Section 2.6.

This chapter provides an overview of the carbon footprint of Australian aircraft operations at the system level. The next two chapters take the same carbon information and look at it from the perspective of the airports and the airlines.

2.2 International Operations

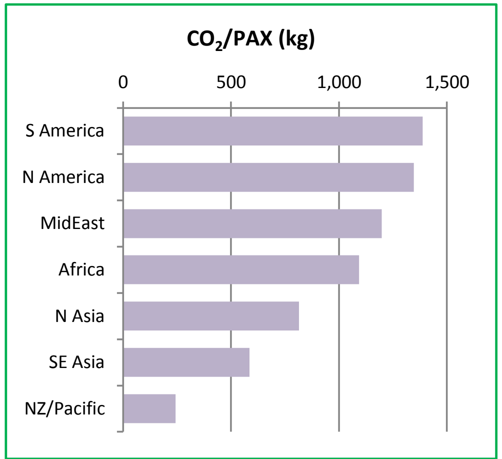
The carbon footprint hierarchy for the top 15 international city-pairs is shown in *Figure 5.* It can be seen that the Sydney-Los Angeles route has a significantly larger carbon footprint than all the other routes. There are a number of routes into SE Asia which have significant carbon footprints and which are of broadly similar magnitude. An alphabetical listing of all the international city-pair carbon footprints is contained in Table A.1 in the Appendix.

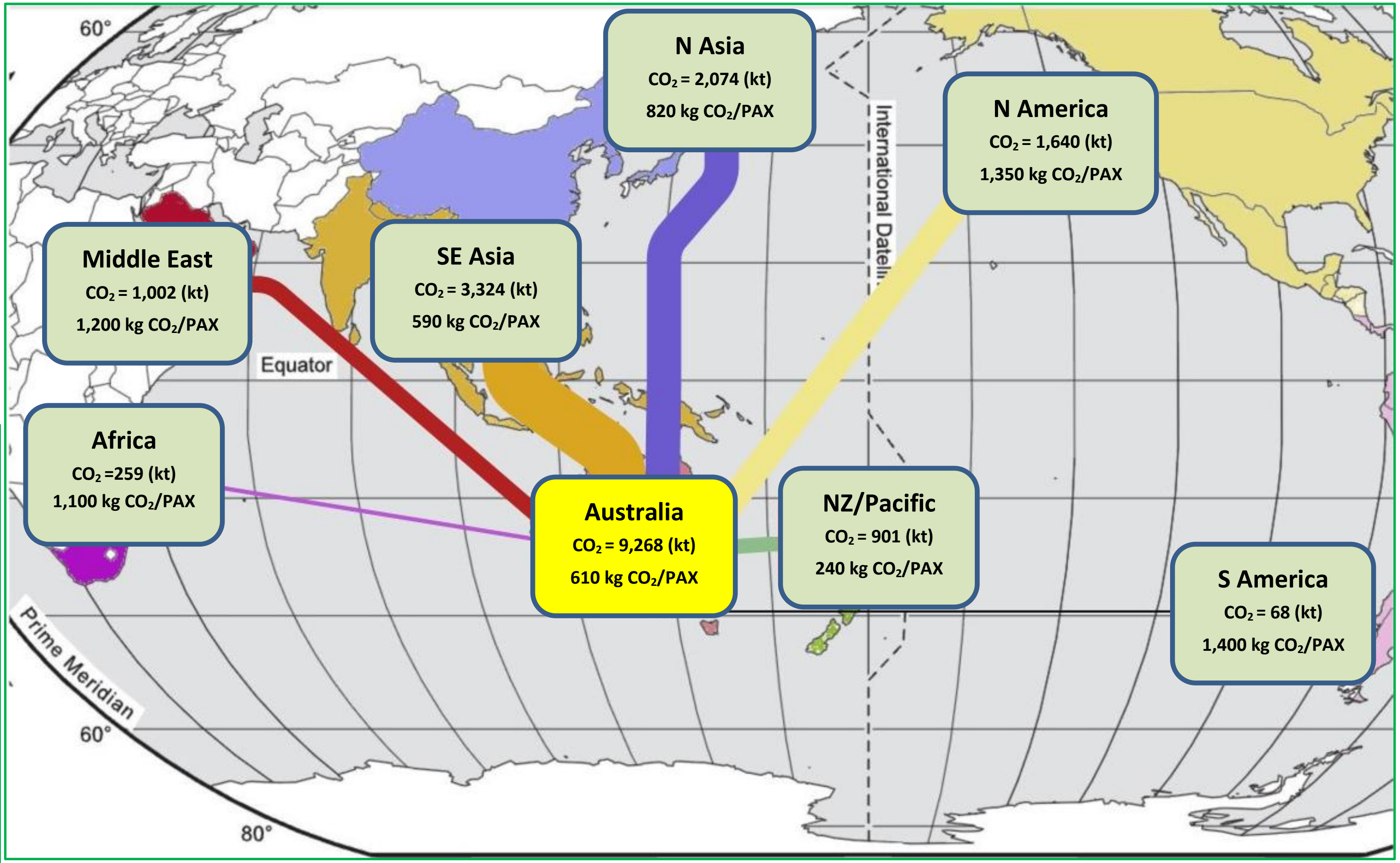
In order to assist comprehension international operations have been clustered into seven regional groupings throughout the report: Africa; Middle East; N America; N Asia; NZ/Pacific; S America; and SE Asia. *Figure 6* provides data on the carbon footprint of international flights originating within Australia to each of these seven regions. It can be seen that Australia's international carbon footprint is dominated by operations to Asia – these operations comprise about 60% of the footprint. For many travellers the journey to Asia constitutes the first leg of flights to more distant places, usually Europe – however, as indicated in Section 1.2 the carbon footprint in this report is only computed to the first port of call. It can also be seen from *Figure 6* that the carbon footprint/person for a journey to SE Asia is of the order of 50% of the footprint of a trip to N and S America and the Middle East.

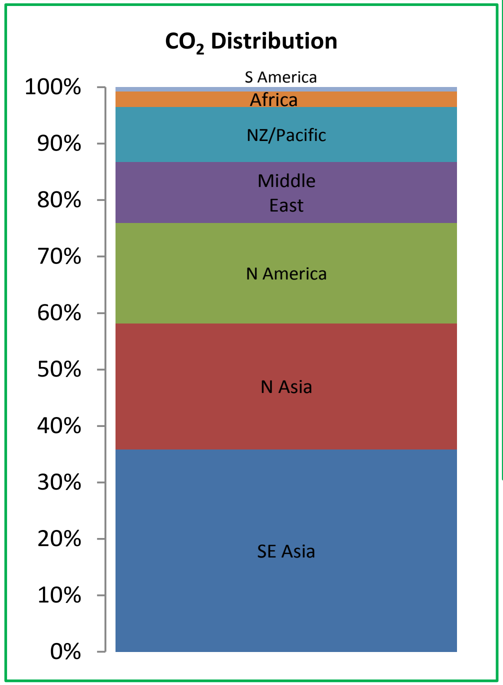
City Pair	CO_2 (kt)	CO_2/PAX (kg)
Sydney-Los Angeles	721	1,302
Sydney-Singapore	491	624
Sydney-Hong Kong	425	742
Sydney-Bangkok	400	696
Melbourne-Singapore	381	609
Brisbane-Singapore	278	605
Melbourne-Hong Kong	270	796
Melbourne-Kuala Lumpur	230	673
Melbourne-Los Angeles	225	1,356
Sydney-Abu Dhabi	206	1,009
Brisbane-Los Angeles	197	1,280
Sydney-Dubai	193	1,220
Sydney-San Francisco	192	1,322
Sydney-Auckland	181	210
Sydney-Seoul	175	899
Other routes	4,706	500
TOTAL	**9,268**	**609**

Figure 5: International CO_2 footprint by city pair

In order to provide a more detailed carbon footprint picture for our own ICAO region (Asia/Pacific), the regional information in *Figure 6* is broken down by country for SE Asia; N Asia; and NZ/Pacific in *Figure 7*. This indicates that CO_2 emissions associated with flights to Singapore dominate while Hong Kong, Thailand, New Zealand, Malaysia and China also provide significant contributions (between them these countries make up 85% of the combined regional footprint for Australian flights). In the Pacific, the Fiji destination footprint dominates that of the other island states.



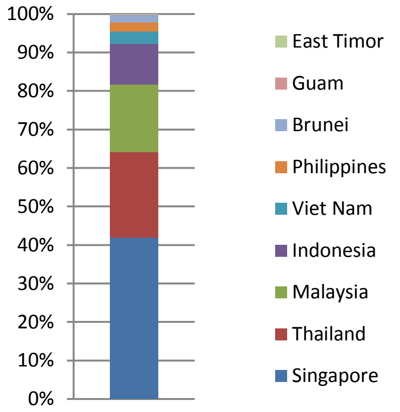




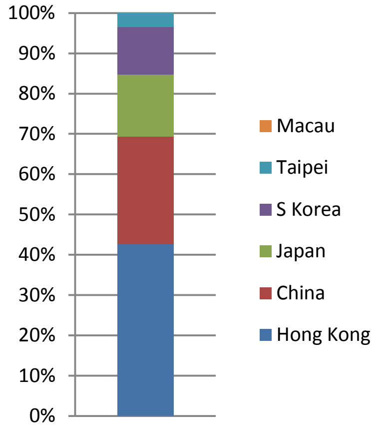
Total International CO_2 = 9.3 Mt

Figure 6: International CO_2 footprint by region

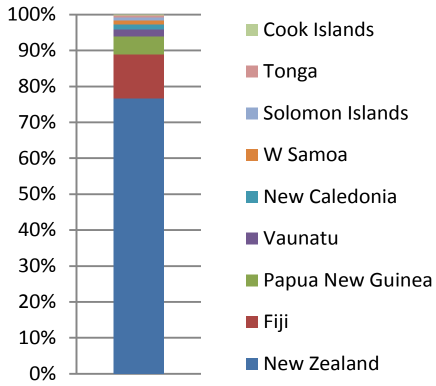
The seven regions shown in the Figure are arbitrary groupings. It can be seen that the carbon footprint is dominated by flights to the two regions in Asia.



SE Asia	
Country	**CO_2 (kt)**
Singapore	1,396
Thailand	733
Malaysia	583
Indonesia	356
Viet Nam	103
Philippines	79
Brunei	66
Guam	5
East Timor	3
TOTAL	**3,324**



N Asia	
Country	**CO_2 (kt)**
Hong Kong	886
China	551
Japan	320
S Korea	245
Taipei	71
Macau	0
TOTAL	**2,074**



NZ/Pacific	
Country	**CO_2 (kt)**
New Zealand	691
Fiji	110
Papua New Guinea	45
Vaunatu	18
New Caledonia	13
W Samoa	9
Solomon Islands	8
Tonga	4
Cook Islands	2
TOTAL	**901**

CO_2 Footprint Breakdown for Asia/Pacific

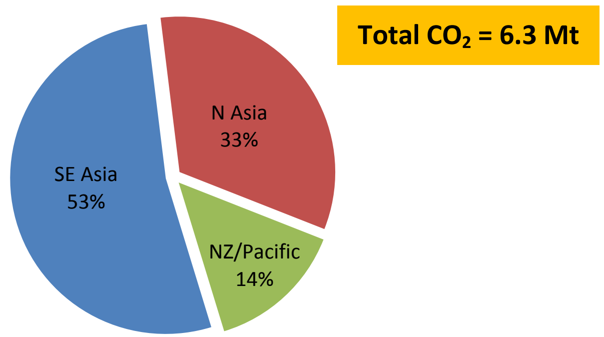


Figure 7: CO_2 footprint for the consolidated Asia/Pacific Region

The countries included in this figure are all part of the ICAO Asia/Pacific region. It can be seen that for each of the constituent sub-regions the total CO_2 footprint is heavily influenced by operations to a small number of countries.

Figure 8 shows the CO_2 footprint for international operations by the top 10 aircraft types. In this figure the aircraft types have been grouped into aircraft families (eg B777). Operations in these 10 aircraft types make up more than 99% of the international carbon footprint for Australia. It can be seen that the carbon footprint of international operations originating in Australia is dominated by the A330 and the B777. These two aircraft types are the main contributors to the carbon footprint for operations to Asia while four engine aircraft (the B747, A380 and the A340) generate the major part of the carbon footprint for flights to N America, Africa and the Middle East. Medium sized two engine aircraft (the B737 and A320) are the prime contributors to the NZ/Pacific carbon footprint.

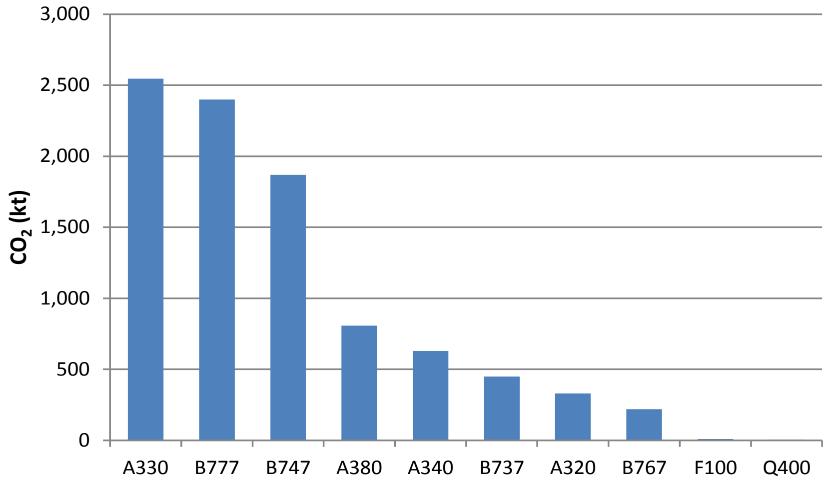


Figure 8: International CO_2 footprint by aircraft type

2.3 Domestic Operations

Figure 9 provides an overview of the key routes making up the carbon footprint of domestic operations in Australia. The airports shown on the figure are the airports in the capital city of each of the mainland States and Territories with the addition of Cairns and the Gold Coast airports which are the major non-capital city international airports in Australia. The figure also includes a grouping of airports termed 'The Pilbara' which has been included to highlight the aviation carbon implications of the current 'mining boom' centred in this area of Australia.

The figure provides information on the CO_2 by route and also the CO_2/passenger. In order to assist interpretation, the routes on the figure are colour coded to show three footprint categories:

- *major* blue >200 kt CO_2
- *intermediate* yellow 100 to 200 kt CO_2
- *lower* green <100 kt CO_2

Key observations include:

- The Sydney-Melbourne city pair generates the highest carbon footprint – this represents about 10% of the domestic footprint.
- Four of the 'major route' city pairs involve flights out of Perth, while Sydney, Melbourne, Brisbane each have three major CO_2 routes. This largely reflects the isolated location of Perth relative to the other Australian capital cities.

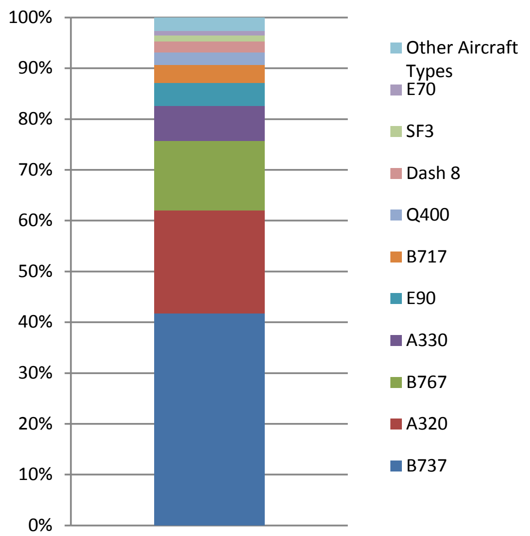
- The Perth-Pilbara 'city pair' is the only intrastate route in the major category. The relatively high carbon footprint on this route reflects the mining boom in the NW of Australia. It is important to point out that the CO_2 data relates solely to scheduled services. There are now a significant number of charter services into the Pilbara and therefore the data in the figure is likely to understate the true carbon footprint of aircraft operations into and out of this region.

- The interstate routes to/from Darwin and Perth are notable in that the magnitude of CO_2/PAX is significantly greater than that on most of the other routes. This simply reflects the relative isolation of Darwin and Perth from the other major cities in Australia.

- The major CO_2 routes (top 7 routes) make up about 45% of the total domestic carbon footprint. The top two route categories combined (top 14 routes) make up about 60% of the footprint.

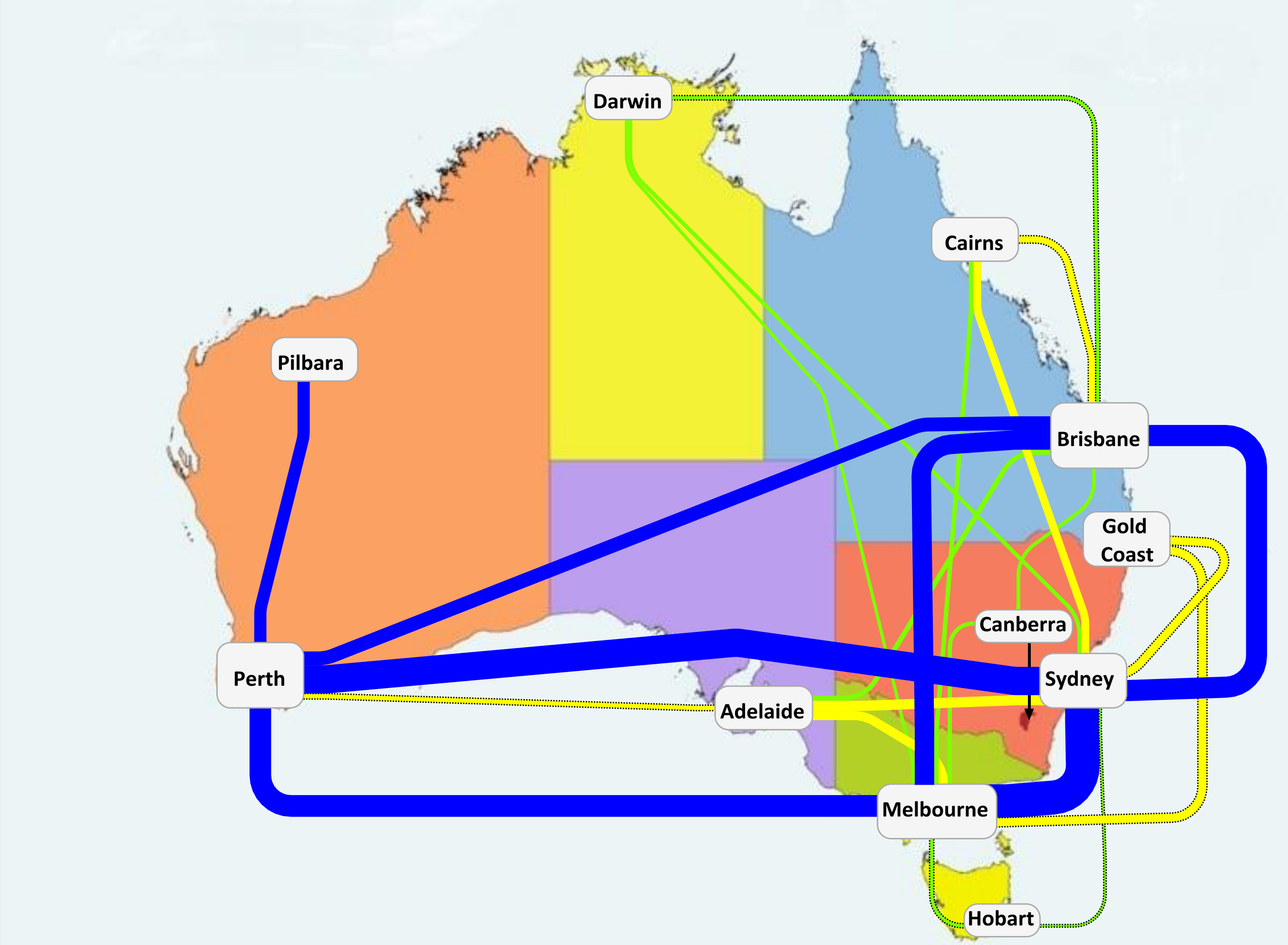
The information in *Figure 9* is supplemented by *Figure 10*. This figure, which has been generated using a Geographic Information System (GIS) software package, shows the aggregated carbon footprint for all the domestic routes contained in the operations dataset. While on one level this gives a somewhat confusing picture it does provide a useful visualisation of the total carbon footprint for all scheduled domestic aircraft operations in 2011.

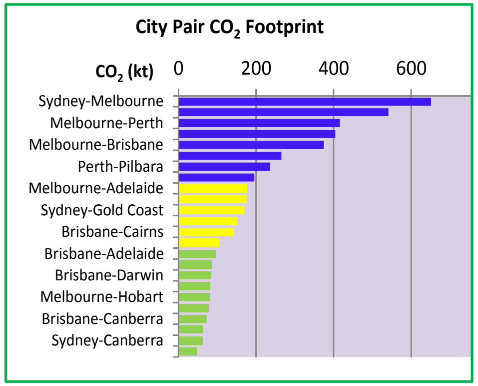
Figure 11 shows the top 10 aircraft types that contribute to the domestic carbon footprint. It can be seen that the domestic carbon footprint is dominated by the B737NG – this aircraft type is the major domestic work horse for both Qantas and Virgin. The A320, the main aircraft type operated by Jetstar, is also a significant contributor to the domestic carbon footprint. These two twin aisle aircraft contribute about 60% of the domestic carbon footprint. The B767 and the A330 families of wide bodied aircraft made up about 20% of the domestic carbon footprint in 2011.



Aircraft Type	CO_2 (kt)
B737	2,753
A320	1,333
B767	900
A330	461
E90	302
B717	227
Q400	165
Dash 8	137
SF3	81
E70	62
Other Aircraft Types	171
Total	**6,592**

Figure 11: Domestic CO_2 footprint by aircraft type





City Pair	CO_2 (kt)	CO_2/PAX (kg)
Sydney-Melbourne	652	90
Sydney-Perth	541	309
Melbourne-Perth	416	247
Sydney-Brisbane	404	91
Melbourne-Brisbane	374	133
Brisbane-Perth	265	306
Perth-Pilbara	236	132
Sydney-Adelaide	195	120
Melbourne-Adelaide	177	85
Melbourne-Gold Coast	176	124
Sydney-Gold Coast	169	86
Sydney-Cairns	151	176
Brisbane-Cairns	142	136
Perth-Adelaide	105	191
Brisbane-Adelaide	97	153
Melbourne-Cairns	86	192
Brisbane-Darwin	84	242
Melbourne-Canberra	82	66
Melbourne-Hobart	81	82
Sydney-Darwin	78	262
Brisbane-Canberra	73	107
Melbourne-Darwin	63	239
Sydney-Canberra	62	46
Sydney-Hobart	48	112
Other Routes	1,836	104
TOTAL	**6,592**	**104**

Figure 9: The CO_2 footprint for the domestic network – key routes

The figure provides a rapid visualisation of the key routes underlying the carbon footprint of Australia's domestic network of scheduled aircraft operations in 2011. The five blue routes make up about 45% of the total domestic carbon footprint. It is interesting to note the focus of the blue routes on Perth which largely results from its isolation from the eastern State capital cities.

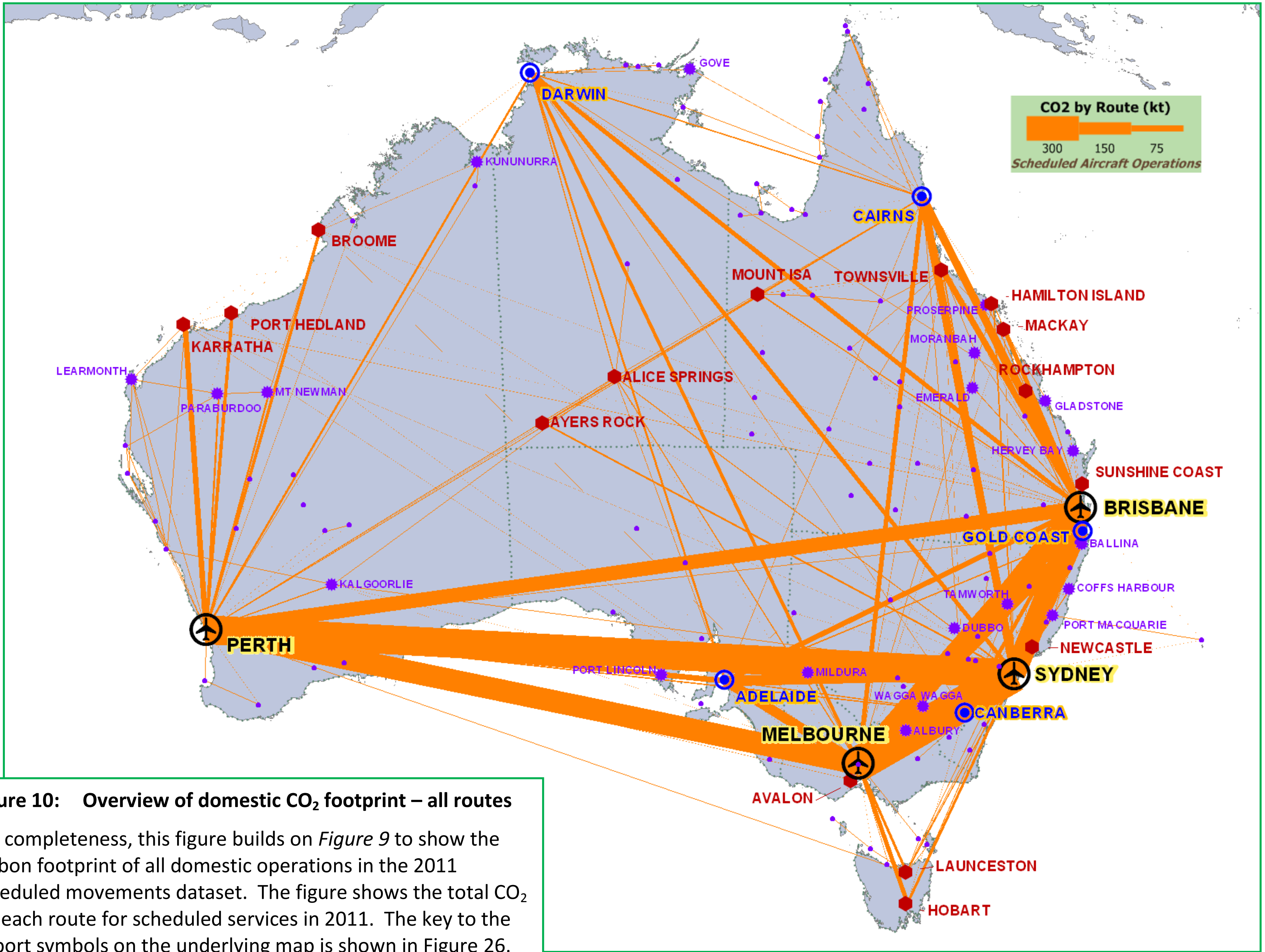
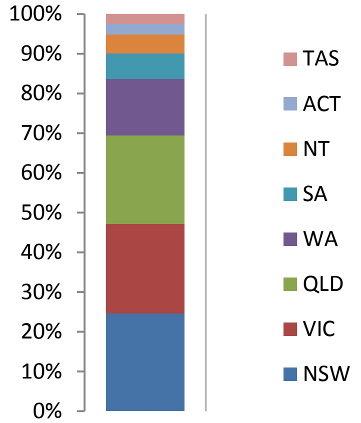


Figure 10: Overview of domestic CO_2 footprint – all routes

For completeness, this figure builds on *Figure 9* to show the carbon footprint of all domestic operations in the 2011 scheduled movements dataset. The figure shows the total CO_2 for each route for scheduled services in 2011. The key to the airport symbols on the underlying map is shown in Figure 26.

2.4 Interstate/Intrastate Split

It was shown in *Figure 4* that interstate and intrastate operations respectively make up 34% and 8% of the network carbon footprint. Domestic departures constitute about 90% of the aircraft departures in Australia. *Figure 12* shows a breakdown of the interstate carbon footprint by State and Territory. The CO_2 values are based on notional fuel uplift and need to be treated with caution (see Section 2.7).

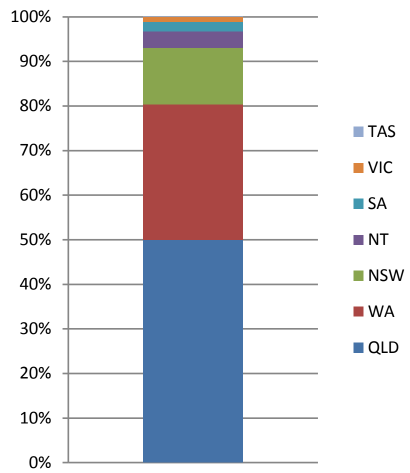


State	CO_2 (kt)
NSW	1,321
VIC	1,202
QLD	1,193
WA	753
SA	353
NT	249
ACT	146
TAS	130
Total	**5,347**

Figure 12: Interstate CO2 footprint by State

It can be seen that the interstate carbon footprint for NSW, Vic and Qld is of a similar magnitude. Collectively departures from these three States generate about 70% of the interstate CO_2 footprint.

Figure 13 provides a similar picture to *Figure 12* for intrastate operations. Not surprisingly, the largest geographic States Qld and WA dominate this footprint – together they comprise about 80% of the national intrastate footprint. Both of these States have some busy intrastate routes which are around 1500 km in length (which naturally have significant carbon footprints).



State	CO_2 (kt)
QLD	623
WA	378
NSW	158
NT	46
SA	27
VIC	14
TAS	0.1
Total	**1,245**

Figure 13: Intrastate CO_2 footprint by State

As the ACT has no scheduled intrastate aviation operations it is not included in *Figure 13*.

Figure 14 shows the top 10 aircraft types which contribute to the intrastate carbon footprint. In line with the picture presented in *Figure 11*, the B737 NG is the dominant aircraft type in this carbon footprint. Turbo props – in particular the Q400, Dash 8 and Saab 340 (SF3) make a substantial contribution to this footprint. Wide-bodied aircraft do not feature in the chart.

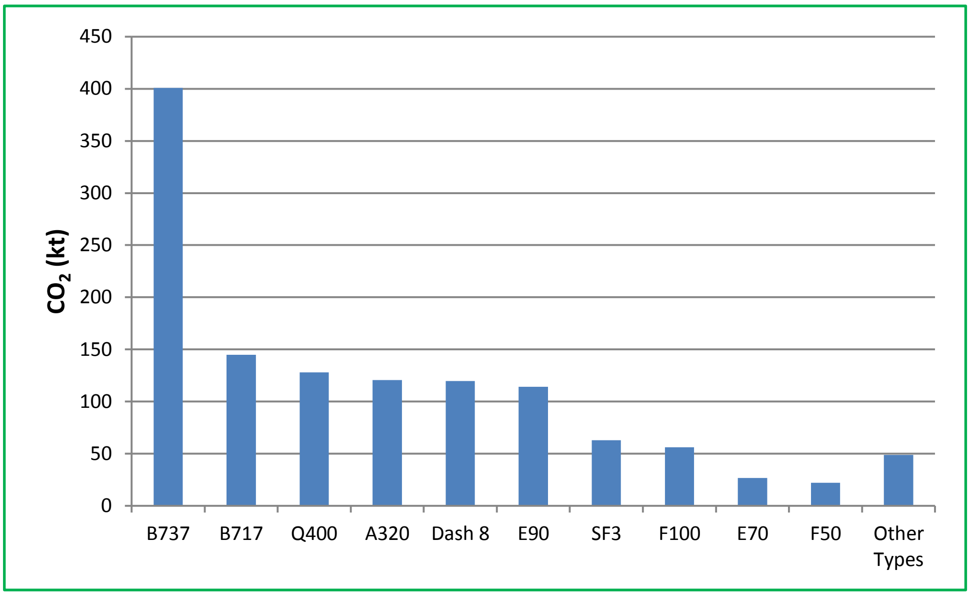


Figure 14: Intrastate CO_2 footprint by aircraft type

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)'.

At the outset, it is important to note that an improving efficiency does not mean a reducing carbon footprint. Globally the fuel efficiency of aviation has improved at a rate of 2% per year for the past two decades while at the same 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.[23]

There are a number of challenges when reporting efficiency using RTK metrics. In many countries, including Australia, RTK data is not routinely collected and/or reported. It is not a transparent metric in that it cannot be computed and verified from published aviation statistical data relating to passenger numbers and load factors – this makes it a less desirable metric than say 'fuel use/ASK (Available Seat Kilometre)' or 'fuel use/RPK (Revenue Passenger Kilometre)' for carbon footprint reporting. Ultimately the robustness of RTK data, if it is provided by industry, has to be largely accepted without verification. Industry sustainability reports commonly report efficiency using the

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

RTK metric (nevertheless, this is often supplemented by information using other metrics such as fuel/RPK).[24,25]

A methodology for estimating RTK has been developed by the Australian Government Department of Infrastructure and Transport and incorporated into TNIP Carbon Counter – this approach has been used to calculate the RTK values in this report.[26]

All computations involving data relating to passenger and seat numbers are inherently uncertain since they have to involve assumptions about both load factors and seat configurations across aircraft types of many different operators – this is discussed in Chapter 6.

Subject to these caveats, *Figure 15* provides estimations of the efficiency of the Australian aviation network. The figure gives indicative values for the system fuel efficiency for the three high level network components used throughout this report. The table indicates that 'International' is the most efficient category when assessed using the L/RTK metric while 'Interstate' is the best performer when efficiency is computed using the L/100RPK metric.

Fuel Efficiency

Sector	L/100RPK	L/RTK
International	4.28	0.37
Interstate	4.11	0.39
Intrastate	4.88	0.47
Total	**4.26**	**0.38**

Figure 15: Fuel efficiency by network component

While the basic data analysis methodology adopted in the preparation of this report does allow the computation of detailed disaggregated efficiency figures, for example by route or by airline, these are only used sparingly in this document due to a lack of confidence in the robustness of the fine resolution computations involved.

The values in *Figure 15* compare well with published airline efficiency data. For example, in its Annual Report for 2011 Qantas reports its fuel efficiency as 38.7 litres of fuel/100RTK[27], while Emirates reports an efficiency of 4.12 litres of fuel/100PK for 2010/11.[28]

2.6 CO_2 Contribution by Trip Length – Long/Short Haul Operations

If the discussion on the efficiency of aviation is taken further, the question needs to broaden out to encompass other modes of transport and not simply stay focussed on aviation. Ultimately, if the fundamental goal is to minimise the global CO_2 footprint across all sectors of the economy, there is a need to examine whether modes of transport other than aviation can provide a more efficient way to carry out the journey from A to B. The quantification of carbon footprints of competing transport modes is complex and goes beyond the scope of this report, nevertheless the carbon footprinting approach adopted in this report can provide some useful insights.

[24] *Emirates Environment Report 2010-2011*. http://www.emirates.com/english/images/The%20Emirates%20Group%20Environment%20Report_tcm233-701728.pdf
[25] *Cathay Pacific Sustainable Development Report 2011*. http://downloads.cathaypacific.com/cx/aboutus/sd/2011/pdf/CX_SDR11_Full.pdf
[26] *TNIP Carbon Counter User Manual,* p81. http://www.infrastructure.gov.au/aviation/environmental/pdf/TNIP_Carbon_Counter_User_Manual_v3_13June2012.pdf
[27] *Qantas Annual Report 2011*, p114. http://www.qantas.com.au/infodetail/about/investors/2011AnnualReport.pdf#page=112
[28] Reference 22, p49.

Modal Shift

As mentioned earlier in the report, a commonly suggested way to reduce aviation's carbon footprint is to promote modal shift. This is based on a widespread perception that aviation is inefficient and therefore that wherever possible journeys should preferentially be taken by other modes of transport such as rail or bus.

In broaching this topic it is probably most useful in the first instance to have an understanding of the CO_2 contribution to the total footprint made by trips of different length. In practice, while there is no real practical alternative to aviation for overseas journeys, it may be possible with current land transport infrastructure (primarily roads) to replace aviation journeys with other modes of transport where the distance travelled is less than say 500 km.

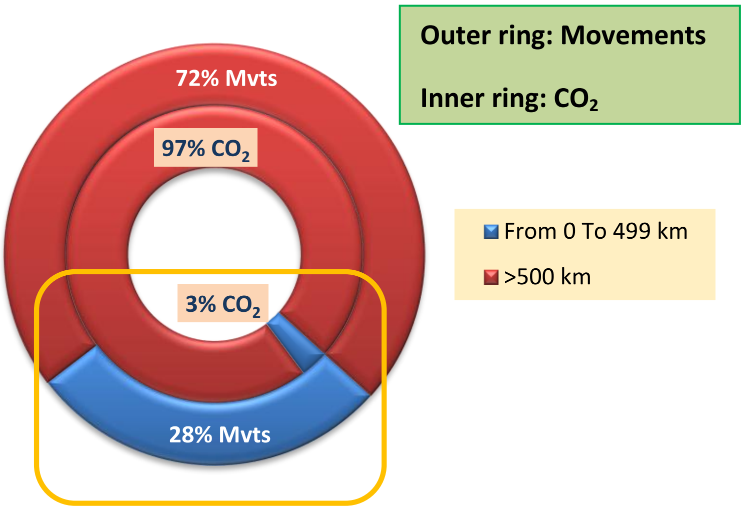


Figure 16: Long/Short haul breakdown

Some interesting information is revealed if this approach is explored. *Figure 16* shows that almost 30% of aviation trips within Australia travel less than 500 km. These may be commonly termed 'short-haul' trips. However, while these trips constitute a very significant proportion of the number of aircraft movements in Australia their contribution to the total aviation CO_2 footprint is around 3%. Therefore even if all flights of less than 500 km in length were replaced by land based transport across Australia this action would not reduce the overall aviation carbon footprint to any great extent. Interestingly, given the relationship between aircraft movements and carbon footprint revealed in *Figure 16,* shifting short-haul flights to other modes of transport could lead to an increase in the aviation carbon footprint. This perverse outcome would eventuate if the airport slots vacated by the short haul flights were taken up by longer haul flights. This would be a likely outcome at capacity constrained airports such as Sydney.

The debate on forcing modal shift away from aviation is predicated on aviation being less efficient than land based public transport and that moving passengers from air to land would result in a smaller transport carbon footprint. As indicated above, this is complex issue which goes beyond the scope of this report – save to say that the perceived CO_2 advantages of rail and/or road transport over aviation cannot validly be assessed simply by considering fuel use and need to be examined using Life Cycle Assessment (LCA) techniques.[29] There are, for example, important questions about the environmental impacts of the large land area footprints of road and rail compared to the relatively small areas of land taken by aviation.[30] The potential for modal shift for each of the major Australian airports is discussed briefly in Chapter 3.

[29] *Life-Cycle Environmental Assessment of California High Speed Rail*, Chester and Horvath, 2010. http://www.uctc.net/access/37/access37_assessing_hsr.pdf

[30] *Environmental Smackdown – Aviation v High Speed Rail*, Mary Ellen Eagan. http://www.hmmh.com/blog/?p=764

The Pattern of Short Haul Routes in Australia

Figure 17 shows the top 10 short haul routes (routes <500 km), by carbon footprint, for scheduled services in 2011. It can be seen that the top 5 of these are concentrated in the SE corner of the continent. This geographic concentration can be clearly seen in *Figure 18*. This figure is a GIS generated carbon footprint for all routes in the operations dataset which are less than 500 km. The green routes on *Figure 18*, which relate to routes with a footprint of less than 11.9 kt in 2011, provide an indication of the magnitude of the carbon footprint of the 'Other routes' referred to in *Figure 17.*

Route	CO_2 (kt)
Melbourne-Canberra	82.0
Sydney-Canberra	62.0
Melbourne-Launceston	49.1
Sydney-Albury	19.9
Sydney-Coffs Harbour	19.7
Brisbane-Gladstone	18.7
Cairns-Townsville	13.6
Melbourne-Mildura	13.6
Sydney-Port Macquarie	13.4
Sydney-Wagga Wagga	11.9
Other routes	185.2
Grand Total	**489.2**

Figure 17: CO_2 footprint of the main short haul routes in Australia

It is important to note that there can be significant differences in the distance between two places depending on whether a journey is taken by air or by land. For example, the great circle distance between Melbourne and Canberra is about 460 km while for road this distance is about 650 km. This difference can be very pronounced where significant geographic features impose constraints on the routing of roads – for example the distance between Adelaide and Port Lincoln by air is around 250 km while by land it is about 650 km since the road between the two locations has to go around Spencer Gulf. By the same token, aircraft do not usually follow a pure great circle distance as they need to be separated from other aircraft and in some circumstances have to avoid particular areas of airspace (eg military airspace, high terrain) – this adds distance to the theoretical air distance.

CO_2 *Relationship between Long and Short Haul*

Figure 19 contains three graphs which provide different perspectives on the aviation carbon footprint by distance. The information in the table emphasises the fact that a relatively small proportion of flights – the long haul flights - generates a large percentage of the carbon footprint of the network, even though long haul flights are more efficient than short haul flights. The cumulative footprint graph shows, for example, that about 50% of Australia's aviation carbon footprint is generated by around 5% of the flights.

It can be seen by cross referencing between the graphs that the CO_2 footprint is largely made up of a number of distance 'nodes'. There is a peak in the CO_2 output from domestic operations in the distance range 0-1,000 km which is principally generated by trips between the major eastern seaboard airports. There is also a smaller peak for domestic operations in the 2,000-3,500 km range which is principally generated by trips between Perth and the eastern States. The international carbon footprint has three peaks: a small one in the distance range 2,000 to 4,000 km which largely represents flights to near neighbours such as NZ, Indonesia and the Pacific; one in the 6,000-8,000 km distance band associated with flights to SE Asia; and one in the 12,000-13,000 km band generated by long haul flights to destinations such as the US and the Middle East.

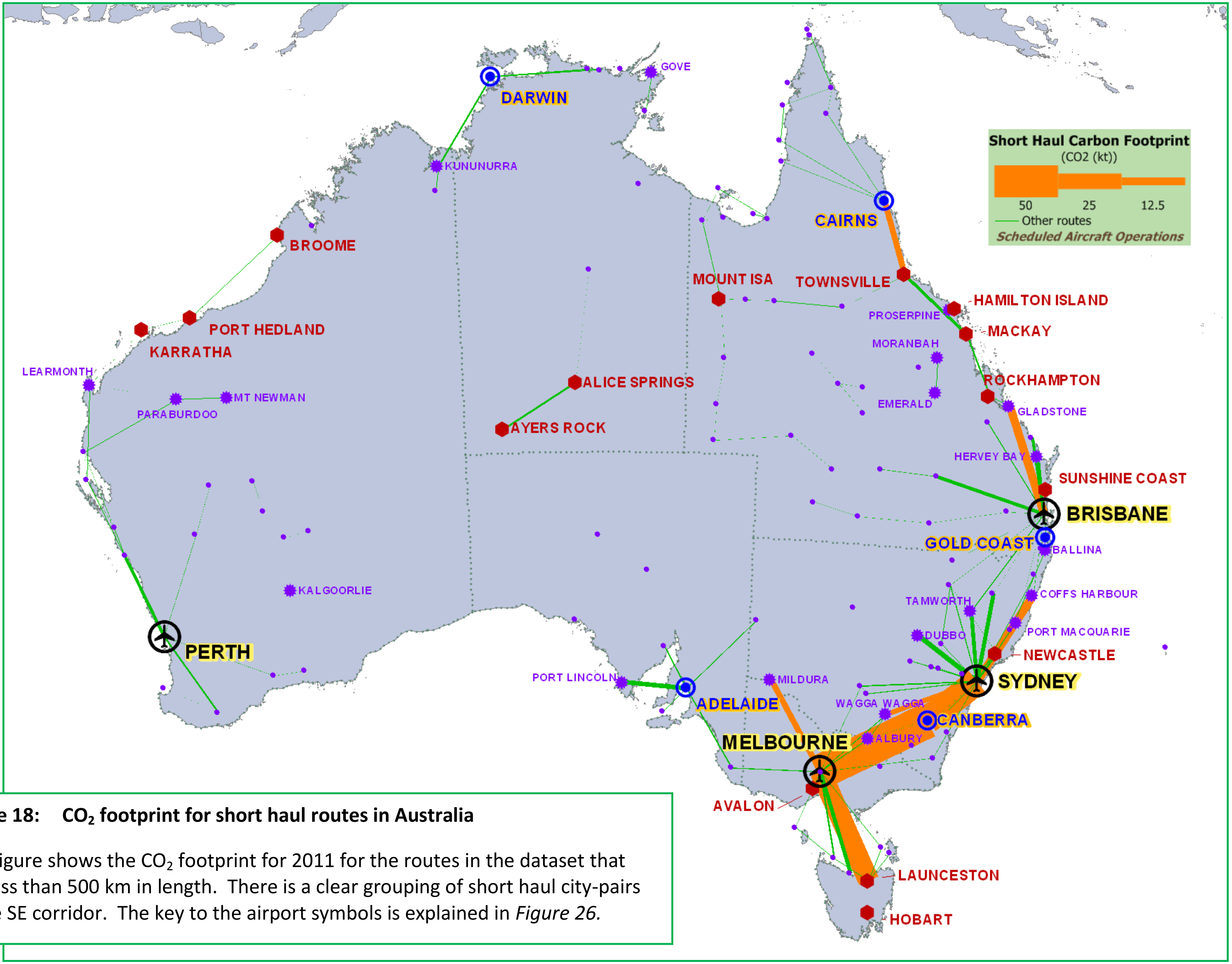
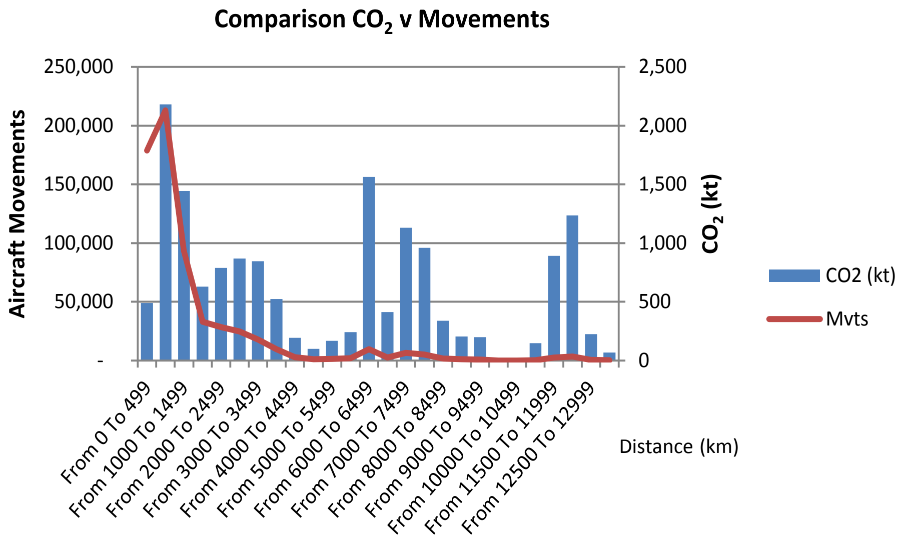


Figure 18: CO_2 footprint for short haul routes in Australia

This figure shows the CO_2 footprint for 2011 for the routes in the dataset that are less than 500 km in length. There is a clear grouping of short haul city-pairs in the SE corridor. The key to the airport symbols is explained in *Figure 26.*



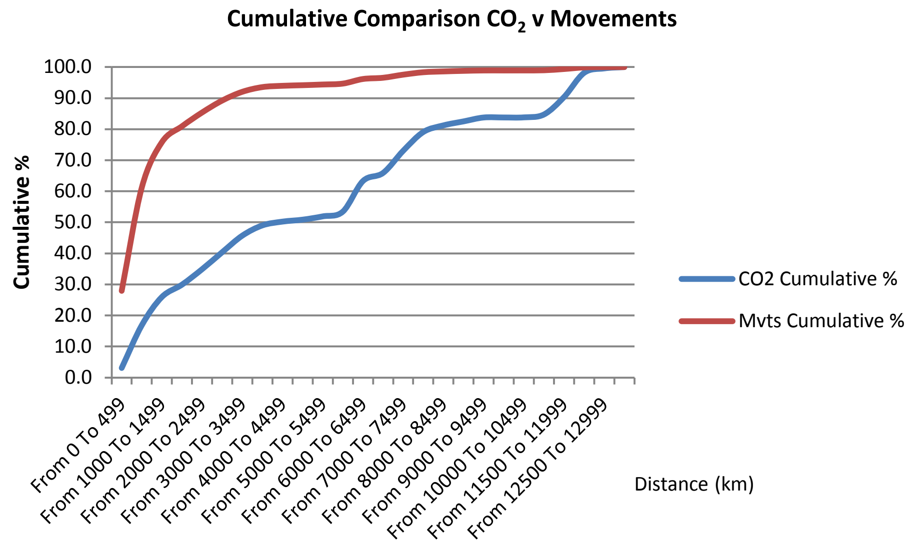
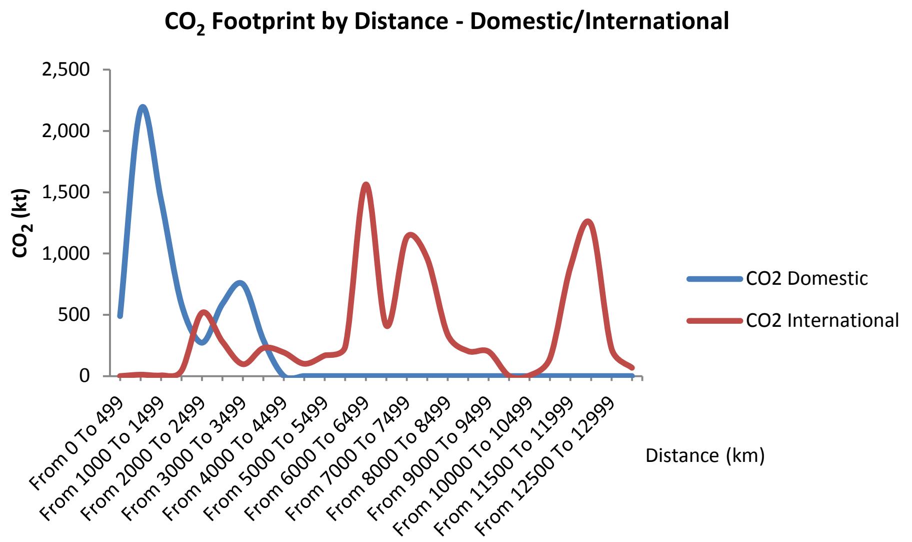


Figure 19: Perspectives on the make-up of the CO_2 footprint

The size of a network's CO_2 footprint is largely determined by the relationship between the distance travelled, the number of aircraft movements and the aircraft types involved. This figure shows that for Australia, the CO_2 contribution from a relatively small number of longer haul flights (those travelling >4,000 km - about 5% of the total number of operations) is similar to the CO_2 contribution made by all the short and medium length flights combined (about 95% of total trips).



2.7 Footprint Overview

Figure 20 gives an overview of the aircraft operations carbon footprint by State (the data includes both domestic and international operations). The numbers in the figure need to be treated with caution since they reflect the notional fuel uplifted rather than the actual fuel uplift. That is, the figure shows the computed CO_2 emissions that would have taken place if all aircraft had been refuelled before each flight. In practice aircraft do not normally re-fuel before every departure but 'tanker' fuel between airports and only re-fuel when considered necessary. The re-fuelling cycle is generally optimised to minimise costs for the airlines (subject to meeting safety requirements). There is a range of reasons why aircraft fuel is tankered – these include the need for rapid turnaround of aircraft on some schedules; variations in the price of jet fuel between airports; the availability and cost of ground handling facilities, etc.

Recognising these constraints, key observations from *Figure 20* include:

- NSW clearly dominates the carbon footprint when viewed from the State perspective – this is largely driven by the leading role played by Sydney Airport in international aircraft operations.
- Qld and Vic have carbon footprints of similar magnitude; the footprint size for Victoria is mainly driven by its significant component of international operations while the size of the Qld footprint is influenced by it being the State with the highest intrastate CO_2 footprint.
- The top three States – NSW, Vic & Qld make up about 80% of the notional aviation CO_2 footprint for Australia.

Figure 21 is an overview visualisation of the carbon footprint of aircraft operations in Australia. This figure pulls together the international, interstate and intrastate footprints and relates these to the airport and airline contributions to the carbon footprint.

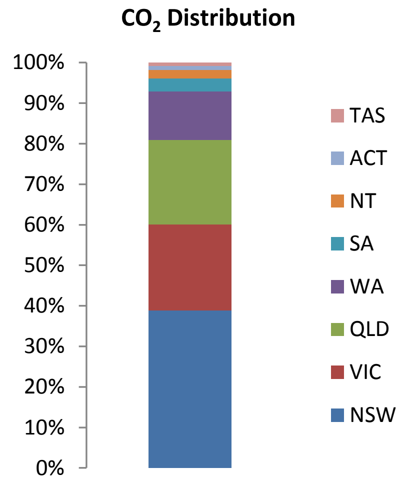
This figure lets the reader rapidly appreciate the dominant roles that Sydney and Melbourne, and to a lesser extent Brisbane, airports play in generating the carbon footprint of international operations for Australia. It is interesting to note that the three main Australian airlines – Qantas, Virgin and Jetstar – do not dominate the international CO_2 footprint.

The picture is more complex for domestic operations. Qantas dominates both the interstate and intrastate carbon footprints while, as would be expected, the carbon footprint is more widely dispersed between airports.

The composition of the Australian aircraft operations carbon footprint is examined in detail from the perspective of the airports and the airlines in the next two chapters.

Figure 20: Aviation CO_2 footprint by State

This Figure shows the notional CO_2 footprint for each of the Australian States and Territories for 2011. The data needs to be treated with some caution as jet fuel is tankered between States in day to day operations. The data relates to notional fuel uplifted for both domestic and international operations. The values for NSW, Vic and Qld are heavily influenced by CO_2 associated with international departures.



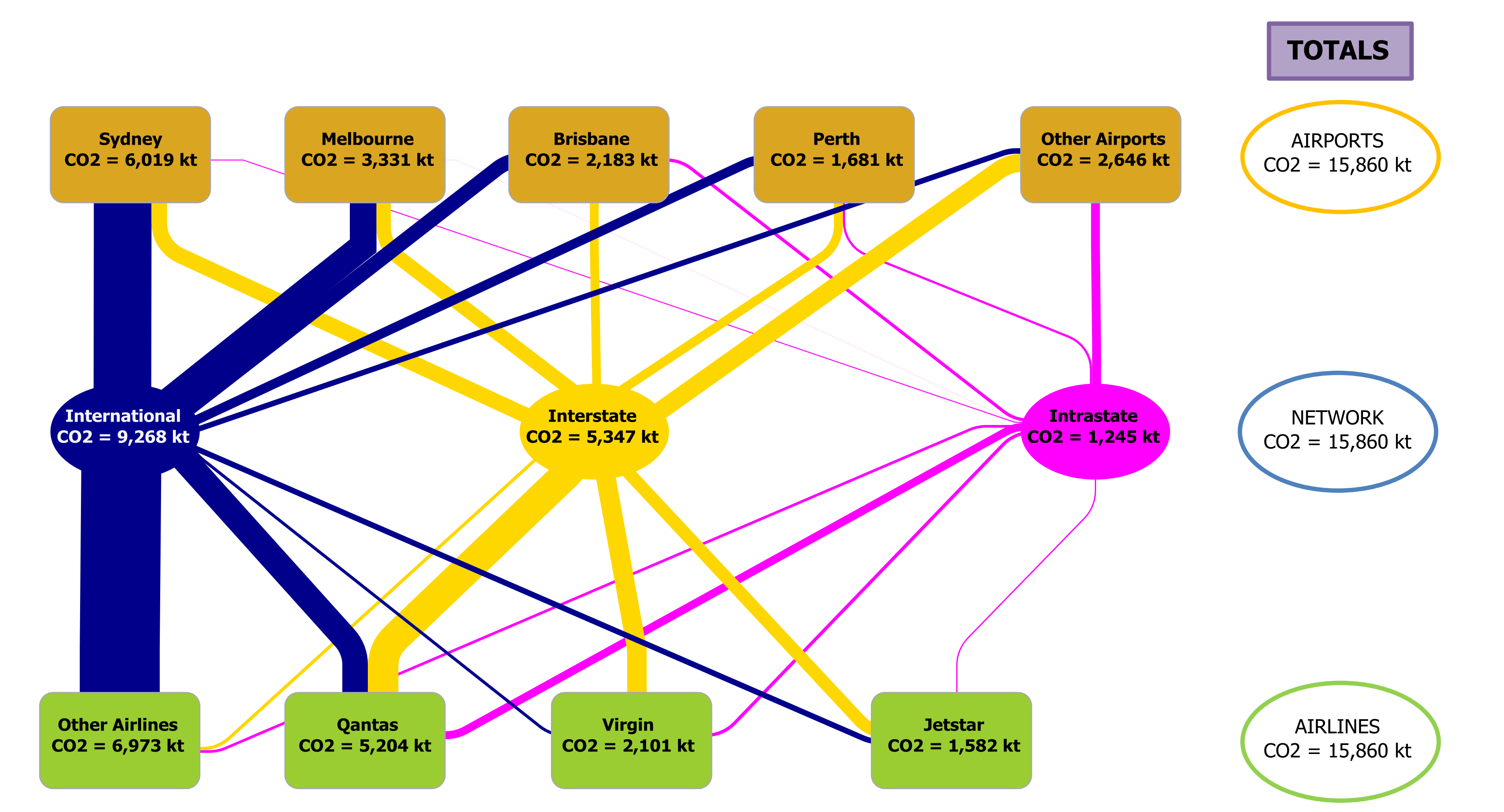


Figure 21: Overview of the key airport and airline contributions to the network CO_2 footprint

This visualisation leads into the airport and airline CO_2 footprint disaggregations contained in the next two chapters. It highlights the magnitude of the CO_2 contributions made by the key airports and airlines to the three high level network components and also provides a quick reference for cross checking the reported footprint values which are shown in the coming pages.

Chapter 3

The Airports

3.1 Introduction

This chapter is aimed at providing a breakdown of the carbon footprint for aircraft operations from the perspective of the airports. The information relates to aircraft operations and not to the carbon footprint of the airports per se. That is, the information does not relate to CO_2 emissions associated with airport owned and managed infrastructure and/or activities such as terminals or ground transport. This distinction is important in understanding the make-up of the aviation industry's carbon footprint.

As far as is known there are no published all-encompassing carbon footprint reports for any Australian airport. Seattle-Tacoma International Airport (SEA-TAC) in the United States has carried out a comprehensive carbon footprinting exercise.[31] *Figure 22* summarises the key components of the SEA-TAC footprint – it can be seen that the airport company itself makes up a small proportion of aviation's carbon footprint. The footprint is dominated by en route aircraft. While this figure portrays the carbon footprint breakdown at one particular overseas airport, it is likely that this would not be significantly different to the major Australian airports with international traffic.

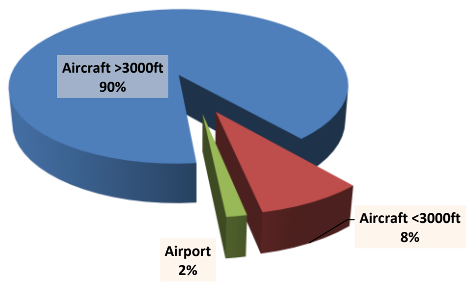


Figure 22: Airport company contribution to the CO_2 footprint

While it is difficult to find published carbon footprint reports for Australian airports, at the global level the airports' major representative group, Airports Council International (ACI), has developed an airport carbon accreditation scheme which incorporates detailed carbon footprinting.[32]

While the airport company carbon footprint contribution is a small component of the total footprint it cannot be ignored. Airport infrastructure can make an important contribution to the overall aviation carbon footprint. For example, if an airport is capacity constrained and the airport does not provide additional runway capacity an increase in the aviation CO_2 may well result. At the very least, delays can build up causing congestion and the holding of aircraft in the vicinity of the airport; a more problematic outcome can be the provision of overflow airport capacity which takes passengers to a less than optimally located alternative airport. Given this, it would appear fundamental that Airport Master Plans include detailed analyses of the CO_2 emissions generated by aircraft operations so that there is an understanding of the CO_2 implications of anticipated future growth. This would be entirely analogous to the requirements for Master Plans to carry out aircraft noise analyses – the airport companies do not make the noise but the nature of the airport infrastructure directly determines the aircraft noise exposure patterns.

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

[32] ACI Airport Carbon Accreditation: http://www.airportcarbonaccreditation.org/about.html

In a similar manner, it is self-evident that any Environmental Impact Statement (EIS) for the provision of additional airport infrastructure, such as the proposed construction of a new runway, needs to include detailed carbon footprint analyses for aircraft operations if an informed decision is to be made about the CO_2 impacts of proceeding, or not proceeding, with a proposed project.

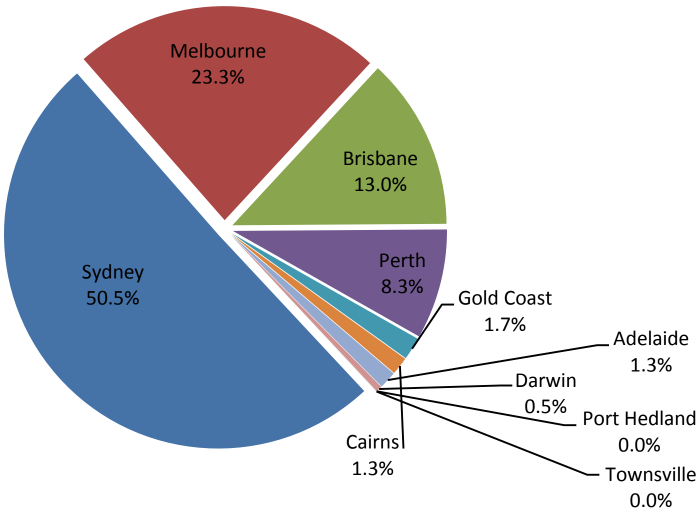
3.2 Airport Footprint Overview

Figure 23 is a summary graphic which shows a comparison of the carbon footprint of aircraft operations associated with Australia's State capital city and international gateway airports. The graphic includes the contribution from both domestic and international operations.

It can be seen that aircraft operations originating from four airports – Sydney, Melbourne, Brisbane and Perth - generate about 80% of the Australian aircraft operations carbon footprint. Sydney, Melbourne and Adelaide Airports dominate the aviation carbon footprints in their respective States while the footprint is more dispersed between airports in the other States/Territories.

An overview of domestic operations between the airports can be gathered from *Figure 9* which is discussed in Section 2.3.

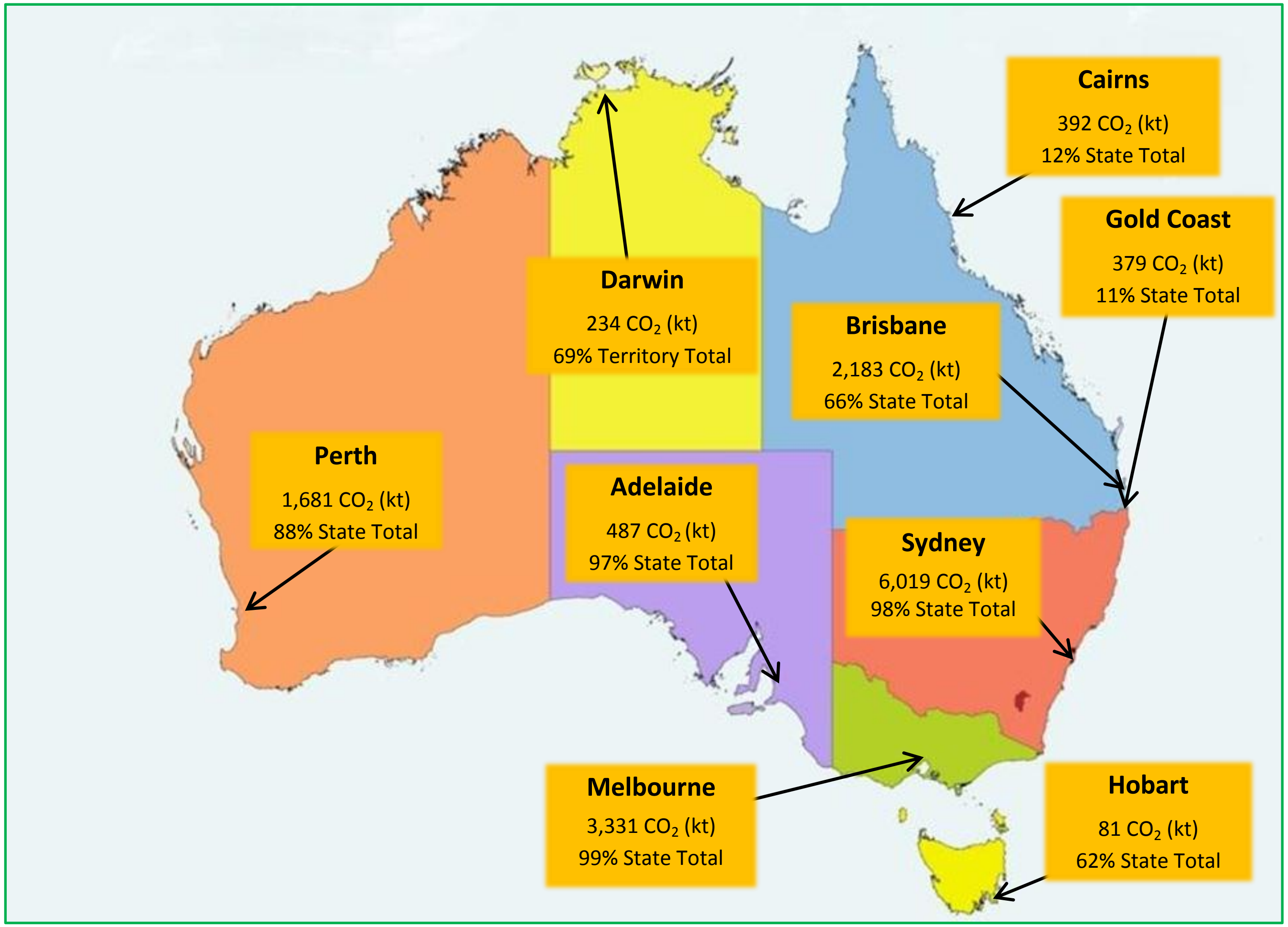
Figure 24 shows the distribution of the international operations carbon footprint between originating Australian airports. The table indicates that there were ten Australian airports with scheduled international departures in 2011. Over 50% of the footprint is generated by flights departing from Sydney Airport while about 95% of the footprint is generated by departures from four airports.



Airport	CO_2 (kt)
Sydney	4,680
Melbourne	2,162
Brisbane	1,205
Perth	771
Gold Coast	157
Cairns	124
Adelaide	122
Darwin	43
Port Hedland	2
Townsville	1
Total	**9,268**

Figure 24: Overview of international CO_2 footprint by airport

A disaggregated view of the airport contributions to the international carbon footprint for each of the seven regions used throughout this report is given in *Figure 25*. This gives an airport by airport break down of the information contained in *Figure 6* in the previous chapter. It can be seen that Sydney is the only airport that has operations to all seven regions and that it also makes the greatest contribution to the carbon footprint for all the regions. The regions within the Asia/Pacific region – N Asia, SE Asia and NZ/Pacific – have the largest diversity in originating Australian airports contributing to the carbon footprint.



Airport	CO_2 (kt)	CO_2/PAX (kg)
Sydney	6,019	320
Melbourne	3,331	245
Brisbane	2,183	211
Perth	1,681	288
Adelaide	487	141
Cairns	392	193
Gold Coast	379	162
Darwin	234	204
Hobart	81	99
Other Airports	1,072	94
TOTAL	**15,860**	**227**

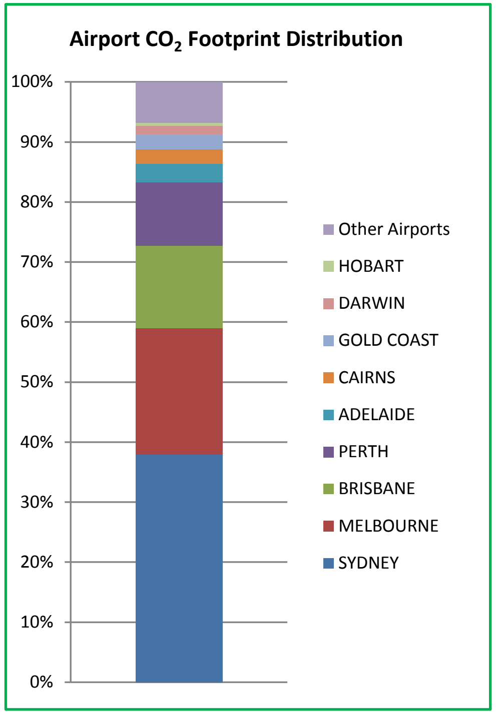


Figure 23: Contribution to Australia's aircraft operations CO_2 footprint by airport

This figure gives a breakdown of the CO_2 footprint resulting from aircraft departures from the capital city and key international airports. It can be seen that for NSW, Vic and SA the State aviation carbon footprint is dominated by departures from the capital city airport. This is less pronounced for the other States.

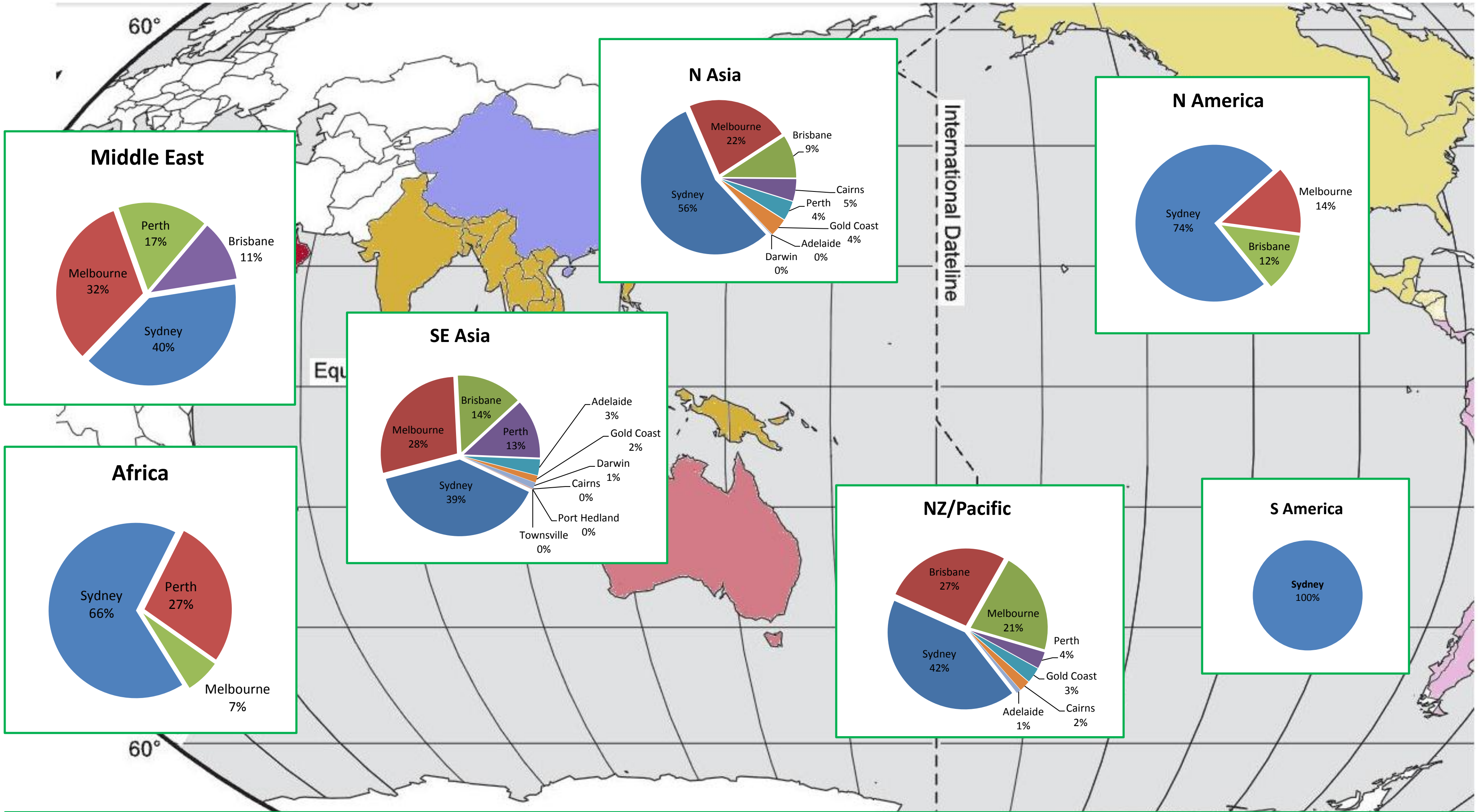


Figure 25: International CO_2 footprint by airport

This figure shows the international CO_2 footprint by region broken down by airport of origin. Operations from Sydney Airport are clearly the dominant CO_2 contributor for all regions. The three Asia/Pacific regions receive CO_2 contributions from a number of airports while the 'outer regions' footprint is solely associated with Sydney, Melbourne, Brisbane and Perth Airports.

Carbon Footprints for Individual Airports

This section contains a carbon footprint report for each of the main capital city airports. These reports examine the carbon footprint of the airports from a number of perspectives including CO_2 contribution by airline, route and aircraft type. In order to give an indication of the potential for modal change, the reports also give a breakdown of the footprint into short and long haul components.

To place the carbon footprint of the capital city airports in context, and to supplement the information in *Figure 24*, *Figure 26* gives an overview of the carbon footprint of the top 25 airports in Australia.

An alphabetical listing of the carbon footprint of all the airports contained in the operations dataset is contained in *Table A1* in the Appendix. This information is shown in graphical form in *Figure 27*. In the figure the airports have been grouped into five CO_2 footprint categories.

Airport	**CO_2 (kt)**	**CO_2/PAX (kg)**
Sydney	6,019	320
Melbourne	3,331	245
Brisbane	2,183	211
Perth	1,681	288
Adelaide	487	141
Cairns	392	193
Gold Coast	379	162
Darwin	234	204
Canberra	146	77
Townsville	95	110
Hobart	81	99
Karratha	60	139
Mackay	53	95
Alice Springs	52	161
Newcastle	50	91
Sunshine Coast	46	117
Broome	42	168
Launceston	42	82
Avalon	40	118
Port Hedland	37	139
Ayers Rock	35	180
Hamilton Island	30	131
Rockhampton	30	71
Mount Isa	20	126
Mt Newman	18	122
Other Airports	278	72
TOTAL	**15,860**	**227**

Figure 26: CO_2 footprint hierarchy by airport

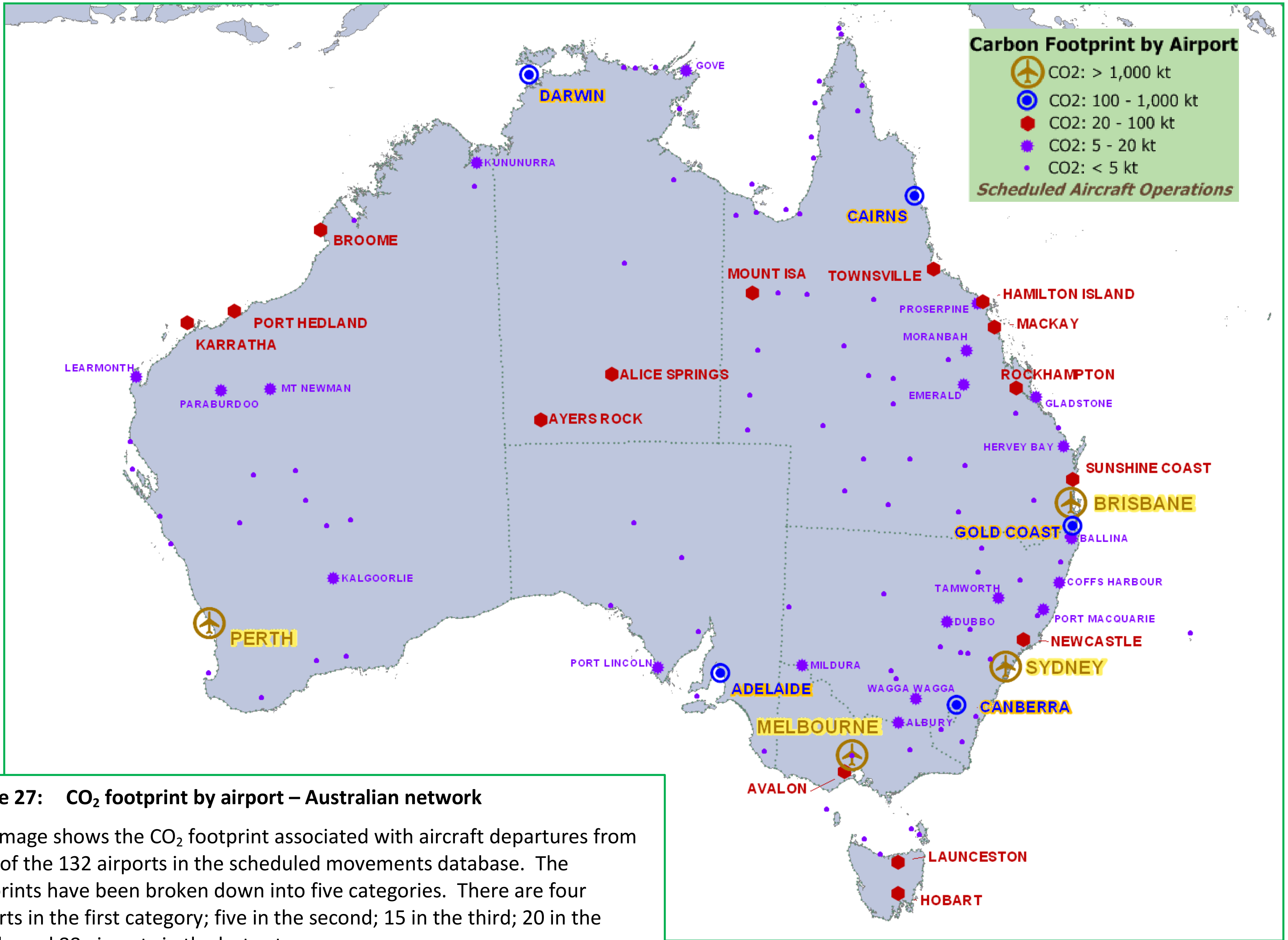


Figure 27: CO_2 footprint by airport – Australian network

This image shows the CO_2 footprint associated with aircraft departures from each of the 132 airports in the scheduled movements database. The footprints have been broken down into five categories. There are four airports in the first category; five in the second; 15 in the third; 20 in the fourth; and 88 airports in the last category.

Sydney Airport

As noted earlier, Sydney dominates the airport aircraft operations carbon footprint for Australia – about 40% of the Australian aviation carbon footprint is generated by aircraft departing from Sydney Airport.

Figure 28 shows the split between the three top level network components. The network split is heavily influenced by international aviation with about 80% of the footprint being associated with international operations.

Component	CO_2 (kt)	CO_2/PAX (kg)
International	4,680	695
Interstate	1,261	116
Intrastate	77	63
TOTAL	**6,019**	**320**

Figure 28: CO_2 footprint sector components at Sydney Airport

Figure 29 provides a dashboard style overview of the components of the carbon footprint of flights departing from Sydney Airport. Key observations about the information in the figures include:

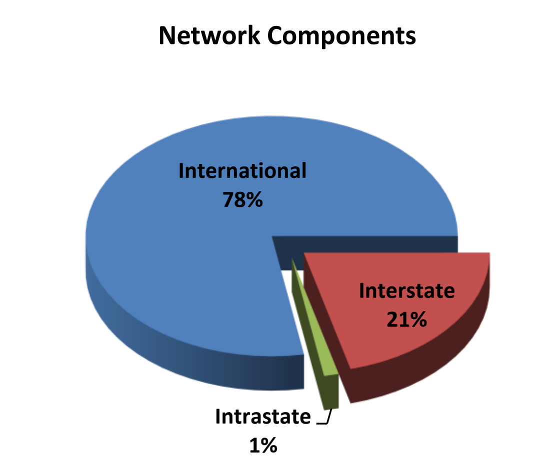
International CO_2 *Footprint* – SE Asia, the US and N Asia provide contributions of similar magnitude – together these three regions make up about 80% of the Airport's international carbon footprint.

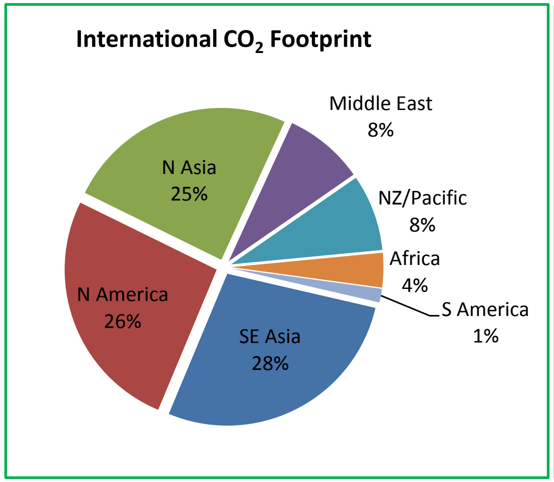
Aircraft Types – the B747 is the aircraft type which makes the largest contribution to the carbon footprint; this contribution derives almost exclusively from aircraft operations on international routes. Two engine wide bodied aircraft make a significant contribution to the international footprint – in total the contribution to the international CO_2 footprint by two and four engine aircraft is broadly similar. The CO_2 contribution from narrow bodied aircraft is primarily associated with the domestic carbon (about 80% of the narrow bodied footprint), however, these aircraft types also contribute to the international footprint through flights associated with the NZ/Pacific region. The top 10 aircraft types at the airport which are shown in the graph make up about 99% of the total carbon footprint for the airport.

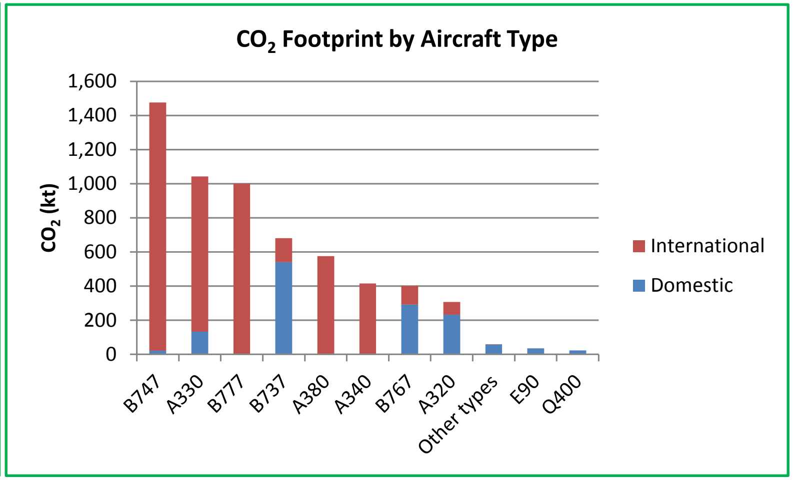
Airlines – the table shows the airline carbon footprint hierarchy for the airport - the data includes both domestic and international operations. It can be seen that the top three airlines are Australian airlines – Qantas, Virgin and Jetstar; these provide both domestic and international services. Qantas, which has its base at Sydney Airport, has a contribution which is about four times that of the other two airlines. A breakdown of the airlines' contribution to Australia's aviation carbon footprint is provided in Chapter 4. The top 10 airlines operating at the airport generate about 75% of the total carbon footprint for the airport.

Modal shift – CO_2 generated by short haul movements (less than 500 km) comprises 1.5% of the airport's carbon footprint despite the fact that these operations make up about 25% of the movements at the airport. On the face of it, the high proportion of short haul operations would indicate a potential for some shift to other transport modes. The Sydney-Canberra city pair is the main short haul route with respect to CO_2 generation for Sydney Airport (see *Figure 16*) – this route is already open to competition from other modes of transport. At the present time, travellers on this route essentially have a choice between three main modes of transport – aviation; bus; and car – and commonly select a different option depending on the travel circumstances. In recent times there has been debate in the media about introducing a high speed train between Canberra and Sydney.

Sydney Airport CO_2 Footprint Overview







Airline CO_2 Footprint Hierarchy		
Airline	**CO_2 (kt)**	**% of Footprint**
Qantas	1,975	32.8
Virgin Australia	481	8.0
Jetstar	333	5.5
United Airlines	331	5.5
Emirates	313	5.2
Singapore Airlines	275	4.6
Cathay Pacific Airways	235	3.9
Etihad	164	2.7
V Australia	155	2.6
British Airways	152	2.5
Thai Airways International	146	2.4
MAS - Malaysian Airlines System	142	2.4
China Southern Airlines	128	2.1
Air Canada	118	2.0
Delta Airlines	113	1.9
Other Operators	957	15.9
TOTAL	**6,019**	**100.0**

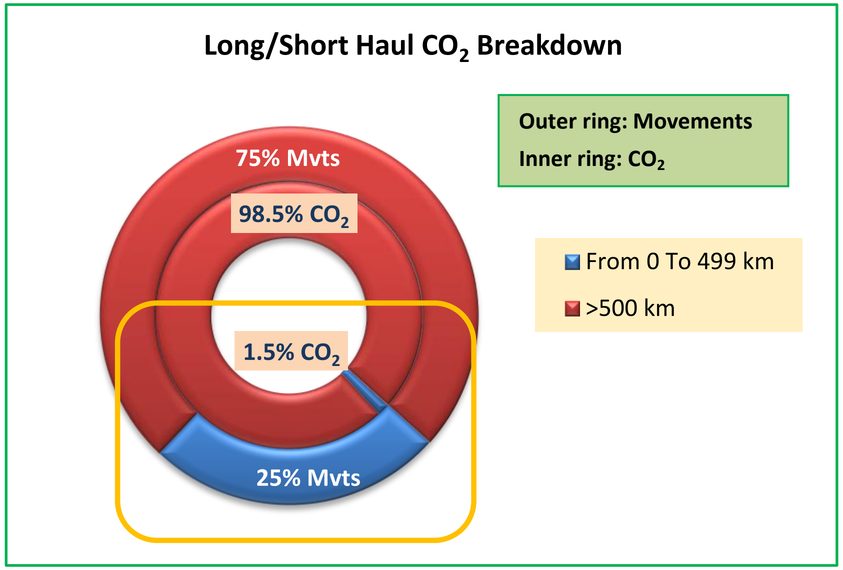


Figure 29: Example CO_2 footprint metrics for Sydney Airport

The metrics are discussed briefly in the text. Ideally this dashboard would contain time series data to show temporal trends.

All the metrics relate solely to the CO_2 associated with departing aircraft.

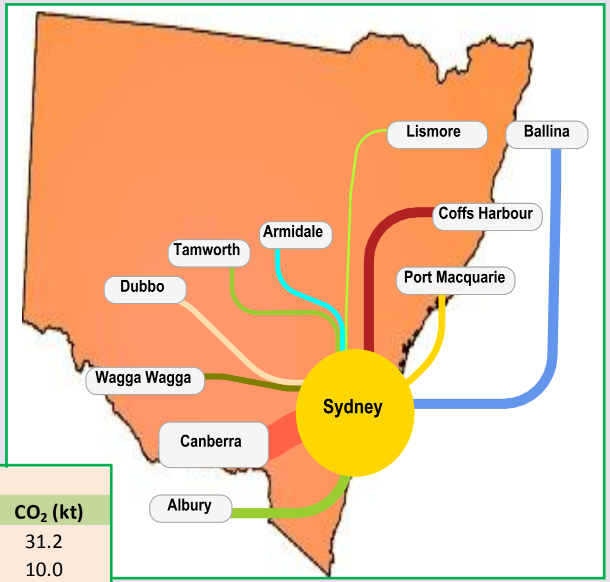
Network Components - *Figure 30* shows the top 15 destinations for departures from Sydney Airport for each of the three network components – international, interstate and intrastate. It is interesting to note the large differences between the carbon distributions. The carbon footprint for domestic operations originating in Sydney is associated with a much smaller number of airports (about 75% of the footprint is associated with flights to the top three airports) compared to international (where flights to the top three airports comprise about 35% of the footprint).

The intrastate footprint is dominated by traffic on the Sydney-Canberra route. Throughout the rest of the report all scheduled flights associated with Canberra are treated as interstate flights. However, for this particular figure Canberra has been treated as being within NSW to allow a comparison to be made between the carbon footprint of flights from Sydney Airport to Canberra and the footprint for flights from Sydney Airport to the regional centres within the State. The inclusion of Canberra in the intrastate category in *Figure 30* leads to an inconsistency with the CO_2 value for intrastate shown in *Figure 28*.

Sydney Airport CO_2 Footprint Overview

International	
Destination Airport	**CO_2 (kt)**
Los Angeles	721
Singagpore	491
Hong Kong	425
Bangkok	400
Abu Dhabi	206
Dubai	193
San Fransisco	192
Auckland	181
Seoul	175
Tokyo	161
Shanghai	154
Johnannesburg	147
Kuala Lumpur	142
Guangzhou	128
Hononlulu	118
Other Destinations	847
TOTAL	**4,680**

Interstate	
Destination Airport	**CO_2 (kt)**
Melbourne	326
Perth	269
Brisbane	199
Adelaide	97
Gold Coast	84
Cairns	76
Darwin	39
Canberra	31
Hobart	24
Sunshine Coast	22
Avalon	18
Ayers Rock	16
Hamilton Island	13
Townsville	13
Launceston	11
Other Desinations	22
TOTAL	**1,261**



Intrastate	
Destination Airport	**CO_2 (kt)**
Canberra	31.2
Ballina	10.0
Albury	9.9
Coffs Harbour	9.9
Port Macquarie	6.7
Wagga Wagga	5.9
Dubbo	5.7
Armidale	4.8
Tamworth	4.5
Lismore	2.4
Lord Howe Island	1.8
Norfolk Island	1.7
Newcastle	1.6
Griffith	1.3
Mooree	1.2
Narrabri	1.2
Other Destinations	8.3
TOTAL	**108.0**

Figure 30: Breakdown of network component operations for Sydney Airport

The metrics are discussed briefly in the text. Ideally this dashboard would contain time series data to show temporal trends. All the metrics relate solely to the CO_2 associated with departing aircraft.

Melbourne Airport

Aircraft operations departing from Melbourne Airport generate the second largest carbon footprint for Australian airports. In line with Sydney the footprint is dominated by international operations. Melbourne is unusual amongst the major airports in that it has virtually no intrastate movements (*Figure 31*).

Component	CO_2 (kt)	CO_2/PAX (kg)
International	2,162	652
Interstate	1,162	114
Intrastate	7	61
TOTAL	**3,331**	**245**

Figure 31: CO_2 footprint sector components at Melbourne Airport

Figure 32 provides a dashboard style overview of the key features of the carbon footprint of flights departing from Melbourne Airport. Key observations about the information in the figure include:

International CO_2 *Footprint* – flights to SE Asia dominate the carbon footprint comprising about 45% of the total international footprint. Four other regions – N Asia, the Middle East, N America and NZ/Pacific – also provide significant contributions to the footprint.

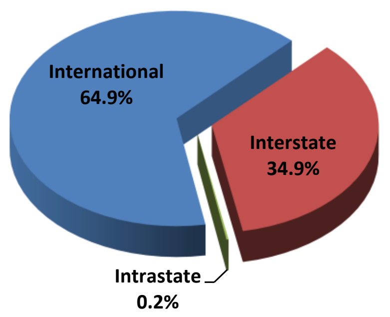
Aircraft Types – in contrast to Sydney the B747 makes a relatively small contribution to the Airport's carbon footprint; two engine wide bodied aircraft make the largest contribution to the international footprint. In total the contribution to the international CO_2 footprint by two engined wide bodied aircraft (B777 & A330) is approximately twice that of four engine aircraft.

Airlines – the table shows the carbon footprint hierarchy for the airport - the data includes both domestic and international operations. In line with Sydney the top three airlines are Australian airlines – Qantas, Virgin and Jetstar; these all provide both domestic and international services. While Qantas is still the dominant player its dominance is much less pronounced than at Sydney. The top 10 airlines operating at the airport generate about 80% of the total carbon footprint for the airport.

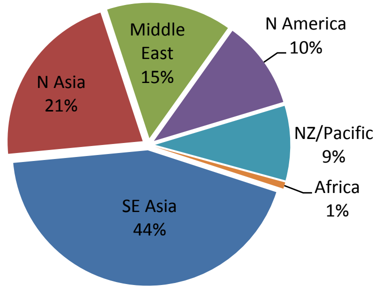
Modal shift – CO_2 generated by short haul movements (less than 500 km) comprises about 3% of the airport's carbon footprint and about 20% of the movements at the airport. On the face of it there would appear to be a very low potential for modal switch to non-aviation modes. Approximately 40% of the short-haul footprint relates to operations to Tasmania, while other airports which make up a major part of the short-haul footprint such as Canberra and Mildura, are closer than 500 km to Melbourne by air but are somewhat more distant by road. Victoria is characterised by having only one scheduled intrastate aviation service – the route between Melbourne and Mildura. Major regional centres in Victoria such as Bendigo and Ballarat, which are about 100 to 150 km from Melbourne by road, only have land based public transport links to the State capital.

Melbourne Airport CO_2 Footprint Overview

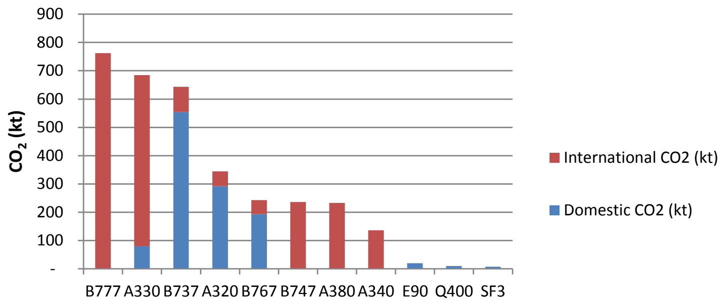
Network Components



International CO_2 Footprint



CO_2 Footprint by Aircraft Type



Airline CO_2 Footprint Hierarchy		
Airline	**CO_2 (kt)**	**% of Footprint**
Qantas	890.2	26.7
Virgin Australia	401.0	12.0
Jetstar	328.0	9.8
Emirates	247.8	7.4
Singapore Airlines	199.7	6.0
Cathay Pacific Airways	177.6	5.3
Thai Airways International	132.8	4.0
Qatar Airways	112.5	3.4
MAS - Malaysian Airlines System	111.5	3.3
Etihad	100.9	3.0
Tiger Airways	79.0	2.4
China Southern Airlines	68.9	2.1
Air Asia X	60.9	1.8
Air New Zealand	60.7	1.8
V Australia	59.9	1.8
Other Operators	299.8	9.0
TOTAL	**3,331.1**	**100.0**

Long/Short Haul CO_2 Breakdown

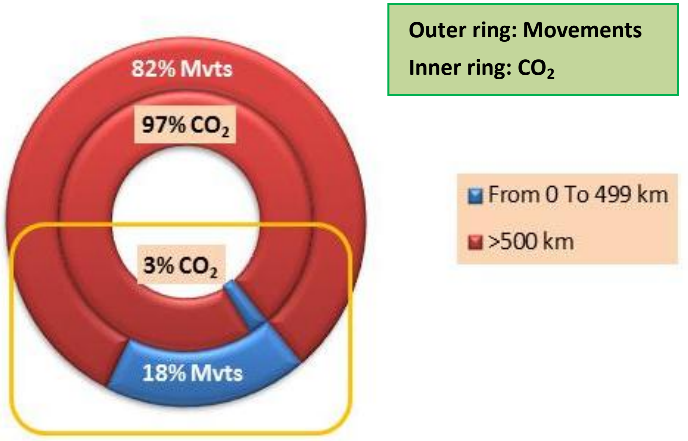


Figure 32: Example CO_2 footprint metrics for Melbourne Airports

The metrics are discussed briefly in the text. Ideally this dashboard would contain time series data to show temporal trends.

All the metrics relate solely to the CO_2 associated with departing aircraft.

Network Components - Figure 33 shows the carbon footprint for the top 15 destinations for departures from Melbourne Airport for international, interstate and intrastate operations. The bias toward international is much less marked than at Sydney Airport. As indicated above, there is only one scheduled intrastate service from Melbourne Airport.

International	
Destination Airport	CO_2 (kt)
Singapore	380
Hong Kong	270
Kuala Lumpur	230
Los Angeles	225
Bangkok	158
Auckland	117
Qatar	112
Dubai	109
Abu Dhabi	101
Shanghai	88
Guangzhou	69
Jakarta	53
Ho Chi Minh City	46
Seoul	29
Christchurch	26
Other Destinations	148
TOTAL	**1,782**

Interstate	
Destination Airport	CO_2 (kt)
Sydney	325
Perth	208
Brisbane	188
Gold Coast	88
Adelaide	82
Cairns	43
Canberra	41
Hobart	41
Darwin	32
Launceston	25
Sunshine Coast	23
Newcastle	20
Alice Springs	10
Hamilton Island	7
Townsville	5
Other Destinations	26
TOTAL	**1,162**

Intrastate	
Destination Airport	CO_2 (kt)
Mildura	6.8
TOTAL	**6.8**

Figure 33: Detailed breakdown of CO_2 footprint sector components

Brisbane Airport

Figure 34 shows the split between the network CO_2 components for Brisbane Airport. Compared to Sydney and Melbourne, the international component is reduced while the intrastate component is significantly increased. It was noted in Section 2.4 that Queensland is the State with the largest intrastate carbon footprint.

Component	CO_2 (kt)	CO_2/PAX (kg)
International	1,205	509
Interstate	717	132
Intrastate	261	104
TOTAL	**2,183**	**211**

Figure 34: CO_2 footprint sector components at Brisbane Airport

Figure 35 provides a dashboard style overview of the key components of the carbon footprint of flights departing from Brisbane Airport. Key observations about the information in the figure include:

International CO_2 *Footprint* – flights to SE Asia dominate the carbon footprint, while the contribution to the total carbon footprint from three other regions – NZ/Pacific, N Asia, and N America – are of similar magnitude.

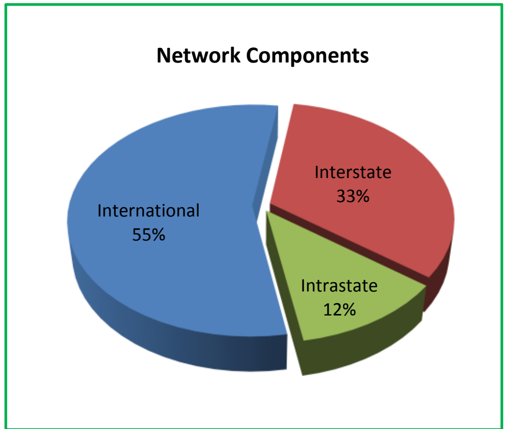
Aircraft Types – in line with Melbourne the B747 is a lesser contributor to the international carbon footprint which is dominated by two engine wide bodied aircraft (the A330 and the B777). The B737 also makes a significant contribution to the international CO_2 footprint through operations to the NZ/Pacific region

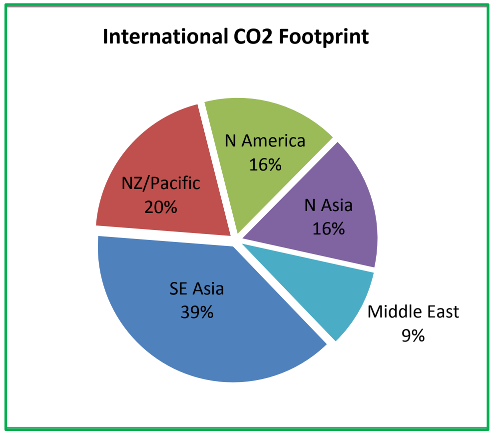
Airlines – as with the other airports Qantas dominates the carbon footprint; Virgin's contribution is a significantly higher proportion of the footprint compared to Sydney reflecting the fact that Virgin is based in Brisbane. Jetstar has a relatively small presence in Brisbane. The top 10 airlines operating at the airport generate about 85% of the total carbon footprint for the airport.

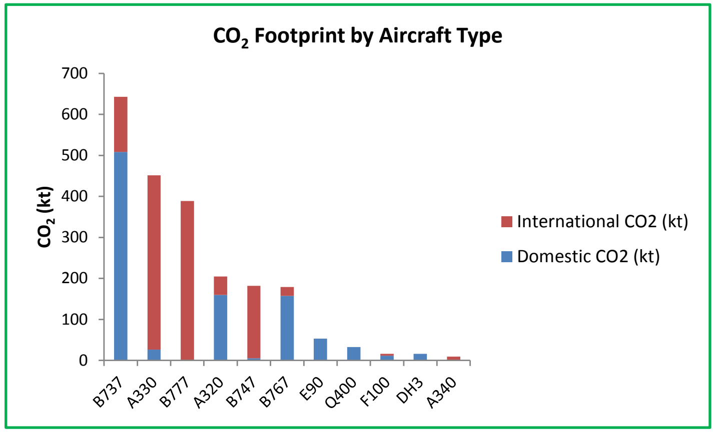
Modal shift – the short-haul carbon footprint is significantly smaller at Brisbane than at Sydney or Melbourne both in terms of the proportion of the airport's total aircraft operations CO_2 footprint and in terms of the proportion of movements. The short-haul footprint is made up of operations to regional towns in SE Qld and in northern NSW. Future improvements in road and rail infrastructure may provide an incentive for some air journeys to be replaced by land travel, however, given the already small size of the short-haul footprint any shift to other transport modes is not likely to be of any carbon significance.

Network Components - Figure 36 shows the top 15 destinations for departures from Brisbane Airport for each of the three network components – international, interstate and intrastate. While the interstate footprint has a similar distribution to that of Melbourne and Sydney with a focus on carbon associated with flights to the other three of 'the big four' airports, its international and intrastate are different. In keeping with Melbourne, Singapore is the prime contributor to the international carbon footprint but the next two international airports are long haul to the 'outer' destinations – Los Angeles and Dubai. The total Melbourne intrastate footprint of 6.8 kt of CO_2 would be the 10^{th} ranked route in the Brisbane intrastate CO_2 hierarchy.

Brisbane Airport CO_2 Footprint Overview







Airline CO_2 Footprint Hierarchy		
Airline	**CO_2 (kt)**	**% of Footprint**
Qantas	743.1	34.0
Virgin Australia	414.2	19.0
Emirates	191.3	8.8
Singapore Airlines	138.3	6.3
Jetstar	125.8	5.8
V Australia	62.1	2.8
Cathay Pacific Airways	60.9	2.8
Thai Airways International	60.4	2.8
Air New Zealand	57.6	2.6
Korean Air	41.1	1.9
MAS - Malaysian Airlines System	37.0	1.7
Royal Brunei Airlines	35.1	1.6
China Airlines	30.3	1.4
China Southern Airlines	27.7	1.3
Air Australia	26.1	1.2
Other Operators	131.6	6.0
TOTAL	**2,182.7**	**100.0**

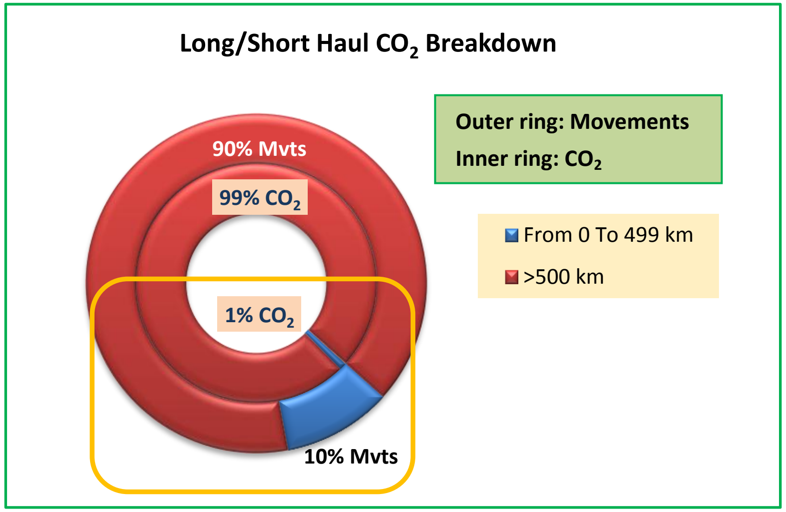


Figure 35: Example CO_2 footprint metrics for Brisbane Airport

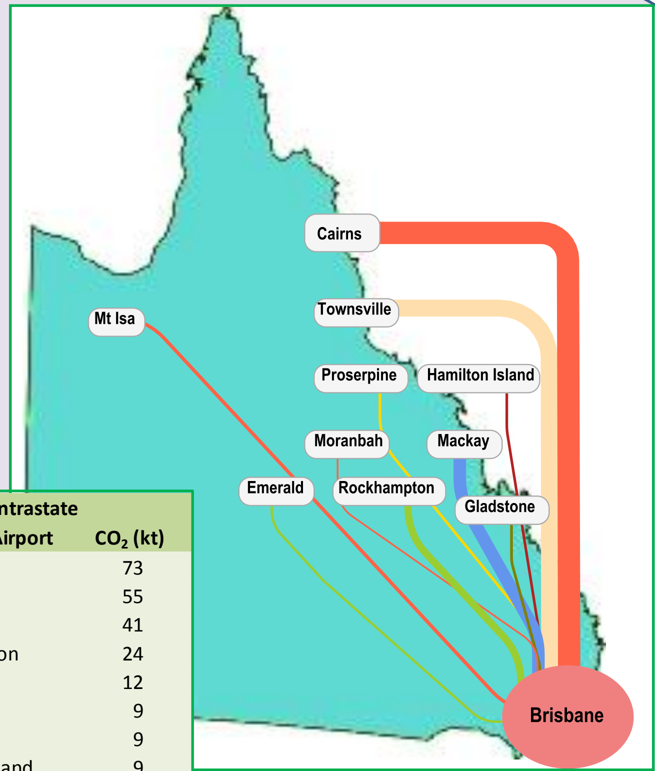
The metrics are discussed briefly in the text. Ideally this dashboard would contain time series data to show temporal trends.

All the metrics relate solely to the CO_2 associated with departing aircraft.

Brisbane Airport CO_2 Footprint Overview

International	
Destination Airport	**CO_2 (kt)**
Singapore	278
Los Angeles	197
Dubai	113
Auckland	97
Hong Kong	87
Bangkok	60
Seoul	41
Kuala Lumpur	37
Taipei	36
Brunei	35
Port Moresby	31
Denpasar	30
Christchurch	30
Guangzhou	28
Nadi	25
Other Destinations	80
TOTAL	**1,205**

Interstate	
Destination Airport	**CO_2 (kt)**
Sydney	205
Melbourne	186
Perth	133
Adelaide	48
Darwin	42
Canberra	36
Newcastle	23
Avalon	12
Hobart	8
Launceston	7
Karratha	4
Norfolk Island	3
Alice Springs	2
Broome	2
Port Hedland	1
Other Destinations	3
TOTAL	**717**



Intrastate	
Destination Airport	**CO_2 (kt)**
Cairns	73
Townsville	55
Mackay	41
Rockhampton	24
Mount Isa	12
Proserpine	9
Gladstone	9
Hamilton Island	9
Emerald	8
Moranbah	6
Roma	4
Bundaberg	4
Hervey Bay	2
Biloela	1
Barcaldine	1
Other Destinations	3
TOTAL	**261**

Figure 36: Breakdown of network component operations for Brisbane Airport

The metrics are discussed briefly in the text. Ideally this dashboard would contain time series data to show temporal trends.

All the metrics relate solely to the CO_2 associated with departing aircraft.

Perth Airport

Perth Airport has the fourth largest aircraft operations carbon footprint. *Figure 37* shows the split between the network components. In contrast to Sydney, Melbourne and Brisbane Airports, its international component is less than 50% of the total. This is largely driven by its relatively large interstate and intrastate components arising from the remote location of Perth from the other Australian capital cities and the key industrial locations in Western Australia (the Pilbara region).

Component	CO_2 (kt)	CO_2/PAX (kg)
International	771	455
Interstate	728	271
Intrastate	182	125
TOTAL	**1,681**	**288**

Figure 37: CO_2 footprint sector components at Perth Airport

Figure 38 provides a dashboard style overview of the key components of the carbon footprint of flights departing from Perth Airport. Key observations about the information in the figure include:

International CO_2 *Footprint* – the distribution of its international CO_2 footprint is consistent with its location in the SW of Australia – SE Asia dominates the carbon footprint while the Middle East, N Asia and Africa also provide significant contributions.

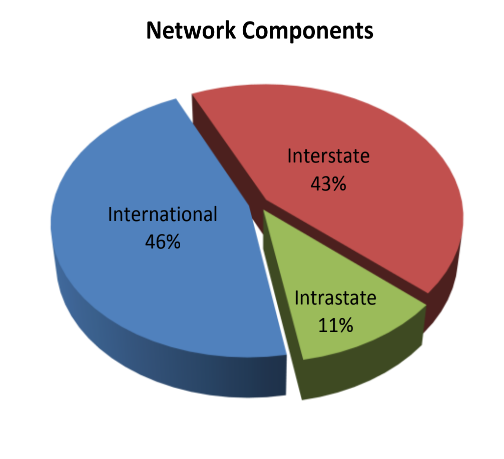
Aircraft Types – as with Melbourne and Brisbane two engine wide bodied aircraft (the A330 and the B777) dominate the international footprint. Wide bodied two engine aircraft (the A330 and the B767) are also prominent aircraft types for the domestic footprint. It is interesting to note that the B747 only makes a relatively minor CO_2 contribution and this is for domestic operations.

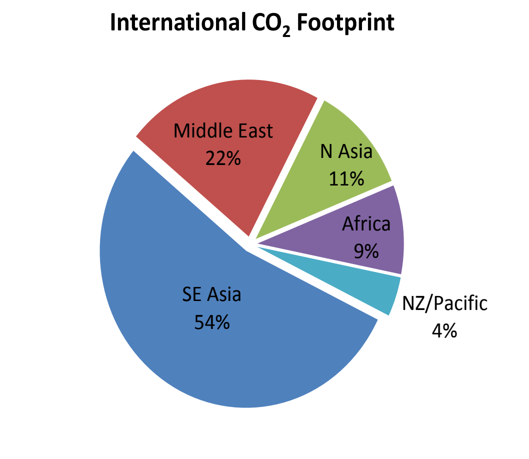
Airlines – Qantas has a very dominant presence generating around 40% of the carbon footprint; as with Brisbane, Jetstar has a relatively minor presence compared to its contribution at Sydney and Melbourne. There are relatively few operators at Perth Airport and it is interesting to note that an intrastate operator – Skywest - is in the top 15 operators. The top 10 airlines operating at the airport generate about 90% of the total carbon footprint for the airport.

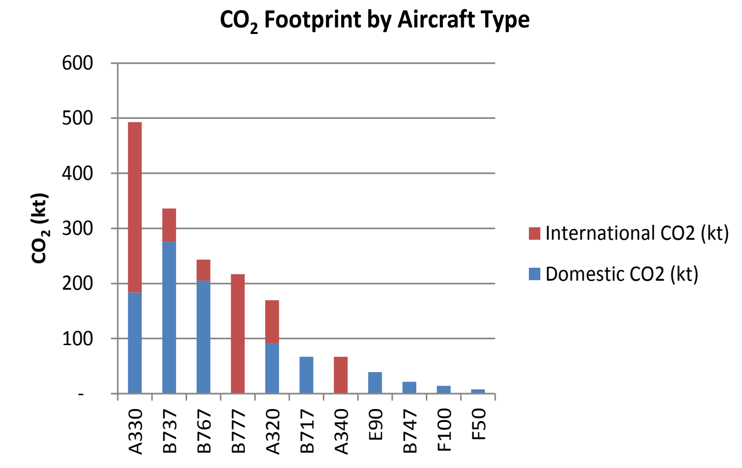
Modal shift – compared to the other airports Perth has a very minor CO_2 contribution from short-haul operations (0.4% of the CO_2 and 6% of the movements). There would appear to be no meaningful potential for moving aviation passengers to other transport modes.

Network Components – Figure 39 shows the top 15 destinations for departures from Perth Airport for each of the three network components – international, interstate and intrastate. The carbon footprint for operations to Singapore is very similar to that for operations to Dubai. Approximately two thirds of the scheduled intrastate carbon footprint is generated by flights to the Pilbara. As indicated earlier, given the now significant level of charter traffic to this region, the understatement of this footprint may be relatively large.

Perth Airport CO_2 Footprint Overview







Airline CO₂ Footprint Hierarchy		
Airline	**CO_2 (kt)**	**% of Footprint**
Qantas	665.8	39.6
Virgin Australia	238.1	14.2
Emirates	167.8	10.0
Jetstar	84.7	5.0
Singapore Airlines	82.3	4.9
South African Airways - SAA	63.5	3.8
MAS - Malaysian Airlines System	59.5	3.5
Cathay Pacific Airways	56.9	3.4
Thai Airways International	39.6	2.4
Air Asia X	34.4	2.0
Indonesia AirAsia	32.0	1.9
Air New Zealand	31.5	1.9
Garuda Indonesia	30.1	1.8
Tiger Airways	28.9	1.7
Skywest	21.9	1.3
Other Operators	44.0	2.6
TOTAL	**1,680.9**	**100.0**

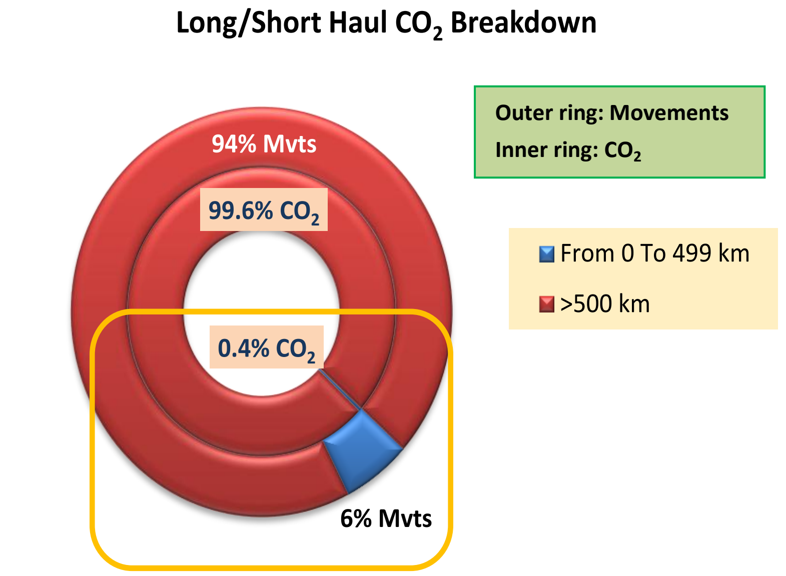


Figure 38: Example CO_2 footprint metrics for Perth Airport

The metrics are discussed briefly in the text. Ideally this dashboard would contain time series data to show temporal trends.

All the metrics relate solely to the CO_2 associated with departing aircraft.

Perth Airport CO_2 Footprint Overview

International

Destination Airport	CO_2 (kt)
Singapore	171
Dubai	168
Denpasar	88
Kuala Lumpur	87
Hong Kong	76
Johannesburg	63
Auckland	31
Phuket	30
Bangkok	20
Brunei	9
Mauritius	7
Kota Kinabalu	7
Tokyo	7
Jakarta	3
Guangzhou	3
TOTAL	771

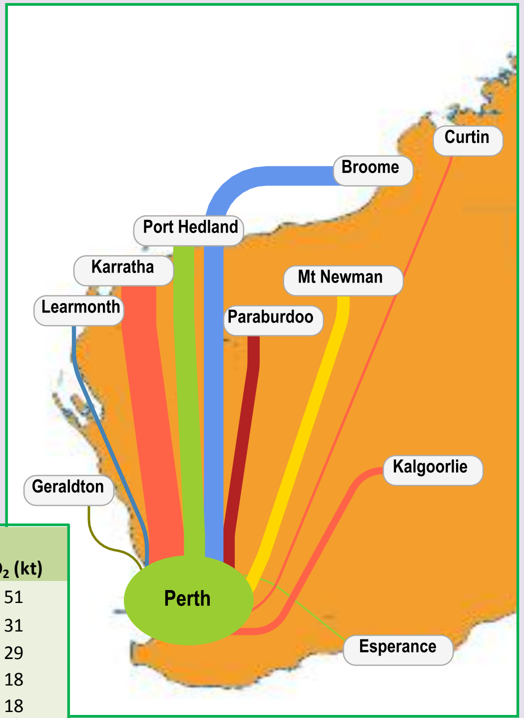
Interstate

Destination Airport	CO_2 (kt)
Sydney	271
Melbourne	208
Brisbane	132
Adelaide	53
Darwin	20
Canberra	12
Cairns	7
Alice Springs	7
Gold Coast	7
Christmas Island	4
Avalon	4
Ayers Rock	3
Cocos Islands	1
Launceston	0
TOTAL	728

Figure 39: Breakdown of network component operations for Perth Airport

The metrics are discussed briefly in the text. Ideally this dashboard would contain time series data to show temporal trends.

All the metrics relate solely to the CO_2 associated with departing aircraft.



Intrastate

Destination Airport	CO_2 (kt)
Karratha	51
Port Hedland	31
Broome	29
Mt Newman	18
Paraburdoo	18
Kalgoorlie	11
Learmonth	6
Curtin	4
Geraldton	4
Esperance	3
Kununurra	2
Albany	2
Carnarvon	1
Leonora	1
Wiluna	1
Other Destinations	2
TOTAL	180

Adelaide Airport

Figure 40 shows the split between the three high level network components for Adelaide Airport. International operations make a relatively minor contribution to the footprint compared to the other airports. While the contribution by intrastate is small in absolute terms, operations by these services comprise 23% of the movements at the airport.

Component	CO_2 (kt)	CO_2/PAX (kg)
International	122	483
Interstate	352	122
Intrastate	13	44
TOTAL	**487**	**141**

Figure 40: CO_2 footprint sector components at Adelaide Airport

Figure 41 provides a dashboard style overview of the key components of the carbon footprint of flights departing from Adelaide Airport.

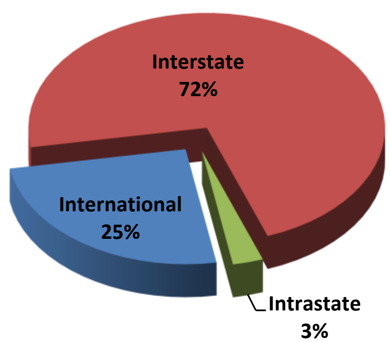
International CO_2 Footprint – this footprint is very heavily associated with operations to SE Asia; there are only two other contributors – NZ/Pacific and N Asia – and these make minor contributions.

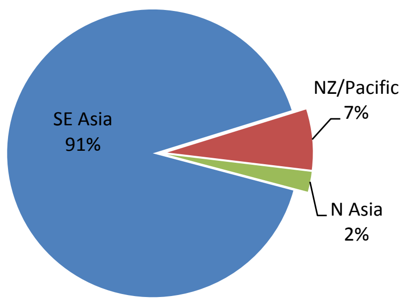
Aircraft Types – given its role primarily as a domestic airport, the footprint is dominated by the B737; consistent with other airports the A330 and the B777 dominate the international footprint.

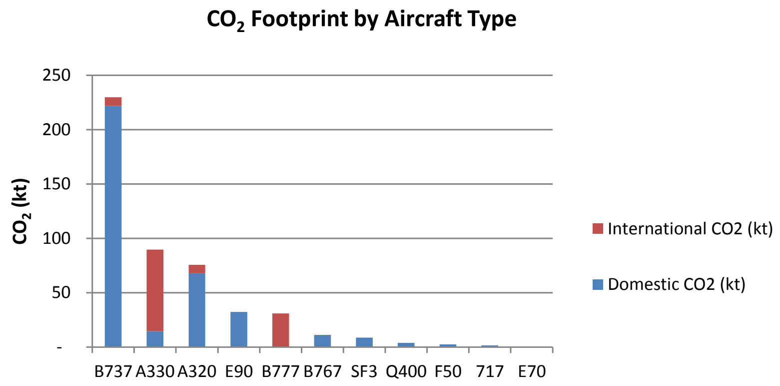
Airlines – Qantas is again the dominant player generating about 40% of the airport's aircraft operations carbon footprint. The database only contains ten operators for the airport.

Modal shift – on the face of it there would appear to be a high potential for modal shift with about 23% of the operations servicing airports within a distance of 500 km. However, any modal shift would have little impact on the airport's total aircraft operations CO_2 footprint since in total short-haul operations contribute about 2% of the airport's aircraft operations carbon footprint. As noted earlier, the geography of South Australia also provides some interesting modal shift challenges. For example, by air the distance between Adelaide and Port Lincoln is about 250 km with a journey time of about 45 min; by road the distance is considerably greater, about 650 km, since the road has to go around Spencer Gulf.

Adelaide Airport CO_2 Footprint Overview







Airline CO_2 Footprint Hierarchy		
Airline	**CO_2 (kt)**	**% of Footprint**
Qantas	198.9	40.8
Virgin Australia	103.4	21.2
Jetstar	57.4	11.8
Singapore Airlines	44.7	9.2
MAS - Malaysian Airlines System	39.7	8.1
Cathay Pacific Airways	15.5	3.2
Tiger Airways	10.4	2.1
Regional Express	8.9	1.8
Air New Zealand	8.3	1.7
China Southern Airlines	0.2	0.0
TOTAL	**487.4**	**100.0**

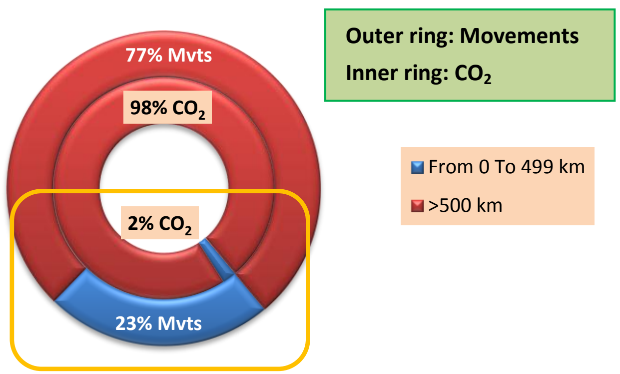


Figure 41: Example CO_2 footprint metrics for Adelaide Airport

The metrics are discussed briefly in the text. Ideally this dashboard would contain time series data to show temporal trends.

All the metrics relate solely to the CO_2 associated with departing aircraft.

Network Components - Figure 42 shows the top destinations for departures from Adelaide Airport for each of the three network components – international, interstate and intrastate. The international footprint is made up by CO_2 from six routes while there are seven intrastate routes. The international footprint is primarily associated with operations to two airports (these operations make up 85% of the footprint). The footprint is dominated by interstate operations – operations to the 'big four' airports (Sydney, Melbourne, Brisbane and Perth) make up about 85% of the footprint.

International

Destination Airport	CO_2 (kt)
Singapore	63.4
Kuala Lumpur	39.7
Auckland	8.3
Denpasar	8.1
Hong Kong	2.6
Guangzhou	0.2
TOTAL	**122.2**

Interstate

Destination Airport	CO_2 (kt)
Sydney	98.0
Melbourne	95.0
Perth	52.4
Brisbane	48.3
Darwin	18.8
Gold Coast	12.0
Canberra	10.4
Alice Springs	6.1
Cairns	5.4
Avalon	1.8
Kalgoorlie	1.7
Hamilton Island	1.0
Broome	0.9
TOTAL	**351.7**

Intrastate

Destination Airport	CO_2 (kt)
Port Lincoln	5.4
Olympic Dam	2.7
Mount Gambier	1.5
Whyalla	1.4
Ceduna	1.0
Kingscote	0.7
Coober Pedy	0.7
TOTAL	**13.5**

Figure 42: Detailed breakdown of CO_2 footprint sector components

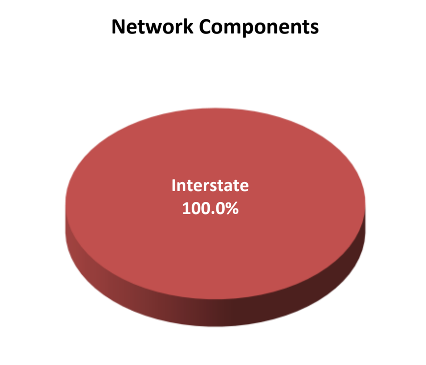
Hobart Airport

Figure 43 shows the breakdown between the three network components for Hobart Airport. It is interesting to note that in 2011 there were no scheduled international or intrastate operations.

Figure 44 provides a dashboard style overview of the key components of the carbon footprint of flights departing from Hobart Airport.

Component	CO_2 (kt)	CO_2/PAX (kg)
International	0	0
Interstate	81	99
Intrastate	0	0
TOTAL	**81**	**99**

Figure 43: CO_2 footprint sector components at Hobart Airport



Airline	CO_2 (kt)	% of Footprint
Jetstar	33	41
Virgin Australia	32	40
Qantas	13	16
Tiger Airways	3	3
TOTAL	**81**	**100**

Interstate

Destination Airport	CO_2 (kt)
Melbourne	40
Sydney	24
Brisbane	8
Gold Coast	6
Canberra	2
TOTAL	**81**

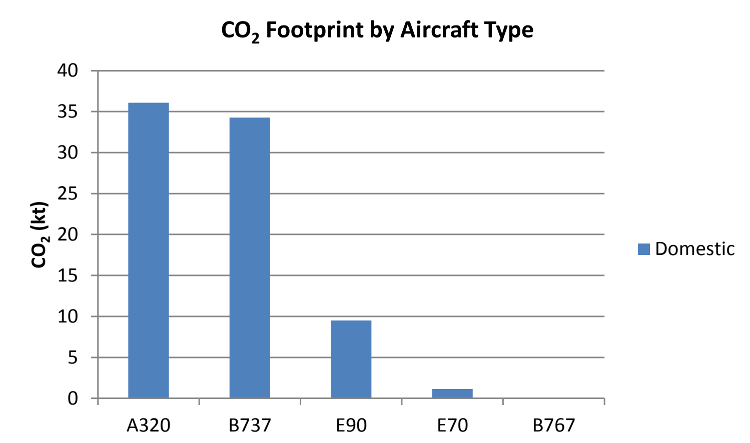


Figure 44: Detailed breakdown of CO_2 footprint sector components

Key observations about the information in the figure include:

Aircraft Types – consistent with being solely an interstate airport the carbon footprint is almost totally generated by narrow bodied two engine aircraft (principally the A320 and B737).

Airlines – this is the only capital city airport where Qantas makes a minor contribution to the carbon footprint – Jetstar and Virgin have similar contributions and between them generate about 80% of the airport' aircraft operations carbon footprint.

Modal shift – there are no short-haul operations from the airport and therefore modal shift is not a realistic option. The road links within Tasmania provide a convenient means for travelling around the island.

Network Components – Hobart Airport serves only five destinations. Almost half of the CO_2 footprint is generated by flights to Melbourne.

Chapter 4

The Airlines

4.1 Introduction

This Chapter examines the carbon footprint of Australian aircraft operations from the perspective of the airlines. In order to aid comprehension the main focus of the chapter is on the three major Australian operators – Qantas, Virgin and Jetstar – which collectively generate approximately 93% of Australia's domestic aircraft operations carbon footprint.

As indicated in Section 2.5, major airlines around the world are now publishing information on their total carbon footprints and on their carbon performance. Both Qantas and Virgin have published useful aggregated CO_2 performance data in their annual reports.[33,34] Aggregated carbon footprint data for the domestic operations of these airlines has also been published under the National Greenhouse and Energy Reporting System (NGERS).[35] This published information provides useful validation data and is discussed in Chapter 6.

The structure of this chapter is similar to the previous chapter and presents a disaggregated picture of the airlines' carbon footprint at both the international and domestic levels.

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.

4.2 Overview

International

Figure 45 provides a similar carbon picture for international operations to *Figure 25* in the previous chapter. The earlier figure examined the international footprint from the perspective of the airport while this figure breaks down the footprint for each region by airline. It can be seen that for most of the regions, but particularly the three Asia/Pacific regions, a number of airlines contribute to the carbon footprint. While Qantas is the dominant contributor to the footprint for services to Africa, N America and S America, the CO_2 distribution for the other regions is more diverse with Qantas typically having a footprint that is about 20% of the regional footprint. It makes zero contribution to the carbon footprint for the Middle East.

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[33] See reference 25.
[34] *Virgin Australia Annual Report 2011.* http://www.virginaustralia.com/cs/groups/internetcontent/@wc/documents/webcontent/~edisp/u_004296.pdf
[35] *Greenhouse and Energy Information 2010-2011*, DCCEE. http://www.cleanenergyregulator.gov.au/National-Greenhouse-and-Energy-Reporting/Publication-of-NGER-data/greenhouse-and-energy-information/Greenhouse-and-Energy-information-2010-2011/Pages/default.aspx

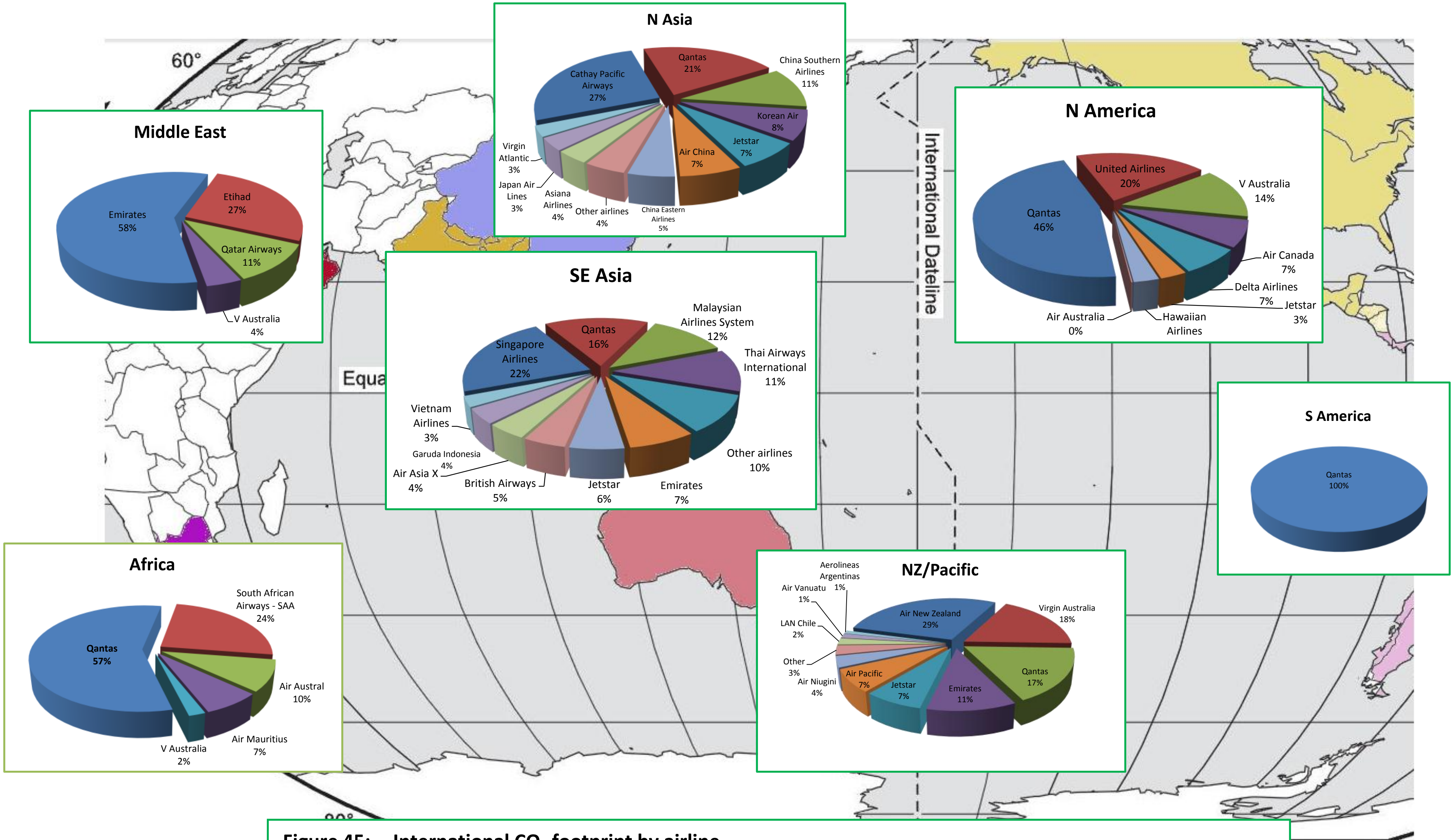


Figure 45: International CO_2 footprint by airline

This figure shows the airline breakdown of the regional carbon footprints generated by aircraft departing from Australia. The magnitudes of the regional footprints are shown in *Figure 6.*

Figure 46 gives a breakdown of the airline contribution to the carbon footprint for the top 20 international routes. The figure shows the footprint share between Qantas, Virgin, Jetstar and provides a comparison with the combined footprint of all the other airlines. This visualisation clearly shows the dominance of the non-Australian airlines as CO_2 generators on the international routes and the dominant position of Qantas, compared to Virgin and Jetstar, as the key Australian contributor to the international aircraft operations carbon footprint.

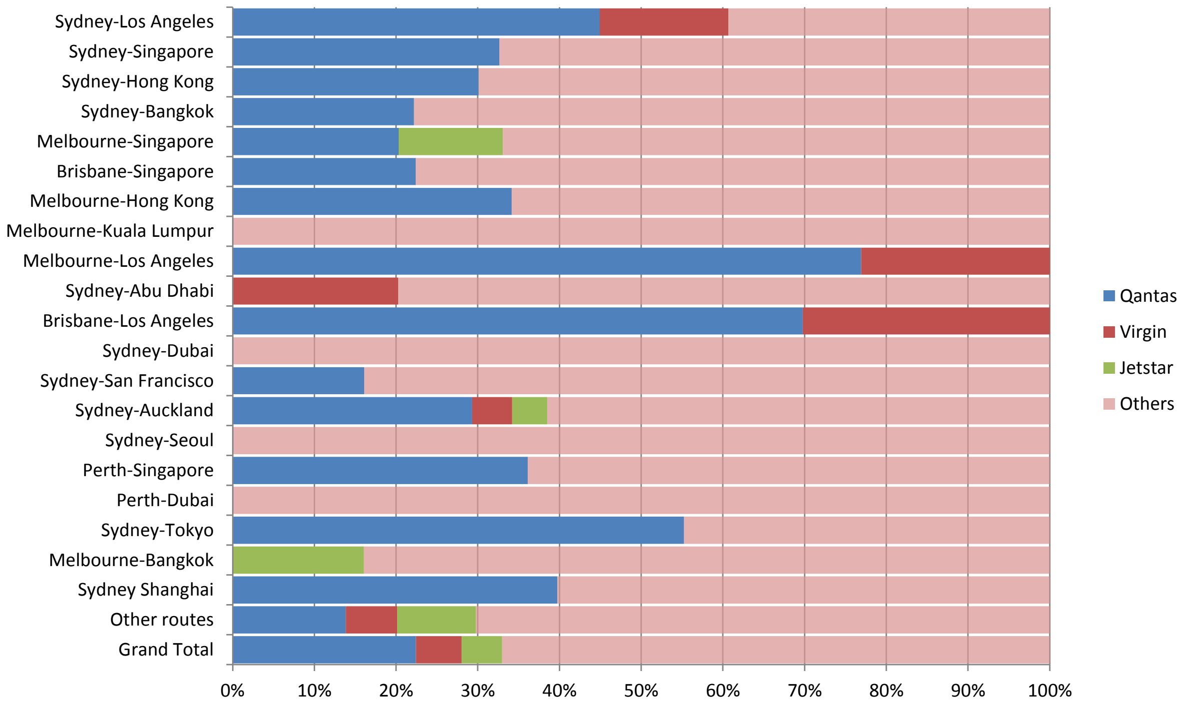


Figure 46: Share of CO_2 footprint for international departures by airline

Figure 47 shows the individual contributions made by the top 14 airlines to the international aircraft operations carbon footprint. While Qantas is the dominant individual airline, it can be seen there are a number of airlines which make a significant contribution to the footprint. Collectively the individual companies cited in the table make up about 80% of the CO_2 footprint.

Airline	CO_2 (kt)	%
Qantas	2,077	22.4
Emirates	920	9.9
Singapore Airlines	740	8.0
Cathay Pacific Airways	553	6.0
Virgin Australia	520	5.6
Jetstar	458	4.9
MAS - Malaysian Airlines System	390	4.2
Thai Airways International	379	4.1
United Airlines	331	3.6
Etihad	286	3.1
Air New Zealand	257	2.8
China Southern Airlines	229	2.5
Korean Air	170	1.8
British Airways	152	1.6
Other airlines	1,805	19.5
TOTAL	**9,268**	**100.0**

Figure 47: CO_2 footprint for international departures by airline

Domestic

In a similar manner to the carbon footprint breakdown for international operations shown in *Figure 46*, *Figure 48* shows a breakdown of the domestic aircraft operations CO_2 footprint between the three main Australian airlines and compares this with the other airlines. It can be seen that Qantas contributes in excess of 50% of the footprint for twelve of the routes and that the three main airlines generate virtually all of the domestic footprint. The 'Other Airlines' generate about 10% of the footprint.

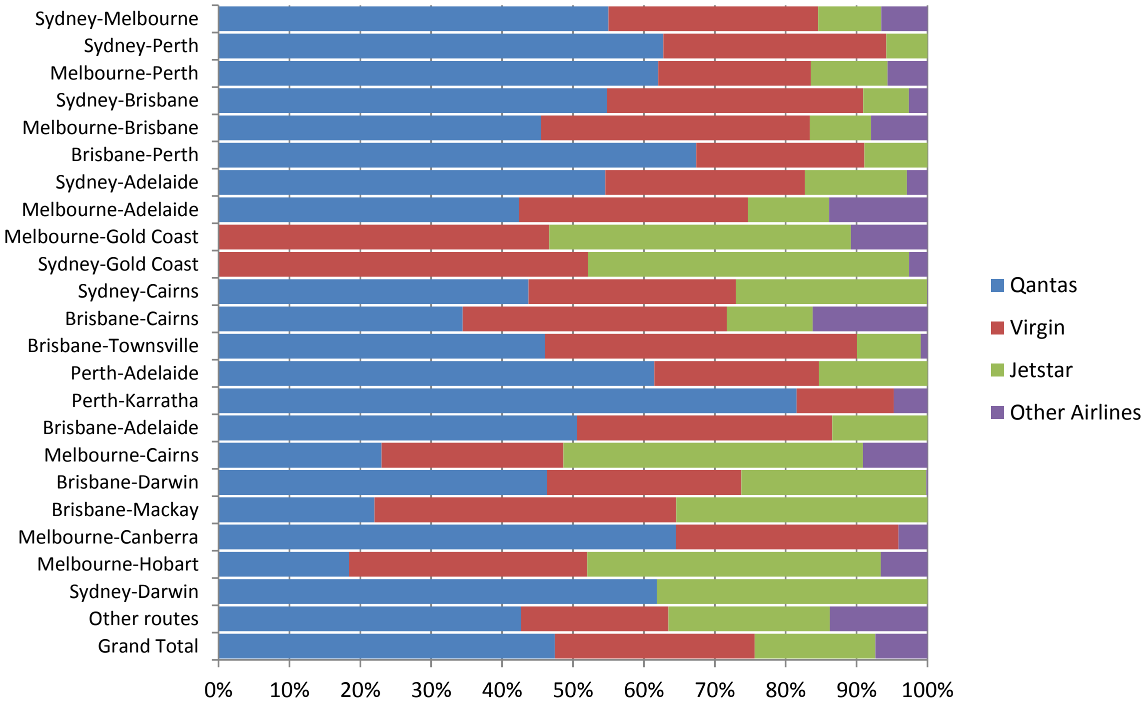


Figure 48: Share of CO_2 footprint for domestic operations by airline

Figure 49 shows the carbon footprint for the top 15 airlines on domestic routes. This indicates that while the small operators make only minor contributions to the total domestic aircraft operations carbon footprint there are a number of airlines that emit in excess of 20 kt of CO_2/annum on domestic operations. While the emissions for most of these airlines are under the NGER reporting threshold for corporations (50 kt/year), the NGER CO_2 threshold for a 'facility' is 25 kt[36] which would suggest that emissions for several of the small operators could be considered significant in the context of the current carbon management regime.

Airline	CO_2 (kt)	%
Qantas	3,126	47.4
Virgin Australia	1,858	28.2
Jetstar	1,124	17.1
Tiger Airways	209	3.2
Regional Express	81	1.2
Skywest	54	0.8
Air North	29	0.4
Skytrans	25	0.4
Brindabella Airlines	25	0.4
Cathay Pacific Airways	19	0.3
Air Australia	14	0.2
Skippers Aviation	11	0.2
Aeropelican	8	0.1
Norfolk Air	7	0.1
Vincent Aviation	2	0.0
Other airlines	1	0.0
TOTAL	**6,592**	**100.0**

Figure 49: CO_2 footprint for domestic operations by airline

[36] NGER reporting threshold: http://www.cleanenergyregulator.gov.au/National-Greenhouse-and-Energy-Reporting/About-NGER/overview-of-NGER/NGER-reporting-step-1/Pages/default.aspx

Cathay Pacific is included in this table since it operates a number of city-pair legs within Australia as part of international flights. These are counted as domestic operations under the UNFCCC carbon accounting system.

4.3 CO_2 Footprint of Individual Airlines

In a similar manner to the previous chapter, this section uses indicators contained in dashboards to provide an insight into the aircraft operations carbon footprints of the three main Australian operators – Qantas, Virgin and Jetstar.

Qantas

Figure 50 is a dashboard which contains a number of graphs giving a perspective on different elements of the Qantas carbon footprint. Key observations include:

Network Components – international operations constitute about 6% of Qantas' take-offs in Australia and generate about 40% of the Qantas Australian footprint; 60% of the carbon footprint derives from domestic operations.

Airports – the Qantas carbon footprint is strongly focussed on Sydney (about 40% of the footprint); operations from three airports (Sydney, Melbourne and Brisbane) generate about 70% of its Australian aircraft operations carbon footprint. Sydney is the only airport where the Qantas international component exceeds the domestic component.

Routes – five of the top six Qantas routes classified by carbon generation are domestic. Just over half of the top 20 CO_2 routes are international.

Aircraft – the most notable feature is the high proportion of the Qantas international aircraft operations carbon footprint that is derived from four engine aircraft (the B747 and A380) – about 75% of the footprint.

Fuel Efficiency – while the quoted fuel efficiency numbers can only be treated as indicative, the efficiency of Qantas operations is broadly in line with published data for other airlines.

Virgin

Figure 51 is a dashboard which contains a number of graphs giving a perspective on different elements of the Virgin carbon footprint. Key observations include:

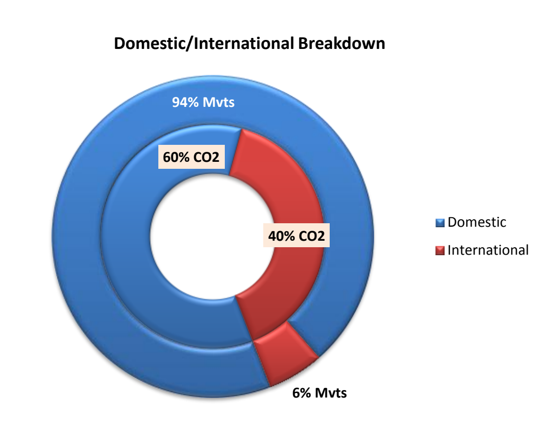
Network Components – similar to Qantas, international operations constitute about 6% of Virgin's take-offs in Australia, however, the proportion of the company carbon footprint generated by international operations, at 22%, is about half that of Qantas; 78% of the Virgin carbon footprint derives from domestic operations.

Airports – Sydney is the dominant CO_2 airport for Virgin (about 25% of the footprint); operations from three airports (Sydney, Melbourne and Brisbane) generate about 65% of its Australian aircraft operations carbon footprint. The Virgin domestic component exceeds the international component at all airports.

Routes – the top two CO_2 routes for Virgin are the same as those for Qantas – Sydney/Melbourne and Sydney/Perth. Also in line with Qantas, the top international CO_2 route is Sydney/Los Angeles.

Aircraft – the Virgin international CO_2 footprint derives exclusively from two engine aircraft – the B777 on the longer haul routes and the B737 on routes in the NZ/Pacific region.

Qantas Carbon Footprint Overview



Network Component	CO_2 (kt)	Mvts
Domestic	3,126	226,640
International	2,077	13,506
TOTAL	**5,204**	**240,146**

Indicative Fuel Efficiency	
L/RTK	0.38
L/100 RPK	4.19

Route CO_2 Hierarchy

Route	CO_2 (kt)	CO_2/PAX (kg)
Sydney-Melbourne	359	92
Sydney-Perth	339	312
Sydney-Los Angeles	324	1,273
Melbourne-Perth	258	259
Sydney-Brisbane	221	93
Brisbane-Perth	179	310
Melbourne-Los Angeles	173	1,335
Melbourne-Brisbane	170	135
Sydney-Singapore	160	622
Sydney-Johannesburg	147	1,216
Brisbane-Los Angeles	137	1,275
Sydney-Hong Kong	128	755
Sydney-Adelaide	106	121
Melbourne-Hong Kong	92	779
Sydney-Tokyo	89	815
Sydney-Bangkok	89	790
Perth-Karratha	83	130
Melbourne-Singapore	77	576
Melbourne-Adelaide	75	81
Sydney-Buenos Aires	68	1,302
Other routes	1,928	146
TOTAL	**5,204**	**190**

Airport CO_2 Hierarchy

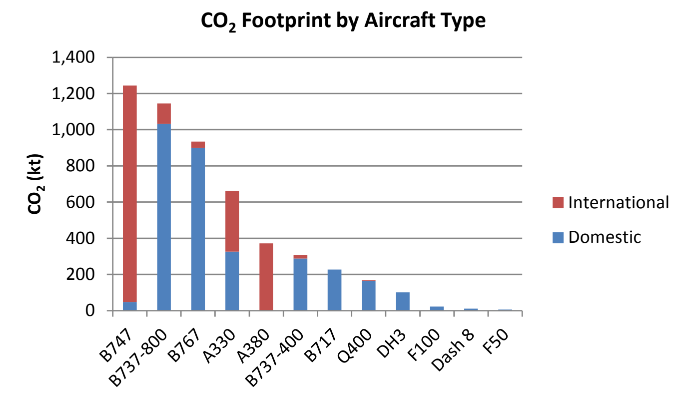
Airport	Domestic CO_2 (kt)	International CO_2 (kt)	% of Total
SYDNEY	651	1,324	38.0
MELBOURNE	505	385	17.1
BRISBANE	486	257	14.3
PERTH	578	88	12.8
ADELAIDE	180	19	3.8
CAIRNS	111	4	2.2
CANBERRA	97	0	1.9
DARWIN	95	0	1.8
ALICE SPRINGS	50	0	1.0
KARRATHA	50	0	1.0
TOWNSVILLE	38	0	0.7
AYERS ROCK	28	0	0.5
BROOME	24	0	0.5
PORT HEDLAND	23	0	0.4
PARABURDOO	18	0	0.3
MT NEWMAN	15	0	0.3
MACKAY	14	0	0.3
MOUNT ISA	14	0	0.3
ROCKHAMPTON	14	0	0.3
HOBART	13	0	0.2
Other airports	125	0	2.4
TOTAL	**3,126**	**2,077**	**100.0**

Figure 50

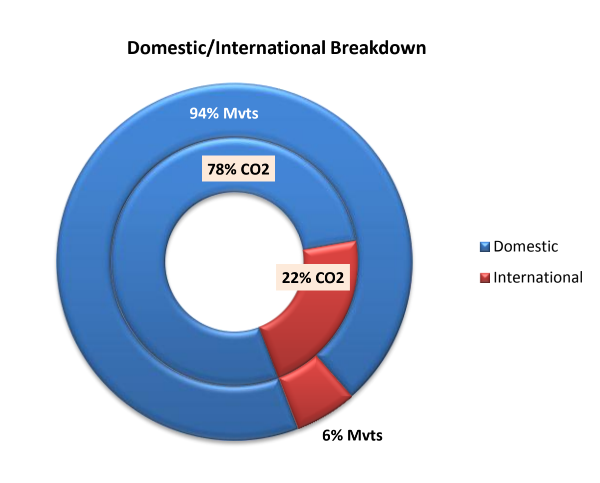
The metrics are discussed briefly in the text. Ideally this dashboard would contain time series data to show temporal trends.

All the metrics relate solely to the CO_2 associated with departing aircraft.

The fuel efficiency metric is indicative and can only be used for very broad comparative purposes.



Virgin Carbon Footprint Overview



Network Component	CO_2 (kt)	Mvts
Domestic	1,858	140,758
International	520	8,359
TOTAL	**2,378**	**149,117**

Indicative Fuel Efficiency	
L/RTK	0.38
L/100 RPK	4.07

Route CO_2 Hierarchy		
Route	**CO_2 (kt)**	**CO_2/PAX (kg)**
Sydney-Melbourne	193	85
Sydney-Perth	170	313
Sydney-Brisbane	146	88
Melbourne-Brisbane	142	133
Sydney-Los Angeles	113	1,351
Melbourne-Perth	89	232
Sydney-Gold Coast	88	82
Melbourne-Gold Coast	82	129
Brisbane-Perth	63	299
Brisbane-Los Angeles	59	1,291
Melbourne-Adelaide	57	80
Sydney-Adelaide	55	117
Brisbane-Cairns	53	135
Melbourne-Los Angeles	52	1,430
Brisbane-Townsville	49	114
Sydney-Cairns	44	178
Sydney-Abu Dhabi	42	1,351
Brisbane-Mackay	35	91
Brisbane-Adelaide	35	153
Melbourne-Hobart	27	78
Other airports	783	132
TOTAL	**2,378**	**163**

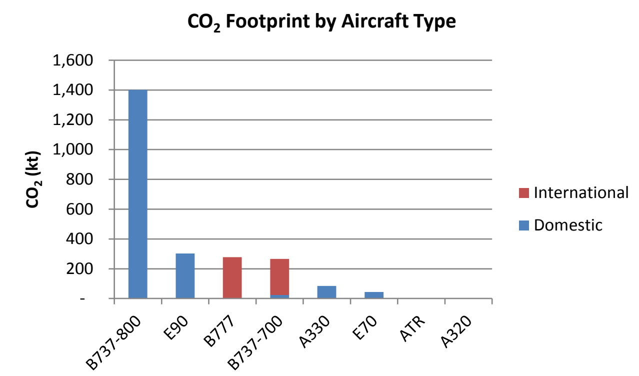
Airport CO_2 Hierarchy			
Airport	**Domestic CO_2 (kt)**	**International CO_2 (kt)**	**% of Total**
SYDNEY/KINGSFORD SMITH	420	216	26.7
BRISBANE	320	156	20.0
MELBOURNE	356	105	19.4
PERTH	214	24	10.0
GOLD COAST	96	9	4.4
ADELAIDE	95	8	4.3
CAIRNS	61	2	2.6
CANBERRA	46	0	1.9
TOWNSVILLE	39	0	1.6
DARWIN	32	0	1.4
HOBART	32	0	1.4
MACKAY	21	0	0.9
LAUNCESTON	16	0	0.7
ROCKHAMPTON	14	0	0.6
SUNSHINE COAST	13	0	0.5
HAMILTON ISLAND	11	0	0.5
PORT HEDLAND	10	0	0.4
NEWCASTLE	9	0	0.4
BROOME	8	0	0.4
AYERS ROCK	7	0	0.3
Other airports	35	0	1.5
TOTAL	**1,858**	**520**	**100.0**

Figure 51:

The metrics are discussed briefly in the text. Ideally this dashboard would contain time series data to show temporal trends.

All the metrics relate solely to the CO_2 associated with departing aircraft.

The fuel efficiency metric is indicative and can only be used for very broad comparative purposes.



Fuel Efficiency – while the quoted fuel efficiency numbers can only be treated as indicative, the efficiency of Virgin operations is broadly in line with published data for other airlines. This is discussed further in Chapter 6.

Jetstar

Figure 52 is a dashboard which contains a number of graphs giving a perspective on different elements of the Jetstar carbon footprint. Key observations include:

Network Components – the proportion of Jetstar movements that contribute to the international carbon footprint exceeds that of Qantas (9% compared to 6%) while the proportion of the total carbon footprint is somewhat less (30% compared to 40%) – this difference presumably reflects the longer haul nature of the Qantas flights.

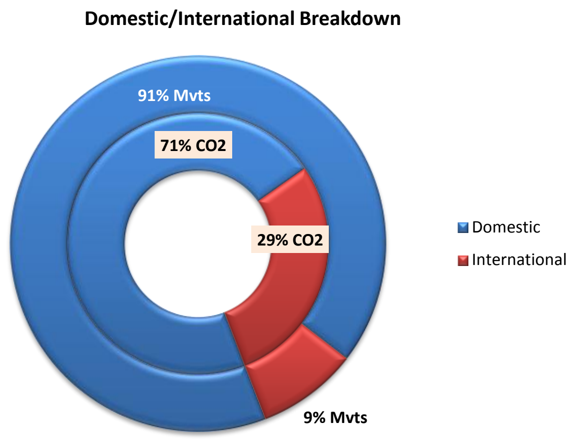
Airports – Sydney and Melbourne are the top two CO_2 airports for Jetstar, however, the hierarchy for Jetstar compared to the other two airlines is somewhat different with a number of regional and less prominent airports making significant contributions to the Jetstar carbon footprint.

Routes – the Gold Coast is involved in the top two CO_2 routes for Jetstar. It is interesting to note that in contrast to Qantas four of the top six routes by carbon generation are international.

Aircraft – Jetstar only operates two engine aircraft – the A330 and the A320. The A330 is the key generator of the Jetstar international aircraft operations carbon footprint, while the A320, which dominates the Jetstar footprint, is used on domestic operations and also on international services to NZ.

Fuel Efficiency – the Jetstar fuel efficiency is similar to that for Qantas and Virgin.

Jetstar Carbon Footprint Overview



Network Component	CO_2 (kt)	Mvts
Domestic	1,124	72,081
International	458	6,854
TOTAL	**1,582**	**78,935**

Indicative Fuel Efficiency	
L/RTK	0.37
L/100 RPK	4.01

Route CO_2 Hierarchy		
Route	**CO_2 (kt)**	**CO_2/PAX (kg)**
Sydney-Gold Coast	77	90
Melbourne-Gold Coast	75	117
Sydney-Melbourne	58	93
Melbourne-Singapore	49	658
Sydney-Honolulu	47	959
Cairns-Tokyo	47	642
Melbourne-Perth	45	226
Gold Coast-Osaka	43	785
Sydney-Cairns	41	173
Gold Coast-Tokyo	38	787
Melbourne-Cairns	36	179
Melbourne-Hobart	34	87
Melbourne-Brisbane	32	122
Sydney-Perth	31	267
Melbourne-Newcastle	31	103
Sydney-Denpasar	31	505
Sydney-Avalon	31	98
Sydney-Darwin	30	258
Sydney-Sunshine Coast	30	103
Brisbane-Mackay	29	100
Other routes	748	159
TOTAL	**1,582**	**160**

Airport CO_2 Hierarchy			
Airport	**Domestic CO_2 (kt)**	**International CO_2 (kt)**	**% of Total**
SYDNEY/KINGSFORD SMITH	208	126	21.1
MELBOURNE	219	109	20.7
GOLD COAST	110	94	12.9
CAIRNS	86	75	10.1
BRISBANE	117	8	8.0
DARWIN	54	33	5.5
PERTH	72	13	5.4
ADELAIDE	57	0	3.6
NEWCASTLE	34	0	2.1
HOBART	33	0	2.1
SUNSHINE COAST	28	0	1.8
AVALON	25	0	1.6
LAUNCESTON	23	0	1.4
HAMILTON ISLAND	17	0	1.1
TOWNSVILLE	16	0	1.0
MACKAY	15	0	0.9
BALLINA	7	0	0.4
PROSERPINE	4	0	0.3
TOTAL	**1,124**	**458**	**100.0**

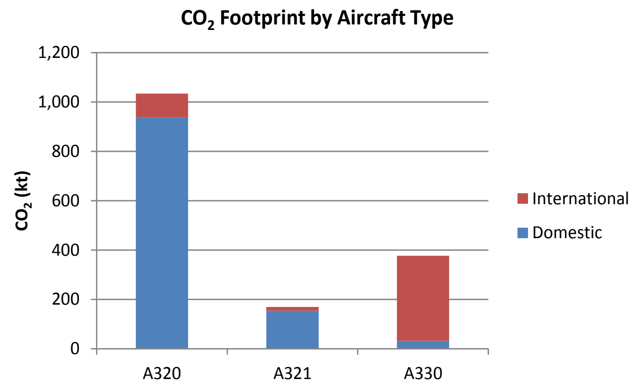


Figure 52:

The metrics are discussed briefly in the text. Ideally this dashboard would contain time series data to show temporal trends. All the metrics relate solely to the CO_2 associated with departing aircraft. The fuel efficiency metric is indicative and can only be used for very broad comparative purposes.

Chapter 5

Monetising Carbon

5.1 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 operations originating in Australia. This chapter converts the earlier carbon footprint information into monetary terms.

Much of the debate surrounding climate change and its management revolves around the price of carbon. This debate has been particularly heated in Australia in the lead up to the commencement of the 'carbon tax' on 1 July 2012. Thinking about, and analysing, aviation carbon footprints in terms of money is important for a number of reasons:

- the use of market based measures to reduce CO_2 emissions is commonly seen as the most cost effective way to manage climate change – much of the current debate within ICAO is in this area
- when considering the imposition of a carbon charge on aviation it is important to understand the potential quantum of funds that will be generated, and from which routes/countries, in order to assess the sums of money that will be available for investment in climate action projects
- the cost impacts of carbon charges need to be understood both in terms of the increased ticket costs for individual travellers on specific routes and also from the point of view of the total costs imposed on specific airline companies.

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 factual 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 $23 AUD/tonne has been used for the computations as this is the price of CO_2 that currently applies in Australia under its carbon management legislation. 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 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.

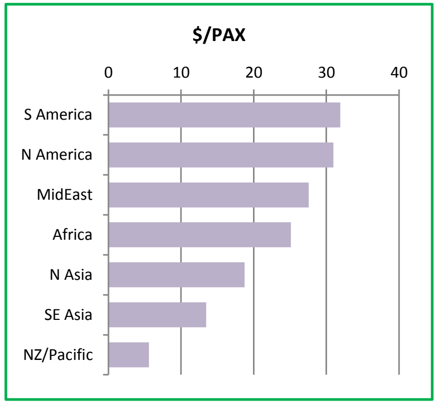
At the present time in Australia there is a carbon tax on domestic aviation ($23/tonne); similar regimes are also in place in New Zealand and Europe. However, debate is continuing within ICAO on the introduction of a carbon charge for international aviation. At the present time there would appear to be little prospect of international agreement being reached on carbon pricing for international aviation in the near future.

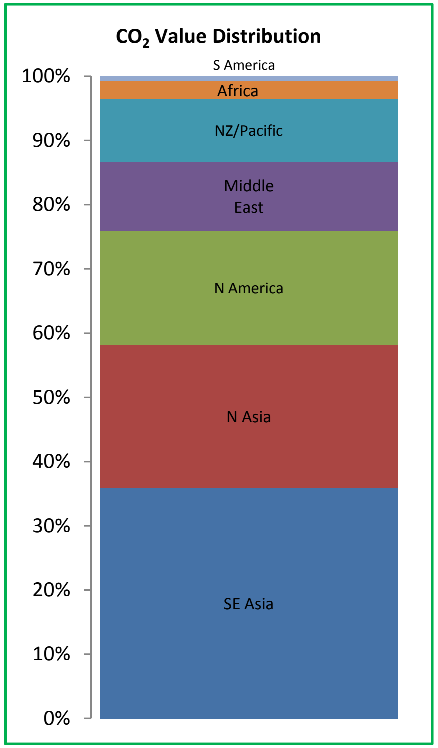
5.2 Network Overview

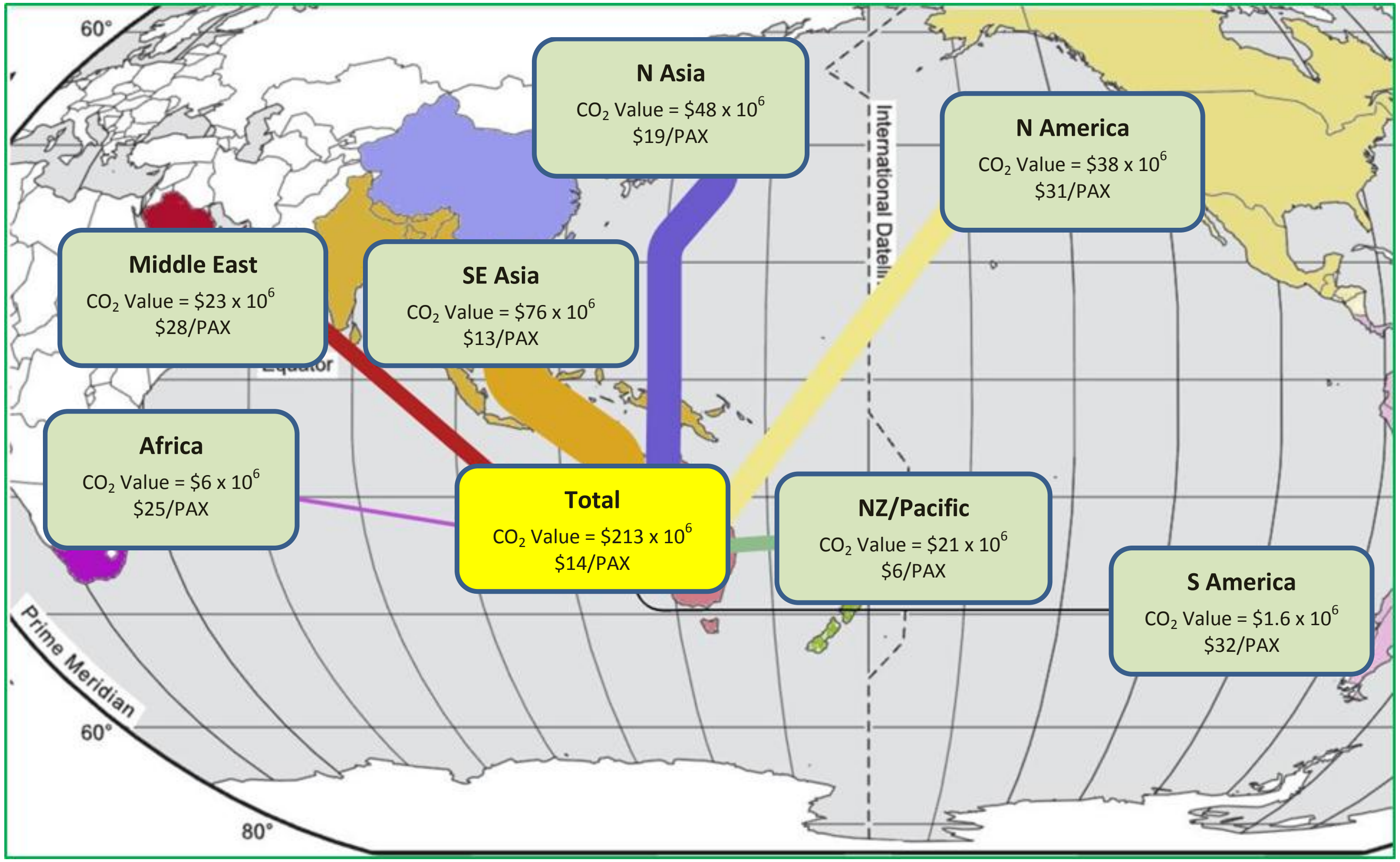
Figure 53 takes *Figure 6* from Chapter 2 and converts the CO_2 values into monetary values. It shows the total $ value of CO_2 generated by international departures into each of the seven international regions used throughout the report. It also shows the carbon costs per passenger.

In a similar manner, *Figure 54* converts the CO_2 values in *Figure 9* into monetary values to give an overview picture of carbon pricing for domestic operations. An alphabetical listing of the CO_2 footprint of all domestic city-pairs in the operations dataset can be found in *Table A3.2* in the Appendix.

It can be seen that if a carbon charge of $23/tonne had been in place for all aircraft departures in Australia in 2011 it would have generated $152 million from domestic operations and $213 million from international operations. On average there would have been an increase of around $2.80 per passenger on domestic flights and $14 per passenger on international flights.





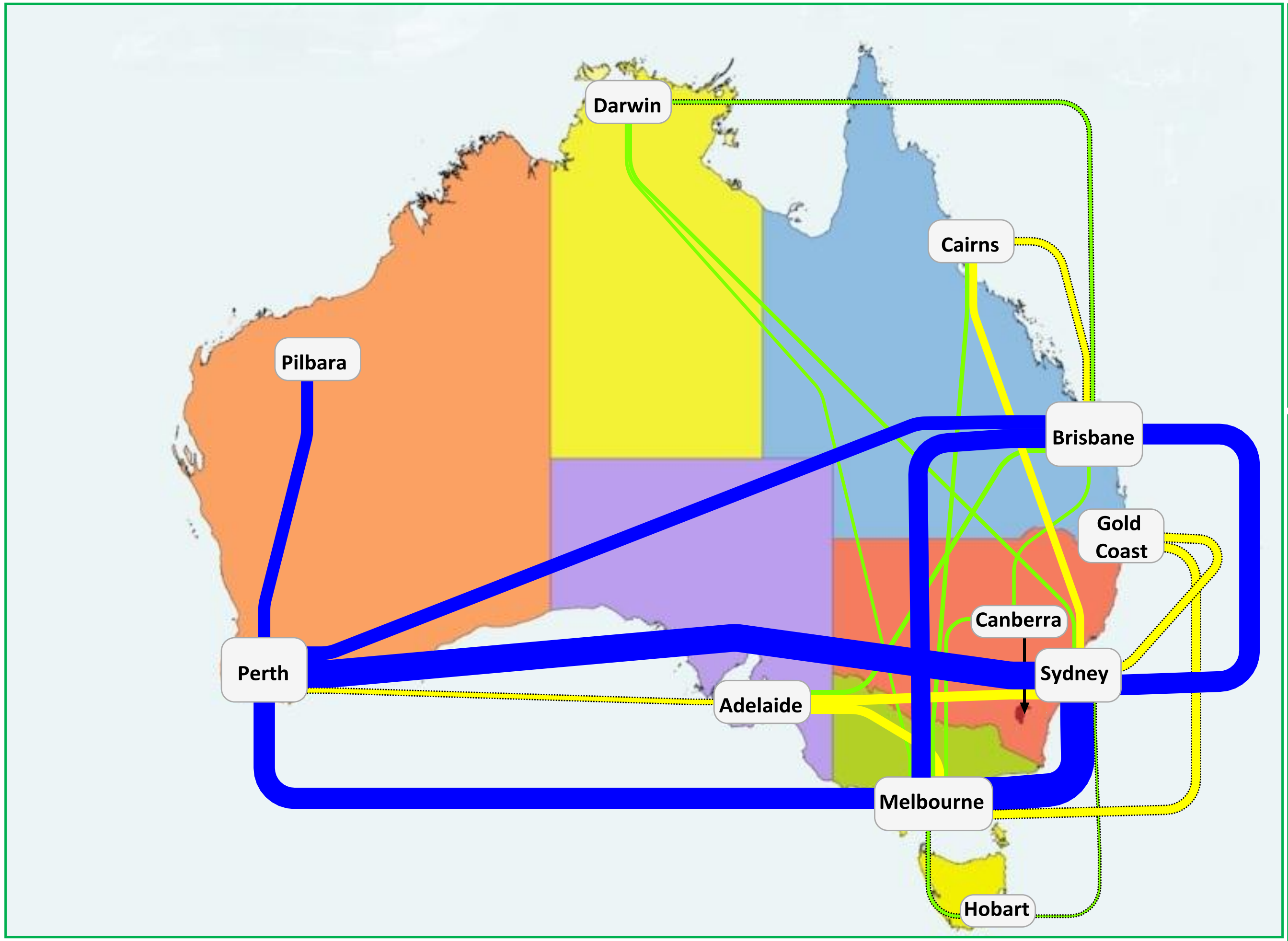


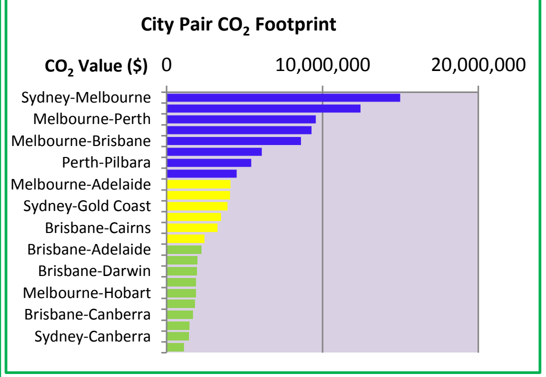
Total International CO_2 value

213×10^6

Figure 53: Monetised international CO_2 footprint

The monetary values have been computed at a carbon price of $23/tonne. The carbon cost per passenger is greatest for flights to S America. Almost 60% of the carbon revenue in 2011, if a carbon charge had been in place for international operations, would have derived from flights to Asia.





City Pair	CO_2 Value ($)	$/PAX
Sydney-Melbourne	14,989,254	2.07
Sydney-Perth	12,441,989	7.12
Melbourne-Perth	9,560,900	5.67
Sydney-Brisbane	9,293,314	2.10
Melbourne-Brisbane	8,612,759	3.06
Brisbane-Perth	6,094,931	7.04
Perth-Pilbara	5,420,307	3.03
Sydney-Adelaide	4,490,029	2.76
Melbourne-Adelaide	4,068,931	1.95
Melbourne-Gold Coast	4,045,832	2.86
Sydney-Gold Coast	3,884,854	1.97
Sydney-Cairns	3,480,794	4.05
Brisbane-Cairns	3,266,787	3.14
Perth-Adelaide	2,412,092	4.39
Brisbane-Adelaide	2,222,214	3.51
Melbourne-Cairns	1,975,957	4.41
Brisbane-Darwin	1,933,521	5.57
Melbourne-Canberra	1,886,979	1.52
Melbourne-Hobart	1,864,162	1.89
Sydney-Darwin	1,796,339	6.03
Brisbane-Canberra	1,669,312	2.46
Melbourne-Darwin	1,450,671	5.49
Sydney-Canberra	1,425,943	1.06
Sydney-Hobart	1,100,237	2.57
Other Routes	42,223,454	2.39
TOTAL	**151,611,561**	**2.78**

Figure 54: Monetised domestic CO_2 footprint

The monetary values have been computed at a carbon price of $23/tonne. The carbon cost per passenger relates to a one-way journey. This cost is greatest for flights between Sydney and Perth. Almost 45% of the carbon revenue in 2011, if a carbon charge had been in place for domestic operations, would have derived from the blue routes.

Total Domestic CO_2 value

$152 x 10^6

5.3 Airports

While airport companies to date have not been active in Australia in raising funds from airport users to implement climate change action, it is nevertheless instructive to understand the magnitude of funds that would be raised if airports introduced some form of carbon charge on airline passengers.

Figure 55, which monetises *Figure 26* from Chapter 3, shows the potential revenue stream for individual airports if some form of carbon charge were imposed by airports on departing passengers.

	Domestic		International	
Airport	**CO_2 Value ($\$x10^6$)**	**Cost/PAX ($)**	**CO_2 Value ($\$x10^6$)**	**Cost/PAX ($)**
Sydney	30.8	2.55	107.7	15.99
Melbourne	26.9	2.61	49.7	14.99
Brisbane	22.5	2.83	27.7	11.71
Perth	20.9	5.04	17.7	10.48
Adelaide	8.4	2.62	2.8	11.10
Cairns	6.2	3.54	2.8	9.81
Gold Coast	5.1	2.52	3.6	11.39
Darwin	4.4	4.81	1.0	4.20
Canberra	3.4	1.78	0.0	-
Townsville	2.2	2.50	<0.1	6.86
Hobart	1.9	2.28	0.0	-
Karratha	1.4	3.21	0.0	-
Mackay	1.2	2.19	0.0	-
Alice Springs	1.2	3.71	0.0	-
Newcastle	1.2	2.10	0.0	-
Sunshine Coast	1.0	2.69	0.0	-
Broome	1.0	3.87	0.0	-
Launceston	1.0	1.89	0.0	-
Avalon	0.9	2.71	0.0	-
Port Hedland	0.8	3.18	<0.1	3.96
Ayers Rock	0.8	4.13	0.0	-
Hamilton Island	0.7	3.00	0.0	-
Rockhampton	0.7	1.63	0.0	-
Mount Isa	0.5	2.89	0.0	-
Mt Newman	0.4	2.81	0.0	-
Other Airports	6.4	1.66	0.0	-
TOTAL	**151.6**	**2.78**	**213.2**	**14.01**

Figure 55: Monetised CO_2 footprint by airport

While it is useful to understand the magnitude of the potential carbon income streams (or imposts on travellers) for individual airports, the imposition of carbon charges at individual airports would be complex particularly as the airline industry is already paying a carbon tax of $23/tonne for domestic aviation and agreement has yet to be reached within ICAO on the introduction of market based measures relating to international operations. Nevertheless, it is worth noting that the imposition of environmental levies at Australian airports is not a new concept. Noise levies at Sydney and Adelaide airports funded the noise insulation programs which were in place at those airports during the period 1995 to 2011. The cost imposed was $3.40 per arriving passenger. It can be seen from *Figure 55* that at a carbon price of $23/tonne, the per passenger carbon charge for domestic aviation would be of a similar magnitude to the now discontinued noise levies.

Figure 55 also broadly indicates the quantum of revenue the Federal Government would have obtained from domestic passengers using the airports shown in the table if the carbon tax had been in place in 2011. It is also interesting to note the differences in effective costs/passenger at each airport – the carbon value/passenger at the more remote airports such as Perth and Darwin is significantly higher than at most airports in the Eastern States.

5.4 Airlines

Under the Australian Government's carbon pricing regime which came into place on 1 July 2012, the airlines are the entities which have to directly pay the tax through an excise on fuel. These companies broadly have the option of either absorbing the costs or passing these on to their customers. Qantas, Virgin and Jetstar have introduced carbon surcharges on airline tickets in response to the introduction of the tax – Qantas and Virgin have introduced a sliding scale surcharge based on distance zones while Jetstar has introduced a flat charge.[37,38]

Figure 56, monetises the CO_2 values for the individual airlines shown in the figures in Chapter 4 (plus some additional airlines). A complete listing of the airline carbon footprints is contained in *Table A2* in the Appendix. This figure gives an indication of the current carbon liability for companies carrying out domestic operations in Australia. The values/costs for international operations are simply notional at this time since no agreement has been reached within ICAO on such charging, nevertheless the numbers are a useful guide to the carbon revenues/costs that may occur if/when agreement is reached.

	Domestic		International	
Airline	**CO_2 Value (x10^6$)**	**Cost/PAX ($)**	**CO_2 Value (x10^6$)**	**Cost/PAX ($)**
Qantas	71.9	2.95	47.8	15.87
Virgin Australia	42.7	2.67	5.6	5.78
Jetstar	25.9	2.92	10.5	10.18
Emirates			21.2	17.38
Singapore Airlines			17.0	12.79
Cathay Pacific Airways	0.4	3.22	12.7	17.69
MAS - Malaysian Airlines System			9.0	14.14
Thai Airways International			8.7	14.69
United Airlines			7.6	30.56
Etihad			6.6	21.64
V Australia			6.4	30.54
Air New Zealand			5.9	5.39
China Southern Airlines			5.3	17.20
Tiger Airways	4.8	2.80	0.3	7.23
Korean Air			3.9	20.07
British Airways			3.5	17.19
Air Asia X			3.3	14.21
Air China			3.2	20.92
Garuda Indonesia			3.2	8.97
Air Canada			2.7	30.75
Delta Airlines			2.6	29.66
Qatar Airways			2.6	29.41
China Eastern Airlines			2.4	16.36
Vietnam Airlines			2.2	16.95
Regional Express	1.9	1.09		
Other airlines	4.0	2.39	19.1	10.43
TOTAL	**151.6**	**2.78**	**213.2**	**14.01**

Figure 56: Monetised CO_2 footprint by airline

[37] Qantas Domestic Carbon Pricing and Carbon Tax charge: http://www.qantas.com.au/travel/airlines/climate-change/global/en

[38] Virgin Australia statement on carbon surcharges: http://www.virginaustralia.com/au/en/about-us/media/2012/SURCHARGES-RESPONSE-CARBON/

The figure indicates that the carbon costs/passenger imposed by the carbon tax on domestic passengers, for the three major airlines, are of the order of $3/passenger. It also needs to be borne in mind that the companies have other carbon costs in addition to jet fuel (eg fuel for road vehicles, ground service equipment, etc) which need to be recovered from passengers; however, both Qantas and Virgin have indicated that these costs are less than the 5% of their total carbon bill.[39,40]

It is interesting to examine the different approaches adopted by Qantas and Virgin to recover the costs of the carbon tax. As indicated above, both these companies have announced a distance based carbon surcharge regime – in essence the companies have introduced distance zones; Qantas has four distance zones, Virgin has three. The distance bands and the surcharge for each band are shown in the first two columns of *Figure 57*. The third column shows the number of passengers in each of these distance zones carried by the airlines in 2011 as computed using TNIP Carbon Counter (see Chapter 6). The notional revenue from the charge, arrived at by multiplying columns two and three, is shown in column four. The right hand side of the table contrasts these notional revenues with those derived by computing the quantum of CO_2 generated by operations of the separate companies in each of the distance bands (using TNIP Carbon Counter and the 2011 scheduled movements dataset). The weight of carbon has been converted into the monetary values shown in the final column using a carbon price of $23/tonne.

Qantas					
Carbon Surcharge Regime				Computed CO_2 Costs	
Distance Band	**Carbon Charge ($)**	**PAX**	**Revenue ($)**	**CO_2 (t)**	**CO_2 Cost ($)**
1-700km	1.82	6,671,579	12,142,274	441,897	10,163,622
701-1200km	2.79	9,286,339	25,908,886	937,354	21,559,144
1201-1900	4.00	3,867,372	15,469,488	560,028	12,880,641
1901+	6.86	4,560,916	31,287,884	1,187,090	27,303,071
TOTAL		**24,386,206**	**84,808,531**	**3,126,369**	**71,906,478**
Virgin					
Carbon Surcharge Regime				Computed CO_2 Costs	
Distance Band	**Carbon Charge ($)**	**PAX**	**Revenue ($)**	**CO_2 (t)**	**CO_2 Cost ($)**
1-900km	1.50	9,158,160	13,737,240	729,503	16,778,568
900-2000km	3.00	5,130,173	15,390,519	673,251	15,484,762
>2000km	6.00	1,740,117	10,440,702	454,900	10,462,695
TOTAL		**16,028,450**	**39,568,461**	**1,857,653**	**42,726,025**

Figure 57: Comparison of Qantas and Virgin CO_2 surcharge regimes

The table shows, for Virgin, an approximate 10% difference between the two approaches to computing the carbon revenues. For Qantas this difference is of the order of 15%. As indicated earlier in the report, there are difficulties in accurately computing per passenger CO_2 metrics due to the need to make assumptions about both load factors and aircraft seat configurations. In this particular comparison the lack of certainty in the computations is compounded by the need to make assumptions about load factors in separate distance band categories. Recognising these uncertainties, on the face of it Qantas is gathering a greater proportion of its carbon revenue from its long distance passengers compared to Virgin.

[39] See reference 34.
[40] See reference 31, p30.

Chapter 6

Computation and Validation

6.1 Background

This Chapter is designed to give 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.

A key aim of this carbon footprinting exercise was to explore the extent to which robust carbon footprinting and reporting can be carried out by the non-expert. As indicated earlier, all the information in the 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 author is not a computer or database specialist.

Carbon footprinting aviation is very much aided by the fact that there is a great deal of publicly available data about aircraft operations. This not only provides many options for computing the carbon footprint but, most importantly, provides a number of data points which can be used to assess the validity of the results.

6.2 Computation and Reporting

Input Data

All the information in the report has been derived from an operations dataset for scheduled aircraft operations in Australia for the year 2011. This dataset was purchased from Innovata, a US based company that specialises in '…the aggregation, management and distribution of…travel data'.[41] The dataset file size is approximately 200kB and was provided as a Microsoft Excel spreadsheet containing 1,822 rows and five columns – an extract from the file is shown in *Figure 58*.

DEPARTURES FROM AUSTRALIA - JAN - DEC 2011 - Total Flights by City Pair

Org	Dst	Equip	Al	2011
ABM	CNS	DH1	Q6	298
ABX	CBR	SWM	FQ	384
ABX	MEL	SF3	ZL	914
ABX	SYD	DH3	QF	962
ABX	SYD	DH4	QF	387
ABX	SYD	E70	DJ	320
ABX	SYD	E90	DJ	396
ABX	SYD	SF3	ZL	1,308
ABX	WGA	SF3	ZL	6
ADL	AKL	320	NZ	253
ADL	AKL	763	NZ	6
ADL	ASP	73H	QF	365
ADL	AVV	320	TT	171
ADL	BHQ	SF3	ZL	740
ADL	BME	73W	DJ	31

Figure 58: Extract from the core input file – scheduled aircraft operations 2011

[41] Innovata: http://www.innovata-llc.com/

Carbon Counting

The derivation of CO_2 information from the Innovata aircraft operations dataset was carried out using TNIP Carbon Counter – a carbon counting application developed by the Australian Government Department of Infrastructure and Transport.[42] 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 airport 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.[43] TNIP Carbon Counter 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 58* and generate, amongst other things, an output table containing information on a wide range of user selected variables for each city-pair operation (eg CO_2, distance, airport, operator, destination State/Country, international/interstate/intrastate status, passenger numbers, etc). The actual computation is very rapid – the carbon counting computation/archiving for Australia for the year 2011 takes less than five minutes.

The TNIP Carbon Counter output was exported to Microsoft Excel to set up a master worksheet. An extract of the master worksheet is shown in *Figure 59*.

Operator	Operator	Airport C	A/P Nam	Country	Aircraft T	City Pair	Dom/Int	Total CO2	Total Fue	Total Fue	Total Pax	RPK	RTK (Tota	Total Dep	CO2 kg/1	Fuel (L)/1	Fuel kg/R	CO2 (kg/	Distance	Total Distance (km)
AR	Aerolinea	YSSY	SYDNEY/I	New Zeal	340	YSSY-NZA	Int	#######	#######	#######	35,948	#######	#######	172	11.8372	4.71634	0.3562	#######	2,157.58	371104
OT	Aeropelic	YBBN	BRISBANE	Australia	J32	YBBN-YN	Dom	326,780	103,511	130,202	2,492	#######	116,320	178	28.6664	11.4218	0.88987	1,835.84	457.44	81424.3
OT	Aeropelic	YCOM	COOMA	Australia	J32	YCOM-YS	Dom	428,462	135,718	170,715	3,962	#######	133,277	283	32.8044	13.0705	1.01832	1,514.00	329.66	93293.8
OT	Aeropelic	YMDG	MUDGEE	Australia	J32	YMDG-YN	Dom	14,553	4,610	5,798	154	38,503	3,929	11	37.797	15.0597	1.1733	1,323.00	250.02	2750.22
OT	Aeropelic	YMDG	MUDGEE	Australia	J32	YMDG-YS	Dom	655,765	207,718	261,280	7,728	#######	166,491	552	40.1912	16.0136	1.24762	1,187.98	211.13	116544
OT	Aeropelic	YNBR	NARRABR	Australia	J32	YNBR-YBI	Dom	326,780	103,511	130,202	2,492	#######	116,320	178	28.6664	11.4218	0.88987	1,835.84	457.44	81424.3
OT	Aeropelic	YNBR	NARRABR	Australia	J32	YNBR-YM	Dom	15,876	5,029	6,326	168	42,003	4,286	12	37.797	15.0597	1.1733	1,323.00	250.02	3000.24
OT	Aeropelic	YNBR	NARRABR	Australia	J32	YNBR-YSS	Dom	#######	368,911	464,039	9,338	#######	402,353	667	29.5366	11.7685	0.91688	1,746.10	422.26	281647
OT	Aeropelic	YNBR	NARRABR	Australia	J32	YNBR-YW	Dom	245,960	77,910	97,999	2,254	755,563	77,098	161	32.5532	12.9704	1.01052	1,527.70	335.21	53968.8
OT	Aeropelic	YSSY	SYDNEY/I	Australia	J32	YSSY-YCO	Dom	428,462	135,718	170,715	3,962	#######	133,277	283	32.8044	13.0705	1.01832	1,514.00	329.66	93293.8
OT	Aeropelic	YSSY	SYDNEY/I	Australia	J32	YSSY-YMI	Dom	656,953	208,094	261,753	7,742	#######	166,793	553	40.1912	16.0136	1.24762	1,187.98	211.13	116755
OT	Aeropelic	YSSY	SYDNEY/I	Australia	J32	YSSY-YNB	Dom	#######	369,464	464,735	9,352	#######	402,957	668	29.5366	11.7685	0.91688	1,746.10	422.26	282070
OT	Aeropelic	YSSY	SYDNEY/I	Australia	J32	YSSY-YWI	Dom	#######	403,572	507,638	20,356	#######	296,201	1,454	43.891	17.4881	1.3625	876.24	142.6	207340

Figure 59: Extract from the 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 to the data in the master worksheet shown in *Figure 59*.

[42] TNIP Carbon Counter: http://www.infrastructure.gov.au/aviation/environmental/transparent_noise/tnip_CC.aspx
[43] ICAO Carbon Calculator: http://www.icao.int/environmental-protection/CarbonOffset/Pages/default.aspx

Generation of Graphics

The graphics were predominantly produced using the standard chart functions contained in Microsoft Excel. The main quantity flow diagrams (eg *Figure 9*) were produced using a flow diagram software tool – e!Sankey.[44] The figures containing geographic coordinate information (eg *Figure 18*), were produced using a GIS application – Maptitude.[45] Some images were modified using 'Gimp', a free image manipulation program.[46]

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 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 75% was used for international flights; and a load factor of 80% was used for domestic operations. These figures were chosen based on reports produced by the Australian Government Bureau of Infrastructure, Transport and Regional Economics (BITRE).[47,48]

- For most computations, the data for 'V Australia' was combined with that for 'Virgin Australia' in order to give a consolidated group figure. However, in some of the figures reference is made to 'V Australia'.

- In some of the published reports used for validation, there is a lack of clarity between data for a calendar year and a financial year. Wherever possible, all references and comparisons have been based on data for the calendar year 2011. In some instances data may apply to the financial year 2010/11 rather than the calendar year – this would not be expected to generate any significant anomalies when considering aggregated data.

6.3 Validation

Overview

There are a number of published sources of information which can be used to assess the robustness of Australian aircraft operations carbon footprint computations. At the aggregated level Australian Government departments publish information on jet fuel sales as a component of national energy statistics and on CO_2 emissions as part of the National Greenhouse Accounts (which are reported to the UNFCCC). At the company level the CO_2 emissions of large airlines are published by the Clean Energy Regulator under the NGERS process while CO_2 data is also published by the airlines as part of their annual or sustainability reporting. Carbon calculators such as the Qantas and ICAO on-line tools can be used to compute CO_2 emissions at the individual flight level.

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[44] e sankey: www.e-sankey.com/
[45] Maptitude: http://www.caliper.com/maptovu.htm
[46] Gimp: www.gimp.org/
[47] International load factors: http://www.bitre.gov.au/publications/ongoing/international_airline_activity-time_series.aspx
[48] Domestic load factors: http://www.bitre.gov.au/statistics/aviation/domestic.aspx

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. Nevertheless, the aggregated airline data published under NGERS does give a solid basis for CO_2 footprint validation at the airline company level.

The validity of input into derived metrics such as CO_2/PAX can be examined using data on passenger numbers published by sources such as BITRE.

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

Validation at the Network Level

Prima facie, it would be expected that the aircraft operations carbon footprint based purely on scheduled movements would understate the 'true' situation. There are significant levels of airwork and aviation training in Australia which are not captured in this report. The level of charter movements is relatively low compared to other parts of the world, but in recent times air charter traffic into the Pilbara region of Western Australia has increased significantly. At the present time there appears to be no published data on the activity levels, aircraft types, etc involved in non-scheduled aircraft operations in Australia.

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 (eg the Civil Aviation Safety Authority (CASA) suspension of Tiger Airways operations in July 2011). Given the overview nature of this report, these weaknesses have simply been recognised – no attempt has been made to clean up the database since on the face of it these 'variations' are unlikely to constitute a major part of the network carbon footprint.

There are two credible carbon footprint validation points which can be used at the network level: published national jet fuel sales; and the Australian CO_2 reporting under the UNFCCC.

National Fuel Sales

The Australian Government Department of Resources, Energy and Tourism (RET) publishes ongoing information on national fuel sales including data on sales of jet fuel.[49] This source indicates that in 2011 7,067.6 megalitres of aviation turbine fuel were sold. This converts to a figure of 17.85 Mt of CO_2. [assuming the specific gravity of jet fuel = 0.8; and the conversion factor of weight of jet fuel to weight of CO_2 = 3.157].

The national jet fuel sales figures include jet fuel used by the military and therefore, for validation purposes, the total sales figure needs to be adjusted to solely reflect jet fuel used for civil aviation. There are questions around the published data for military use of jet fuel. Nevertheless, it would appear from data published by the Australian Government Department of Climate Change and Energy Efficiency (DCCEE) that for 2011 the CO_2 footprint for military aviation in Australia was

[49] *Australian Petroleum Statistics-2011*, Table 3A, Department of Resources, Energy and Tourism. http://www.bree.gov.au/publications/aps/2011/index.html

583.21 kt CO_2 .[50] This therefore provides a figure of **17.23 Mt CO_2** for the carbon footprint of civil aviation in Australia in 2011.

UNFCCC reporting

The Australian Government Department of Climate Change and Energy Efficiency (DCCEE) reports Australia's CO_2 emissions under the UNFCCC on an annual basis. Reference to the Aegis database that underlies this reporting shows that for 2011 the carbon footprint for domestic civil aviation was 6.16 Mt CO_2[51] and for international aviation it was 10.33 Mt CO_2.[52] This gives the total civil aviation carbon footprint for 2011 = **16.49 Mt CO_2**.

These figures compare with the figure of **15.86 Mt CO_2** for the network carbon footprint computed in this report through applying TNIP Carbon Counter to the Innovata scheduled movements dataset.

Network Carbon Footprint 2011 CO_2 (Mt)		
Fuel Sales	**DCCEE**	**TNIP Carbon Counter**
17.23	16.49	15.86

The computed network carbon footprint reported in the earlier chapters (ie 15.86 Mt) is approximately **8% less** than the footprint derived from fuel sales data and about **4% less** than Australia's UNFCCC reported carbon footprint.

This validation can be further explored by examining the breakdown between the domestic and international components of the aircraft operations carbon footprint. As indicated above, DCCEE has published disaggregated CO_2 data for domestic and international aviation.[53]

Network Carbon Footprint 2011 CO_2 (Mt)		
	DCCEE	**TNIP Carbon Counter**
Domestic	6.2	6.6
International	10.3	9.3
TOTAL	**16.5**	**15.9**

This shows that the estimates computed in this report for the domestic carbon footprint are approximately **6.5% higher** than the figures contained in the National Greenhouse Accounts while the estimates for the international footprint are **lower by 9.7%**. It is interesting to view the figures for the domestic carbon footprint in the light of the airline CO_2 validation data presented in the next subsection.

[50] Military aviation fuel use: http://ageis.climatechange.gov.au/#
[51] Aegis Domestic aviation: http://ageis.climatechange.gov.au/Chart_KP.aspx?OD_ID=27152551629&TypeID=1
[52] Aegis International aviation: http://ageis.climatechange.gov.au/Chart_KP.aspx?OD_ID=27152509190&TypeID=1
[53] See references 51 and 52.

Validation at the Airline Level

Under the National Greenhouse and Energy Reporting Act 2007 (NGERS) major CO_2 emitters are required to provide information on their domestic greenhouse gas emissions to the Clean Energy Regulator on an annual basis. In the published emissions data for the year 2010-2011 Qantas and Virgin respectively reported the following weights of CO_2-e emissions.[54]

- Qantas (includes Jetstar): 4,362,807 t CO_2-e (scope 1)
- Virgin: 1,887,287 t CO_2-e (scope 1)

'Scope 1' essentially refers to emissions generated by the companies' use of liquid fuel. The reported values include emissions other than from jet fuel, for example operating Ground Service Equipment. However, both Qantas and Virgin have indicated that almost all the CO_2-e emissions reported under NGERS are associated with their jet fuel use. Qantas has stated that "Over 95% of the Qantas Group's global carbon footprint results from jet fuel consumed in flying operations" [55] while Virgin has indicated that "Our greenhouse gas emissions are by far our airline's most significant environmental impact. 98% of our emissions footprint is the result of aircraft fuel burn".[56] Applying the numbers in these statements, the carbon footprint from domestic aircraft operations for 2011 for Qantas is between **4,362,807** and **4,144,667 t CO_2-e** and for Virgin the carbon footprint can be taken to be **1,849,541 t CO_2-e**.

These figures compare with a figure of **4,250 kt CO_2** for domestic operations for the Qantas Group (includes Jetstar) and a figure of **1,858 kt CO_2** for Virgin computed using TNIP Carbon Counter (see Chapter 4).

Airline Carbon Footprint 2011 CO_2 (kt)		
	Qantas	**Virgin**
NGER Report	4,363-4,145	1,850
TNIP Carbon Counter	4,250	1,858

The difference between the NGERS figures and the computed airline carbon footprints reported in Chapter 4 for both Qantas and Virgin is **less than 1%** (taking the mid-point of the Qantas CO_2 range).

Validation at the Route Level

Validation of the carbon footprinting computations can be made at the route level by reference to recognised city-pair carbon calculators. The table below shows the comparison between the results of the output of the Qantas and ICAO carbon calculators[57,58] for three randomly selected routes and the computed carbon footprint shown for these routes shown in *Figure 50* (TNIP Carbon Counter). It can be seen that for these routes the TNIP carbon counter results lie in between the results of the other two calculators. [This comparison needs to be treated with caution since the first two columns relate solely to Qantas operations while the ICAO Carbon Calculator column shows a figure for all operators on the cited routes.]

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[54] *Greenhouse and Energy Information 2010-2011*, DCCEE. http://www.cleanenergyregulator.gov.au/National-Greenhouse-and-Energy-Reporting/Publication-of-NGER-data/greenhouse-and-energy-information/Greenhouse-and-Energy-information-2010-2011/Pages/default.aspx

[55] Qantas Scope 1 CO_2 emissions: See reference 34.

[56] Virgin Scope 1 CO2 emissions: http://www.virginaustralia.com/au/en/about-us/sustainability/environment/

[57] Qantas carbon calculator: https://www.qantas.com.au/travel/airlines/offset-my-flight/global/en

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

Table A3 in the Appendix contains CO_2 footprint information for every city-pair in the Innovata dataset and can be used for further validation if desired.

City-Pair	CO_2/PAX (kg)		
	Qantas Calculator	TNIP Carbon Counter	ICAO Carbon Calculator
Sydney-Los Angeles	1,388	1,273	984
Sydney-Melbourne	109	92	88
Sydney-Perth	320	312	265

It can be seen that at this more detailed level of interrogation the differences between the different carbon footprinting methods become much greater. For these routes the differences between the TNIP Carbon Counter numbers and the 'real' answer (ie the Qantas calculator) is **up to 15%**.

Validation for Derived Metrics

The CO_2 values shown in the previous subsections involve several assumptions which are inherent to great circle carbon footprinting techniques. It has been shown that this approach gives CO_2 values that are likely to be within 5-10% of the correct answer for high level database interrogations. However, when the CO_2 data is then taken and used to underpin other metrics such as CO_2/PAX or fuel use/RTK additional assumptions have to be made and the level of uncertainty in the answers increases. In particular, the use of 'per PAX' metrics requires assumptions about load factors and seat configurations while 'per RTK' metrics require additional assumptions about the weight of freight that is carried.

BITRE produces a number of publications which enable passenger numbers to be explored in detail if desired. Given the nature of this report, which is essentially a system level analysis, it was not considered necessary to delve into this area too deeply. However, preliminary examination of BITRE data[59] reveals the differences between TNIP Carbon Counter computations and the 'real' situation for passenger numbers for 2011 were generally **within about 2%** for the high level interrogations shown in the table. TNIP Carbon Counter generally produced a higher PAX figure than the published BITRE number.

Sector/Airport	2011 PAX	
	BITRE	TNIP
Domestic	54.52	54.76
International	13.97	14.27
Sydney	17.81	18.38
Melbourne	13.80	13.40
Brisbane	10.15	10.17
Perth	5.66	5.74

While the table shows generally good agreement between the two sets of figures, it is important to recognise that these levels of agreement are unlikely to be achieved when 'drilling down' in a dataset. When disaggregating, the seat configuration and load factor values can vary widely from company to company and route to route and hence large relative errors may well occur when examining small subsets of the data (although the magnitude of the absolute errors may not be significant).

[59] Airport Traffic Data. Bureau of Infrastructure, Transport and Regional Economics. http://www.bitre.gov.au/publications/ongoing/airport_traffic_data.aspx

6.4 Observations on the methodology

- The levels of agreement between the computed CO_2 values and the published validation points suggest that the computational approach adopted in this report can provide a reliable picture of the carbon footprint of aircraft operations across a network (say with an error in the 5-10% range for aggregated data).
- Australia has relatively low levels of charter aircraft activity. The use of scheduled aircraft movement datasets may not give reliable carbon footprinting results for regions of the world where there are high levels of non-scheduled aircraft movements.
- The level of agreement between the computed CO_2 emissions and the published emissions for Qantas and Virgin appear unreasonably close. Carbon footprinting for other years will be needed to test whether the results for 2011 are an aberration.
- More refined computations for the 'per person' metrics (eg fuel/PAX) could be carried out by using published company and/or route specific load factors and aircraft seat configurations. However, this would probably be of questionable value given the level of accuracy that is required to present a reliable overview carbon footprint picture of an aircraft operations system.
- This report is limited in that it is simply a one year snapshot of the Australian aircraft operations carbon footprint. On-going reports will be needed to track temporal change and to assess the success of any climate change management policies which have been adopted.
- The visualisations contained in the report may or may not provide useful carbon footprint insights for the reader. Pictures of aircraft operations carbon footprints can be provided using a large number of techniques – it is likely that over time preferred approaches will emerge as the capacity to gather, analyse and present data evolves.
- A relatively unsophisticated carbon footprinting methodology has intentionally been adopted in this report since the report is focussed on providing an overview 'carbon picture'. However, there are many footprinting avenues which are currently being explored which will require more detailed analysis. For example, it would appear that further work is required on understanding the computation of fuel efficiency across aircraft operations networks since ICAO has adopted fuel efficiency as a metric to track progress on the management of aviation's global carbon footprint.

APPENDIX

The Appendix contains three Tables:

Table A1: An alphabetical listing of the carbon footprints of all the airports contained in the scheduled movements dataset.

Table A2: An alphabetical listing of the carbon footprints of all the airlines contained in the scheduled movements dataset.

Table A3.1: An alphabetical listing of the carbon footprints of all the international city-pair combinations contained in the scheduled movements dataset.

Table A3.2: An alphabetical listing of the carbon footprints of all the domestic city-pair combinations contained in the scheduled movements dataset.

The data has been ordered alphabetically to enable rapid access to the CO_2 sources that are not shown in the hierarchy tables in the body of the report. Many of the entries have small absolute values and hence they may contain high relative errors. The 'CO_2/PAX' and '$/PAX' values have a greater level of uncertainty than the 'CO_2' values.

'CO_2 (kt)' refers to the total computed weight of CO_2 generated in the year 2011. The monetary values in *Table A3* have been computed using a carbon price of $23/tonne.

Table A.1: Airports

Airport	CO_2 (kt)	CO_2/PAX (kg)	Airport	CO_2 (kt)	CO_2/PAX (kg)
Adelaide	487.4	141.0	Kununurra	7.5	104.6
Albany	2.0	45.0	Launceston	41.8	82.1
Albury	11.1	61.7	Laverton	0.4	88.0
Alice Springs	52.0	161.1	Learmonth	6.7	142.9
Argyle	0.3	126.1	Leinster	0.6	166.0
Armidale	5.0	77.5	Leonora	1.5	148.4
Aurukun	1.1	147.9	Lismore	2.4	72.3
Avalon	39.6	117.9	Lockhart River	0.7	87.8
Ayers Rock	35.1	179.6	Longreach	2.5	117.9
Ballina	12.5	87.3	Lord Howe Island	2.2	113.4
Bamaga	1.6	176.2	Mackay	52.5	95.0
Barcaldine	0.2	27.3	Maningrida	2.4	80.6
Bathurst	0.7	26.4	Mcarthur River Mine	1.6	92.0
Bedourie	0.4	62.1	Meekatharra	0.8	165.7
Biloela	1.1	74.7	Melbourne	3,331.1	244.8
Birdsville	0.5	79.9	Merimbula	1.5	38.2
Blackall	0.3	37.1	Mildura	6.8	61.0
Boulia	0.5	72.2	Milingimbi	0.3	39.2
Brisbane	2,182.7	211.5	Moranbah	5.7	108.8
Broken Hill	2.7	70.9	Moree	1.4	74.1
Broome	42.3	168.3	Mornington Island	1.0	66.4
Bundaberg	3.6	53.6	Moruya	1.0	29.2
Burketown	0.3	43.4	Mount Gambier	2.6	47.5
Busselton	0.2	34.8	Mount Hotham	0.1	77.6
Cairns	392.1	192.8	Mount Isa	19.7	125.5
Canberra	146.3	77.3	Mount Magnet	0.3	75.3
Cape Barren Island	<0.1	61.3	Mudgee	0.7	85.0
Carnarvon	1.6	131.9	Narrabri	1.8	119.8
Ceduna	1.0	62.4	Narrandera	1.0	31.6
Charleville	1.7	87.1	Newcastle	50.1	91.2
Clermont	0.7	177.1	Mt Newman	18.3	122.3
Cloncurry	0.7	51.3	Normanton	1.6	101.9
Cobar	0.4	72.2	Olympic Dam	2.7	55.9
Coen	0.2	45.8	Orange	1.0	32.8
Coffs Harbour	11.5	62.3	Paraburdoo	17.9	137.0
Coober Pedy	0.7	84.5	Parkes	0.9	39.1
Cooma	0.4	108.1	Perth	1,680.9	287.6
Cunnamulla	0.5	76.9	Pormpuraaw	0.5	71.8
Curtin	3.6	166.5	Port Hedland	36.7	139.4
Darwin	234.3	203.8	Port Lincoln	5.4	40.2
Devonport	4.6	65.6	Port Macquarie	6.9	54.9
Doomadgee	1.1	70.4	Proserpine	9.1	101.9
Dubbo	6.2	56.7	Quilpie	0.5	72.4
Elcho Island	0.5	62.2	Ravensthorpe	0.4	50.6
Emerald	8.1	83.9	Richmond	1.3	159.0
Esperance	2.4	57.9	Rockhampton	29.6	70.9
Essendon	<0.1	122.1	Roma	4.6	80.3
Flinders Island	<0.1	79.2	Shark Bay	0.6	105.0
Geraldton	4.4	55.7	St George	0.6	92.4
Gladstone	10.2	55.7	Sunshine Coast	45.5	117.0
Gold Coast	379.3	161.6	Sydney	6,018.6	320.1
Gove	9.7	126.1	Tamworth	5.7	61.9
Grafton	0.9	37.6	Taree	1.8	38.4
Griffith	2.2	43.6	Tennant Creek	<0.1	69.3
Groote Eylandt	2.0	97.4	Thargomindah	0.2	64.7
Hamilton Island	29.8	130.5	Toowoomba	1.1	84.9
Hervey Bay	6.1	76.1	Townsville	95.2	109.7
Hobart	81.1	99.2	Wagga Wagga	6.9	52.1
Horn Island	4.2	108.5	Weipa	3.2	93.1
Hughenden	0.8	98.2	Whyalla	1.4	36.7
Julia Creek	0.8	100.4	Wiluna	0.2	62.7
Kalbarri	0.3	71.1	Windorah	0.5	84.9
Kalgoorlie	13.4	85.0	Winton	0.2	44.4
Karratha	59.8	139.4	Wynyard	2.0	48.8
Karumba	<0.1	24.2	**Total**	**15,859.6**	**227.4**
King Island	0.4	40.1			
Kingscote	0.7	23.1			
Kowanyama	0.6	80.3			

Table A.2: Airlines

Airline	CO_2 (kt)	CO_2/PAX (kg)
Aerolineas Argentinas	9.2	255.4
Aeropelican	8.3	88.3
Air Asia X	142.4	617.6
Air Austral	24.6	1,019.1
Air Australia	55.5	330.9
Air Caledonie International	7.9	187.3
Air Canada	117.6	1,337.0
Air Cargo Express	13.5	314.5
Air China	138.9	909.6
Air Macau	0.1	359.6
Air Mauritius	18.5	737.3
Air Nauru	2.0	197.4
Air New Zealand	257.3	234.4
Air Niugini	32.3	181.7
Air North	31.2	95.6
Air Pacific	64.4	306.9
Air Tasmania	0.1	69.5
Air Vanuatu	12.7	207.1
Airlines of PNG	4.8	208.2
Asiana Airlines	75.3	907.0
Brindabella Airlines	24.6	102.1
British Airways	151.5	747.5
Cathay Pacific	572.0	670.0
China Airlines	65.1	537.3
China Eastern Airlines	104.9	711.2
China Southern	228.8	747.9
Continental Airlines	5.4	323.7
Delta Airlines	113.1	1,289.4
Emirates	919.8	755.6
Etihad	286.2	941.1
EVA Air	14.3	735.0
Garuda Indonesia	137.4	389.9
Hainan Airlines	16.8	807.5
Hawaiian Airlines	44.8	731.6
Indonesia AirAsia	39.0	205.4
Japan Air Lines	71.9	856.6
Jetstar	1,581.8	159.9
Korean Air	170.1	872.5
LAN Chile	18.1	255.4
MAS - Malaysian Airlines	389.9	614.7
Norfolk Air	6.7	167.2
Philippine Air Lines	47.5	613.0
Qantas	5,203.9	189.9
Qatar Airways	112.5	1,278.7
Regional Express	80.5	47.2
Royal Brunei Airlines	66.4	558.6
Silkair	0.0	271.8
Singapore Airlines	740.2	556.1
Skippers Aviation	10.7	141.6
Skytrans	24.6	102.6
Skywest	55.5	96.2
Solomon Airlines	4.6	193.1
South African Airways - SAA	63.5	811.9
Thai Airways	378.8	638.8
Tiger Airways	223.0	126.4
United Airlines	331.4	1,328.6
V Australia	277.0	1,328.0
Vietnam Airlines	95.7	736.9
Vincent Aviation	2.1	93.9
Virgin Atlantic	61.8	557.1
Virgin Australia	2,101.1	123.6
Total	**15,859.7**	**227.4**

Table A3.1: City-pairs: international

City-pair	CO_2 (kt)	$/PAX
Adelaide-Auckland	8.3	6.11
Adelaide-Baiyun	0.2	17.49
Adelaide-Denpasar	8. 1	7.14
Adelaide-Hong Kong	2.6	17.20
Adelaide-Kuala Lumpur	39.7	13.64
Adelaide-Singapore	63.4	11.62
Brisbane-Auckland	97.3	5.44
Brisbane-Baiyun	27.7	17.08
Brisbane-Bangkok	60.4	17.24
Brisbane-Brunei	35.1	13.60
Brisbane-Christchurch	29.8	4.92
Brisbane-Denpasar	30.1	8.81
Brisbane-Dubai	112.6	30.85
Brisbane-Dunedin	6.4	5.05
Brisbane-Faleolo	2.2	7.40
Brisbane-Hamilton	5.2	4.76
Brisbane-Henderson	8.3	4.49
Brisbane-Hong Kong	87.5	16.29
Brisbane-Honolulu	1.1	20.43
Brisbane-Kuala Lumpur	37.0	14.42
Brisbane-Los Angeles	196.6	29.44
Brisbane-Luganville	1.1	4.06
Brisbane-Manila	6.7	12.45
Brisbane-Nadi	24.6	5.33
Brisbane-Noumea	3.4	3.43
Brisbane-Phuket	16.3	17.69
Brisbane-Port Moresby	31.3	4.53
Brisbane-Port Vila	6.2	3.95
Brisbane-Queenstown	3.2	4.77
Brisbane-Seoul	41.1	18.25
Brisbane-Singapore	277.8	13.92
Brisbane-Taipei	36.5	15.40
Brisbane-Wellington	19.7	4.96
Cairns-Auckland	11.8	6.76
Cairns-Baiyun	0.6	14.23
Cairns-Guam	5.4	7.44
Cairns-Hong Kong	25.4	14.00
Cairns-Moro	0.2	3.59
Cairns-Osaka	24.4	14.60
Cairns-Port Moresby	8.7	2.58
Cairns-Shenzhen	0.1	12.06
Cairns-Tokyo	47.3	14.76
Darwin-Denpasar	16.8	3.39
Darwin-Dili	2.5	2.14
Darwin-Ho Chi Minh City	7.2	6.89
Darwin-Macau	0.1	9.40
Darwin-Manila	4.4	5.99
Darwin-Singapore	11.7	5.24
Gold Coast-Auckland	22.7	4.47
Gold Coast-Baiyun	0.2	15.31
Gold Coast-Christchurch	4.2	4.75
Gold Coast-Kuala Lumpur	47.1	16.29
Gold Coast-Osaka	43.0	18.05
Gold Coast-Queenstown	2.1	4.59
Gold Coast-Tokyo	38.2	18.10
Melbourne-Abu Dhabi	100.9	23.35
Melbourne-Auckland	117.3	5.85
Melbourne-Baiyun	68.9	16.93
Melbourne-Bangkok	158.2	16.83
Melbourne-Beijing	7.0	22.74
Melbourne-Brunei	22.7	14.16
Melbourne-Christchurch	25.6	4.77
Melbourne-Denpasar	52.5	9.39
Melbourne-Doha	112.5	29.41
Melbourne-Dubai	109.5	30.00
Melbourne-Dunedin	0.5	4.58
Melbourne-Ho Chi Minh City	45.8	16.76
Melbourne-Hong Kong	269.6	18.31
Melbourne-Honolulu	1.3	23.79
Melbourne-Jakarta	18.1	11.28
Melbourne-Johannesburg	5.3	26.55
Melbourne-Kuala Lumpur	229.9	15.48
Melbourne-Los Angeles	225.2	31.19
Melbourne-Manila	16.9	14.22
Melbourne-Mauritius	11.3	18.91
Melbourne-Nadi	23.0	7.38
Melbourne-Phuket	16.2	17.46
Melbourne-Port Vila	1.6	6.16
Melbourne-Pudong	88.2	17.52
Melbourne-Queenstown	4.7	4.35
Melbourne-Seoul	29.5	21.32
Melbourne-Singapore	380.5	14.01
Melbourne-Wellington	19.3	5.11
Perth-Auckland	31.5	9.88
Perth-Baiyun	3.1	13.17
Perth-Bangkok	20.2	13.35
Perth-Brunei	8.7	8.75
Perth-Denpasar	87.8	5.06
Perth-Dubai	167.8	22.14
Perth-Hong Kong	76.5	14.44
Perth-Jakarta	3.2	5.73
Perth-Johannesburg	63.5	18.67
Perth-Kota Kinabalu	6.7	7.92
Perth-Kuala Lumpur	87.2	10.46
Perth-Mauritius	7.3	14.63
Perth-Phuket	29.6	10.82
Perth-Singapore	171.3	8.30
Perth-Tokyo	6.6	15.06
Port Hedland-Denpasar	1.6	3.96
Sydney-Abu Dhabi	205.7	23.21
Sydney-Auckland	180.7	4.83
Sydney-Baiyun	127.9	17.55
Sydney-Bangkok	399.6	16.00
Sydney-Beijing	55.5	22.35
Sydney-Buenos Aires	68.0	29.94
Sydney-Christchurch	54.1	4.87
Sydney-Dallas/Fort Worth	67.3	35.23
Sydney-Denpasar	68.1	10.33
Sydney-Dubai	192.7	28.06
Sydney-Dunedin	0.6	4.27
Sydney-Faleolo	7.1	8.11
Sydney-Ho Chi Minh City	50.0	17.12
Sydney-Hong Kong	424.7	17.06
Sydney-Honolulu	118.2	18.60
Sydney-Jakarta	68.0	13.11
Sydney-Johannesburg	147.4	27.97
Sydney-Kuala Lumpur	142.3	16.06
Sydney-Los Angeles	721.4	29.94
Sydney-Manila	51.3	13.87
Sydney-Nadi	62.3	7.02
Sydney-Noumea	9.8	4.44
Sydney-Nukualofa	4.0	6.84
Sydney-Phuket	25.4	18.17
Sydney-Port Moresby	5.0	5.38
Sydney-Port Vila	8.7	4.96
Sydney-Pudong	154.4	17.49
Sydney-Queenstown	9.2	4.02
Sydney-Rarotonga	2.3	9.21
Sydney-Reunion	24.6	23.44
Sydney-Rotorua	2.3	4.58
Sydney-San Francisco	191.5	30.41
Sydney-Seoul	174.8	20.69
Sydney-Shenzhen	16.8	18.57
Sydney-Singapore	490.9	14.36

City-pair	CO_2 (kt)	$/PAX
Sydney-Taipei	34.7	15.59
Sydney-Tokyo	160.7	19.16
Sydney-Vancouver	117.6	30.75
Sydney-Wellington	34.6	4.52
Townsville-Denpasar	1.3	6.86

Table A3.2: City-pairs: domestic

City-pair	CO_2 (kt)	$/PAX
Adelaide-Alice Springs	6.10	2.95
Adelaide-Avalon	1.83	2.08
Adelaide-Brisbane	48.29	3.51
Adelaide-Broken Hill	1.05	1.21
Adelaide-Broome	0.87	4.95
Adelaide-Cairns	5.38	4.33
Adelaide-Canberra	10.37	2.46
Adelaide-Ceduna	1.00	1.43
Adelaide-Coober Pedy	0.65	1.94
Adelaide-Darwin	18.77	5.13
Adelaide-Gold Coast	12.04	3.49
Adelaide-Kalgoorlie	1.73	4.51
Adelaide-Kingscote	0.73	0.53
Adelaide-Melbourne	94.97	1.99
Adelaide-Mount Gambier	1.51	1.10
Adelaide-Olympic Dam	2.72	1.29
Adelaide-Perth	52.36	4.40
Adelaide-Port Lincoln	5.44	0.92
Adelaide-Sydney	98.00	2.76
Adelaide-Whyalla	1.42	0.84
Albany-Busselton	0.10	0.90
Albany-Perth	1.90	1.05
Albury-Canberra	0.21	0.83
Albury-Melbourne	0.96	0.90
Albury-Sydney	9.94	1.53
Albury-Wagga Wagga	<0.01	0.49
Alice Springs-Adelaide	6.10	2.95
Alice Springs-Avalon	0.28	3.94
Alice Springs-Ayers Rock	2.31	1.71
Alice Springs-Brisbane	2.41	4.06
Alice Springs-Cairns	5.48	4.07
Alice Springs-Darwin	10.15	3.76
Alice Springs-Kalgoorlie	0.02	4.06
Alice Springs-Melbourne	9.68	3.89
Alice Springs-Perth	7.01	5.23
Alice Springs-Sydney	8.57	4.15
Alice Springs-Tennant Creek	0.03	1.59
Argyle-Darwin	0.19	2.26
Argyle-Perth	0.10	5.91
Armidale-Brisbane	0.15	1.64
Armidale-Sydney	4.82	1.79
Aurukun-Cairns	1.12	3.42
Aurukun-Pormpuraaw	<0.01	1.45
Avalon-Adelaide	1.83	2.08
Avalon-Alice Springs	0.28	3.94
Avalon-Brisbane	12.21	3.18
Avalon-Gold Coast	3.24	3.09
Avalon-Mackay	0.37	4.02
Avalon-Perth	3.65	5.15
Avalon-Rockhampton	0.21	3.69
Avalon-Sydney	17.82	2.25
Ayers Rock-Alice Springs	2.31	1.71
Ayers Rock-Cairns	12.93	4.79
Ayers Rock-Perth	3.47	4.48
Ayers Rock-Sydney	16.44	4.46
Ballina-Grafton	<0.01	0.50
Ballina-Melbourne	2.37	2.95
Ballina-Newcastle	0.09	1.29

City-pair	CO_2 (kt)	$/PAX
Ballina-Sydney	10.03	1.88
Bamago-Cairns	1.57	4.05
Barcaldine-Longreach	0.20	0.63
Bathurst-Parkes	0.07	0.56
Bathurst-Sydney	0.64	0.61
Bedourie-Birdsville	0.20	1.45
Bedourie-Boulia	0.19	1.40
Biloela-Brisbane	1.09	1.72
Birdsville-Bedourie	0.20	1.45
Birdsville-Windorah	0.30	2.22
Blackall-Longreach	0.27	0.85
Boulia-Bedourie	0.19	1.40
Boulia-Mount Isa	0.26	1.92
Brisbane-Adelaide	48.33	3.52
Brisbane-Alice Springs	2.41	4.06
Brisbane-Armidale	0.15	1.64
Brisbane-Avalon	12.21	3.18
Brisbane-Barcaldine	0.92	2.85
Brisbane-Biloela	1.09	1.72
Brisbane-Blackall	0.86	2.71
Brisbane-Broome	1.88	6.40
Brisbane-Bundaberg	3.59	1.23
Brisbane-Cairns	73.30	3.17
Brisbane-Canberra	36.26	2.46
Brisbane-Charleville	0.46	2.54
Brisbane-Clermont	0.65	4.07
Brisbane-Coffs Harbour	0.50	1.19
Brisbane-Darwin	42.23	5.58
Brisbane-Emerald	8.12	1.93
Brisbane-Gladstone	8.96	1.36
Brisbane-Gold Coast	0.01	0.64
Brisbane-Hamilton Island	8.64	2.33
Brisbane-Hervey Bay	2.48	1.25
Brisbane-Hobart	8.07	3.77
Brisbane-Karratha	4.23	7.12
Brisbane-Launceston	6.61	3.58
Brisbane-Longreach	0.41	2.66
Brisbane-Lord Howe Island	0.30	2.53
Brisbane-Mackay	41.21	2.26
Brisbane-Melbourne	186.41	3.06
Brisbane-Moranbah	5.72	2.54
Brisbane-Moree	0.17	1.19
Brisbane-Mount Isa	11.60	3.40
Brisbane-Narrabri	0.37	2.63
Brisbane-Newcastle	22.68	2.07
Brisbane-Norfolk Island	2.76	3.84
Brisbane-Perth	133.24	7.03
Brisbane-Port Hedland	1.42	6.77
Brisbane-Port Macquarie	0.14	0.83
Brisbane-Proserpine	9.13	2.34
Brisbane-Rockhampton	23.70	1.68
Brisbane-Roma	4.05	1.93
Brisbane-Sydney	205.32	2.11
Brisbane-Tamworth	1.14	1.87
Brisbane-Toowoomba	0.30	1.11
Brisbane-Townsville	55.36	2.66
Broken Hill-Adelaide	1.05	1.21
Broken Hill-Dubbo	0.50	1.79
Broken Hill-Sydney	1.12	2.30
Broome-Adelaide	0.87	4.95
Broome-Brisbane	1.88	6.40
Broome-Darwin	1.20	3.02
Broome-Karratha	0.29	1.97
Broome-Kununurra	3.84	2.39
Broome-Learmonth	0.36	3.33
Broome-Melbourne	2.28	6.02
Broome-Perth	28.96	4.04

City-pair	CO_2 (kt)	$/PAX
Broome-Port Hedland	0.61	1.84
Broome-Sydney	1.98	6.48
Bundaberg-Brisbane	3.59	1.23
Burketown-Doomadgee	0.11	0.84
Burketown-Mornington Island	0.16	1.16
Bussleton-Albany	0.09	0.87
Bussleton-Perth	0.07	0.73
Cairns-Adelaide	5.38	4.33
Cairns-Alice Springs	5.48	4.07
Cairns-Aurukun	0.40	3.42
Cairns-Ayers Rock	12.97	4.79
Cairns-Bamago	1.53	4.05
Cairns-Brisbane	68.74	3.11
Cairns-Canberra	0.02	4.98
Cairns-Coen	0.51	2.64
Cairns-Darwin	12.87	3.48
Cairns-Gold Coast	10.78	3.84
Cairns-Gove	4.52	3.35
Cairns-Groote Eylandt	0.10	3.05
Cairns-Hamilton Island	1.37	2.14
Cairns-Horn Island	4.24	2.49
Cairns-Kowanyama	0.36	2.67
Cairns-Lockhart River	0.40	2.94
Cairns-Melbourne	42.94	4.41
Cairns-Mount Isa	1.37	4.18
Cairns-Normanton	0.97	2.86
Cairns-Perth	7.13	6.41
Cairns-Pormpuraaw	0.50	2.82
Cairns-Sydney	75.56	4.05
Cairns-Townsville	6.85	1.29
Cairns-Warren	0.01	4.87
Cairns-Weipa	3.22	2.14
Canberra-Adelaide	11.05	2.48
Canberra-Albury	0.21	0.83
Canberra-Brisbane	36.32	2.46
Canberra-Darwin	4.57	6.08
Canberra-Gold Coast	3.54	2.30
Canberra-Hobart	2.40	2.27
Canberra-Melbourne	41.06	1.52
Canberra-Newcastle	1.05	1.60
Canberra-Perth	12.34	5.98
Canberra-Sydney	30.82	1.06
Canberra-Tamworth	0.05	1.38
Canberra-Townsville	2.87	3.95
Cape Barren Island-Launceston	0.02	1.41
Carnarvon-Geraldton	0.28	2.11
Carnarvon-Paraburdoo	0.02	1.18
Carnarvon-Perth	1.26	3.80
Carnarvon-Shark Bay	0.07	1.22
Ceduna-Adelaide	1.00	1.43
Charleville-Brisbane	0.46	2.54
Charleville-Quilpie	0.22	1.65
Charleville-Roma	0.58	1.43
Charleville-Toowoomba	0.46	3.38
Clermont-Brisbane	0.65	4.07
Cloncurry-Mount Isa	0.22	0.60
Cloncurry-Townsville	0.53	1.94
Cobar-Sydney	0.43	1.66
Coen-Lockhart River	0.20	1.05
Coffs Harbour-Brisbane	0.49	1.19
Coffs Harbour-Melbourne	1.11	2.62
Coffs Harbour-Sydney	9.86	1.38
Coober Pedy-Adelaide	0.65	1.94
Cooma-Sydney	0.43	2.49
Cunnamulla-St George	0.28	2.05
Cunnamulla-Thargomindah	0.20	1.49
Curtin-Perth	3.64	3.83

City-pair	CO_2 (kt)	$/PAX
Darwin-Adelaide	18.77	5.13
Darwin-Alice Springs	10.15	3.76
Darwin-Argyle	0.19	2.26
Darwin-Brisbane	41.83	5.57
Darwin-Broome	1.21	3.02
Darwin-Cairns	12.71	3.49
Darwin-Canberra	4.57	6.08
Darwin-Elcho Island	<0.01	1.42
Darwin-Gove	4.60	2.75
Darwin-Groote Eylandt	1.27	2.45
Darwin-Kununurra	1.95	1.54
Darwin-Maningrida	1.63	2.54
Darwin-Mcarthur River Mine	1.62	2.12
Darwin-Melbourne	31.55	5.49
Darwin-Milingimbi	<0.01	1.27
Darwin-Mount Isa	0.86	3.15
Darwin-Perth	19.58	5.27
Darwin-Rockhampton	0.10	5.59
Darwin-Sydney	39.01	6.03
Devonport-Melbourne	4.59	1.51
Doomadgee-Burketown	0.11	0.84
Doomadgee-Mornington Island	0.25	1.28
Doomadgee-Mount Isa	0.72	2.12
Dubbo-Broken Hill	0.50	1.79
Dubbo-Sydney	5.71	1.27
Elcho Island-Darwin	<0.01	1.42
Elcho Island-Maningrida	0.46	1.43
Emerald-Brisbane	8.12	1.93
Esperance-Perth	2.23	1.50
Esperance-Ravensthorpe	0.19	0.58
Essendon-Flinders Island	<0.01	2.81
Flinders Island-Essendon	<0.01	2.81
Flinders Island-Launceston	0.01	1.63
Geraldton-Carnarvon	0.23	1.99
Geraldton-Kalbarri	0.02	0.52
Geraldton-Kalgoorlie	0.04	2.73
Geraldton-Learmonth	0.09	1.75
Geraldton-Perth	3.60	1.17
Geraldton-Port Hedland	0.44	3.02
Geraldton-Shark Bay	0.01	0.99
Gladstone-Brisbane	9.75	1.37
Gladstone-Mackay	0.05	1.32
Gladstone-Rockhampton	0.43	0.53
Gold Coast-Adelaide	12.00	3.49
Gold Coast-Avalon	3.24	3.09
Gold Coast-Cairns	10.82	3.84
Gold Coast-Canberra	3.54	2.30
Gold Coast-Hobart	6.20	3.67
Gold Coast-Launceston	0.04	3.43
Gold Coast-Melbourne	87.95	2.86
Gold Coast-Mount Isa	1.04	3.80
Gold Coast-Newcastle	4.00	1.78
Gold Coast-Perth	7.00	6.72
Gold Coast-Sydney	84.44	1.97
Gold Coast-Townsville	1.68	2.95
Gove-Cairns	4.52	3.35
Gove-Darwin	4.60	2.75
Gove-Groote Eylandt	0.59	1.82
Grafton-Ballina	<0.01	0.50
Grafton-Sydney	<0.01	1.34
Grafton-Taree	0.89	0.87
Griffith-Melbourne	0.44	1.15
Griffith-Narrandera	0.21	0.35
Griffith-Sydney	1.51	1.30
Groote Eylandt-Cairns	0.11	3.05
Groote Eylandt-Darwin	1.26	2.45
Groote Eylandt-Gove	0.59	1.82

City-pair	CO_2 (kt)	$/PAX
Hamilton Island-Brisbane	8.64	2.33
Hamilton Island-Cairns	1.37	2.14
Hamilton Island-Melbourne	6.82	4.08
Hamilton Island-Sydney	12.92	3.33
Hervey Bay-Brisbane	2.48	1.25
Hervey Bay-Sydney	3.63	2.42
Hobart-Brisbane	8.07	3.77
Hobart-Canberra	2.40	2.27
Hobart-Gold Coast	6.20	3.67
Hobart-Melbourne	40.47	1.90
Hobart-Sydney	23.93	2.57
Horn Island-Cairns	4.24	2.49
Hughenden-Julia Creek	<0.01	0.90
Hughenden-Richmond	0.64	3.53
Hughenden-Townsville	0.18	1.00
Julia Creek-Hughenden	<0.01	0.90
Julia Creek-Mount Isa	0.16	0.85
Julia Creek-Richmond	0.69	3.79
Kalbarri-Carnarvon	0.05	2.41
Kalbarri-Geraldton	0.03	0.52
Kalbarri-Perth	0.06	3.07
Kalbarri-Shark Bay	0.19	1.77
Kalgoorlie-Adelaide	1.73	4.51
Kalgoorlie-Geraldton	0.03	2.73
Kalgoorlie-Melbourne	1.14	6.31
Kalgoorlie-Perth	10.54	1.67
Karratha-Brisbane	4.19	7.12
Karratha-Broome	0.29	1.97
Karratha-Geraldton	0.10	2.07
Karratha-Learmonth	0.05	0.97
Karratha-Melbourne	1.90	6.34
Karratha-Perth	51.00	3.01
Karratha-Port Hedland	0.26	0.93
Karratha-Sydney	2.06	7.00
Karumba-Normanton	0.01	0.56
King Island-Melbourne	0.40	0.90
King Island-Wynyard	0.02	1.81
Kingscote-Adelaide	0.73	0.53
Kowanyama-Cairns	0.48	2.67
Kowanyama-Pormpuraaw	0.10	0.76
Kununurra-Argyle	<0.01	0.86
Kununurra-Broome	3.51	2.35
Kununurra-Darwin	1.96	1.55
Kununurra-Perth	2.05	5.60
Launceston-Brisbane	6.57	3.58
Launceston-Cape Barren Island	0.02	1.41
Launceston-Flinders Island	0.01	1.63
Launceston-Gold Coast	0.02	3.43
Launceston-Melbourne	24.56	1.55
Launceston-Perth	0.03	5.77
Launceston-Sydney	10.54	2.38
Launceston-Wynyard	<0.01	1.36
Laverton-Leonora	0.16	1.21
Laverton-Perth	0.22	4.07
Learmonth-Broome	0.36	3.33
Learmonth-Geraldton	0.09	1.75
Learmonth-Karratha	0.05	0.97
Learmonth-Paraburdoo	0.04	1.93
Learmonth-Perth	6.12	3.44
Learmonth-Shark Bay	0.02	1.10
Leinster-Perth	0.62	3.82
Leonora-Laverton	0.07	1.21
Leonora-Perth	1.46	3.72
Lismore-Sydney	2.38	1.66
Lockhart River-Aurukun	0.32	1.53
Lockhart River-Bamago	<0.01	1.79
Lockhart River-Cairns	0.34	2.94

City-pair	CO_2 (kt)	$/PAX
Longreach-Brisbane	2.39	3.00
Longreach-Townsville	0.04	1.41
Longreach-Winton	0.06	0.66
Lord Howe Island-Brisbane	0.30	2.53
Lord Howe Island-Pt Macquarie	0.08	2.16
Lord Howe Island-Sydney	1.80	2.65
Mackay-Avalon	0.37	4.02
Mackay-Brisbane	41.21	2.26
Mackay-Gladstone	0.05	1.37
Mackay-Melbourne	1.78	3.95
Mackay-Rockhampton	1.87	1.17
Mackay-Sydney	3.73	3.33
Mackay-Townsville	3.51	1.40
Maningrida-Darwin	1.63	2.54
Maningrida-Elcho Island	0.46	1.43
Maningrida-Milingimbi	0.29	0.90
Mcarthur River Mine	1.62	2.12
Meekatharra-Perth	0.83	3.81
Melbourne-Adelaide	81.94	1.90
Melbourne-Albury	1.01	0.90
Melbourne-Alice Springs	9.68	3.89
Melbourne-Ballina	2.37	2.95
Melbourne-Brisbane	188.06	3.06
Melbourne-Broome	2.28	6.02
Melbourne-Cairns	42.97	4.41
Melbourne-Canberra	40.98	1.52
Melbourne-Coffs Harbour	1.10	2.62
Melbourne-Darwin	31.52	5.49
Melbourne-Devonport	4.59	1.51
Melbourne-Gold Coast	87.96	2.86
Melbourne-Griffith	0.44	1.15
Melbourne-Hamilton Island	6.82	4.08
Melbourne-Hobart	40.58	1.89
Melbourne-Kalgoorlie	1.14	6.31
Melbourne-Karratha	1.90	6.34
Melbourne-King Island	0.40	0.90
Melbourne-Launceston	24.54	1.55
Melbourne-Mackay	1.78	3.95
Melbourne-Merimbula	0.64	1.26
Melbourne-Mildura	6.82	1.40
Melbourne-Mount Gambier	1.12	1.08
Melbourne-Newcastle	19.79	2.31
Melbourne-Norfolk Island	1.29	5.48
Melbourne-Perth	208.13	5.70
Melbourne-Port Hedland	1.80	6.13
Melbourne-Rockhampton	0.83	3.60
Melbourne-Sunshine Coast	23.17	3.21
Melbourne-Sydney	325.28	2.07
Melbourne-Townsville	5.24	4.22
Melbourne-Wagga Wagga	0.93	1.09
Melbourne-Wynyard	1.96	1.12
Merimbula-Melbourne	0.64	1.26
Merimbula-Moruya	0.37	0.50
Merimbula-Sydney	0.52	1.06
Mildura-Melbourne	6.82	1.40
Milingimbi-Darwin	<0.01	1.27
Milingimbi-Maningrida	0.29	0.90
Moranbah-Brisbane	5.64	2.53
Moranbah-Emerald	<0.01	0.74
Moranbah-Townsville	0.06	1.38
Moree-Brisbane	0.17	1.19
Moree-Sydney	1.23	1.81
Mornington Island-Burketown	0.16	1.16
Mornington Island-Doomadgee	0.26	1.28
Mornington Island-Karumba	0.03	1.62
Mornington Island-Normanton	0.58	1.84

City-pair	CO_2 (kt)	$/PAX
Moruya-Merimbula	0.40	0.50
Moruya-Sydney	0.64	0.86
Mount Gambier-Adelaide	1.51	1.10
Mount Gambier-Melbourne	1.12	1.08
Mount Hotham-Sydney	0.14	1.79
Mount Isa-Boulia	0.26	1.92
Mount Isa-Brisbane	11.60	3.40
Mount Isa-Cairns	1.48	4.18
Mount Isa-Cloncurry	0.16	0.55
Mount Isa-Darwin	0.86	3.15
Mount Isa-Doomadgee	0.70	2.12
Mount Isa-Gold Coast	1.04	3.80
Mount Isa-Julia Creek	0.16	0.85
Mount Isa-Townsville	3.47	2.19
Mount Magnet-Meekatharra	0.28	1.73
Mudgee-Narrabri	0.01	2.17
Mudgee-Sydney	0.66	1.95
Narrabri-Brisbane	0.37	2.63
Narrabri-Mudgee	0.02	2.17
Narrabri-Newcastle	0.25	2.51
Narrabri-Sydney	1.16	2.87
Narrandera-Griffith	0.28	0.35
Narrandera-Sydney	0.74	1.23
Newcastle-Ballina	0.09	1.29
Newcastle-Brisbane	22.69	2.07
Newcastle-Canberra	1.05	1.60
Newcastle-Gold Coast	4.00	1.78
Newcastle-Melbourne	19.79	2.31
Newcastle-Narrabri	0.25	2.51
Newcastle-Norfolk Island	0.83	4.07
Newcastle-Sydney	1.38	1.29
Newman-Broome	0.01	1.90
Newman-Perth	18.30	2.81
Normanton-Cairns	0.94	2.86
Normanton-Mornington Island	0.62	1.84
Olympic Dam-Adelaide	2.72	1.29
Orange-Sydney	1.04	0.75
Paraburdoo-Carnarvon	0.02	1.18
Paraburdoo-Learmonth	0.04	1.93
Paraburdoo-Newman	0.01	1.41
Paraburdoo-Perth	17.84	3.16
Parkes-Bathurst	0.07	0.56
Parkes-Sydney	0.86	0.95
Perth-Adelaide	52.51	4.38
Perth-Albany	1.90	1.05
Perth-Alice Springs	7.03	5.23
Perth-Avalon	3.65	5.15
Perth-Ayers Rock	3.47	4.48
Perth-Brisbane	131.76	7.04
Perth-Broome	28.61	4.03
Perth-Bussleton	0.07	0.73
Perth-Cairns	7.13	6.41
Perth-Canberra	12.24	6.20
Perth-Carnarvon	1.15	3.88
Perth-Christmas Island	3.76	5.32
Perth-Cocos Island	0.92	6.07
Perth-Curtin	3.64	3.83
Perth-Darwin	19.58	5.27
Perth-Esperance	2.72	1.50
Perth-Geraldton	3.60	1.17
Perth-Gold Coast	6.79	6.72
Perth-Kalbarri	0.35	2.84
Perth-Kalgoorlie	10.52	1.67
Perth-Karratha	51.09	3.01
Perth-Kununurra	2.48	5.68
Perth-Launceston	0.03	5.77
Perth-Laverton	0.55	4.07

City-pair	CO_2 (kt)	$/PAX
Perth-Learmonth	6.12	3.44
Perth-Leonora	1.09	3.72
Perth-Melbourne	207.56	5.65
Perth-Mount Magnet	0.48	2.94
Perth-Newman	18.28	2.81
Perth-Paraburdoo	17.84	3.16
Perth-Port Hedland	30.68	3.13
Perth-Shark Bay	0.21	2.90
Perth-Sydney	271.50	7.14
Perth-Wiluna	0.66	4.07
Pormpuraaw-Cairns	0.38	2.82
Pormpuraaw-Kowanyama	0.14	0.76
Port Hedland-Brisbane	1.42	6.77
Port Hedland-Broome	0.60	1.83
Port Hedland-Geraldton	0.32	3.41
Port Hedland-Karratha	0.29	0.90
Port Hedland-Melbourne	1.80	6.13
Port Hedland-Perth	30.65	3.13
Port Lincoln-Adelaide	5.44	0.92
Port Macquarie-Brisbane	0.14	0.83
Pt Macquarie-Lord Howe Island	0.08	2.16
Port Macquarie-Sydney	6.72	1.27
Proserpine-Brisbane	9.13	2.34
Quilpie-Charleville	0.22	1.65
Quilpie-Windorah	0.23	1.68
Ravensthorpe-Perth	0.38	1.16
Richmond-Hughenden	0.64	3.53
Richmond-Julia Creek	0.69	3.79
Rockhampton-Avalon	0.21	3.69
Rockhampton-Brisbane	22.78	1.68
Rockhampton-Gladstone	0.75	0.52
Rockhampton-Mackay	1.87	1.17
Rockhampton-Melbourne	0.83	3.60
Rockhampton-Sydney	1.99	2.87
Rockhampton-Townsville	1.21	1.85
Roma-Brisbane	4.05	1.93
Roma-Charleville	0.58	1.43
Shark Bay-Carnarvon	0.08	1.04
Shark Bay-Kalbarri	0.05	1.41
Shark Bay-Learmonth	0.02	1.10
Shark Bay-Perth	0.48	3.62
St George-Cunnamulla	0.28	2.05
St George-Toowoomba	0.30	2.20
Sunshine Coast-Melbourne	23.17	3.21
Sunshine Coast-Sydney	22.36	2.30
Sydney-Adelaide	97.22	2.76
Sydney-Albury	9.94	1.53
Sydney-Alice Springs	8.57	4.15
Sydney-Armidale	4.82	1.79
Sydney-Avalon	17.82	2.25
Sydney-Ayers Rock	16.42	4.46
Sydney-Ballina	10.03	1.88
Sydney-Bathurst	0.64	0.61
Sydney-Brisbane	198.73	2.09
Sydney-Broken Hill	1.12	2.30
Sydney-Broome	1.98	6.48
Sydney-Cairns	75.78	4.05
Sydney-Canberra	31.18	1.06
Sydney-Cobar	0.43	1.66
Sydney-Coffs Harbour	9.86	1.38
Sydney-Cooma	0.43	2.49
Sydney-Darwin	39.09	6.03
Sydney-Dubbo	5.70	1.27
Sydney-Gold Coast	84.46	1.97
Sydney-Grafton	0.01	1.34
Sydney-Griffith	1.26	1.30

City-pair	CO_2 (kt)	$/PAX
Sydney-Hamilton Island	12.92	3.33
Sydney-Hervey Bay	3.63	2.42
Sydney-Hobart	23.90	2.57
Sydney-Kalgoorlie	0.03	5.49
Sydney-Karratha	2.06	7.00
Sydney-Launceston	10.54	2.38
Sydney-Lismore	2.37	1.66
Sydney-Lord Howe Island	1.80	2.65
Sydney-Mackay	3.73	3.33
Sydney-Melbourne	326.43	2.07
Sydney-Merimbula	0.48	1.06
Sydney-Moree	1.23	1.81
Sydney-Moruya	0.69	0.86
Sydney-Mount Hotham	0.14	1.79
Sydney-Mudgee	0.66	1.95
Sydney-Narrabri	1.17	2.87
Sydney-Narrandera	0.97	1.23
Sydney-Newcastle	1.60	1.25
Sydney-Norfolk Island	1.66	4.23
Sydney-Orange	1.04	0.75
Sydney-Parkes	0.86	0.95
Sydney-Perth	269.46	7.09
Sydney-Port Macquarie	6.72	1.27
Sydney-Rockhampton	2.05	2.89
Sydney-Sunshine Coast	22.36	2.30
Sydney-Tamworth	4.47	1.34
Sydney-Taree	0.93	0.90
Sydney-Townsville	12.77	3.61
Sydney-Wagga Wagga	5.93	1.22
Tamworth-Brisbane	1.14	1.87
Tamworth-Canberra	0.05	1.38
Tamworth-Sydney	4.47	1.34
Taree-Grafton	0.89	0.87
Taree-Sydney	0.93	0.90
Tennant Creek-Alice Springs	0.03	1.59
Thargomindah-Cunnamulla	0.20	1.49

City-pair	CO_2 (kt)	$/PAX
Toowoomba-Brisbane	0.30	1.11
Toowoomba-Charleville	0.46	3.38
Toowoomba-St George	0.30	2.20
Townsville-Brisbane	55.38	2.66
Townsville-Cairns	6.79	1.28
Townsville-Canberra	2.87	3.95
Townsville-Cloncurry	0.74	2.16
Townsville-Gold Coast	1.68	2.95
Townsville-Horn Island	0.01	4.00
Townsville-Hughenden	0.18	1.00
Townsville-Longreach	0.04	1.41
Townsville-Mackay	3.51	1.40
Townsville-Melbourne	5.24	4.22
Townsville-Moranbah	0.06	1.38
Townsville-Mount Isa	3.34	2.17
Townsville-Rockhampton	1.21	1.85
Townsville-Sydney	12.77	3.61
Townsville-Winton	0.13	1.38
Wagga Wagga-Albury	<0.01	0.49
Wagga Wagga-Melbourne	0.93	1.09
Wagga Wagga-Sydney	5.93	1.22
Weipa-Cairns	3.22	2.14
Whyalla-Adelaide	1.42	0.84
Wiluna-Leinster	0.23	1.44
Windorah-Birdsville	0.30	2.22
Windorah-Quilpie	0.23	1.68
Winton-Longreach	0.06	0.66
Winton-Townsville	0.13	1.38
Wynyard-King Island	0.02	1.81
Wynyard-Launceston	<0.01	1.36
Wynyard-Melbourne	1.96	1.12

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.[60] In 2008 Dave was awarded the Australian Government *Public Service Medal* (PSM) for his work in this area.[61]

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.[62]

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

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[60] *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

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

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