Aviation and Greenhouse Gas Emissions in the ACT

Research Paper No. 50

January 2008

Andrew Macintosh[1] and Christian Downie[2]

Summary

The aviation market in the ACT has experienced rapid growth in recent times. Over the past decade, passenger numbers at Canberra International Airport grew at four per cent per annum, reaching 2.7 million in 2007. Fuelled by falling prices and rising incomes, the growth in aviation is projected to continue. Capital Airport Group Pty Ltd (CAG) expects annual passenger numbers to increase to between 6.2 and 7.9 million by 2028. To service this growth in passenger numbers, annual aircraft movements at Canberra Airport would have to rise from their current level of 81,732 to between 136,209 and 180,551. By 2050, it is projected by consultants engaged by the Airport's managers that more than 700 aircraft will arrive and depart Canberra Airport every day, including almost 70 international passenger flights. The vision for Canberra Airport is to convert it into an international, domestic and regional aviation hub.

The ACT Government has established a long-term target to reduce the Territory's greenhouse gas emissions by 60 per cent on 2000 levels by 2050.To date, no assessment has been made of the impact the expansion of air services at Canberra Airport could have on the potential to achieve this emission target. The objective of this paper is to partially fill this void by projecting the ACT's passenger-related aviation emissions over the period 2005 – 2050 using data published by CAG and its related entities.

Key findings include the following.

- Domestic passenger-related emissions are projected to increase by 297 per cent, rising from 117,000 tonnes of carbon dioxide equivalent (t CO_2-e) in 2005 to 465,000 t CO_2-e in 2050.

[1] Andrew Macintosh is Associate Director of the ANU Centre for Climate Law and Policy.
[2] The authors wish to thank Dr Hugh Saddler for his detailed comments on a draft of this paper. The final paper is the responsibility of the authors.

- International passenger-related emissions are projected to be 187,000 t CO_2-e in 2025 and 3.14 million tonnes (Mt) CO_2-e in 2050.

- By 2025, aviation emissions are projected to account for nine per cent of the Territory's total emission allowance under the ACT Climate Change Strategy.

- By 2050, aviation emissions are projected to be twice as large as the ACT's total emission allowance, accounting for 216 per cent of its permitted emissions.

The implication of these findings is that if CAG's plans for Canberra Airport are realised, and aviation emissions are included in the accounting framework under the ACT Climate Change Strategy, the Territory's emission reduction target is likely to be unachievable.

To limit demand and promote technological innovation, aviation emissions (confined to CO_2 emissions and emissions of the other five main direct greenhouse gases) should be included in the proposed national emissions trading scheme. The inclusion of international aviation emissions in the scheme should preferably be done in collaboration with the International Civil Aviation Organization (ICAO). The design of the scheme should also be consistent with the proposal to include international aviation emissions in the European Union's emission trading scheme.

The inclusion of aviation emissions in the emissions trading scheme will not be sufficient to achieve the desired environmental outcomes. Additional measures will be necessary to control non-CO_2 emissions. These measures could include non-CO_2 emission taxes and emission standards for new aircraft and engines.

Prior to the emissions trading scheme reaching maturity, there is a risk of unsustainable investments being made in the aviation industry. This could result in assets being stranded when emission caps are introduced and subsequently tightened. The resulting financial losses and employment impacts could create political barriers to the introduction of effective greenhouse policies.

To reduce these risks, the Federal Government should consider the immediate introduction of a flat-rate greenhouse charge on all domestic flights. New airport developments and airport master plans should also be subject to formal statutory environmental assessment procedures that require the evaluation of the greenhouse implications of the relevant actions and related increases in aviation traffic.

1. Introduction

International and domestic aviation markets have grown considerably in recent decades. Between 1960 and the mid-1990s, world-wide air passenger traffic grew by almost nine per cent per annum, 2.4 times the average growth rate of GDP (IPCC 1999). Total domestic and international passenger numbers in Australia are now in excess of 60 million, an increase of more than 50 per cent since 1996 (BTRE 2006). The aviation market in the Australian Capital Territory (ACT) has mirrored the national trends. Over the past decade, passenger numbers at Canberra International Airport (hereafter referred to as Canberra Airport) grew at four per cent per annum, reaching 2.7 million in 2007 (CAG 2005; CIA 2007; BTRE 2007a).[3]

The managers of the airport, the Capital Airport Group Pty Ltd (CAG), have stated that their 'long-term aim is to grow Canberra International Airport into a true international, domestic and regional hub' (CAG 2005, p. 22). However, no detailed assessment has been made of the impact the further expansion of Canberra Airport could have on the implementation of the ACT Climate Change Strategy. National projections indicate that if aviation continues to expand under business-as-usual conditions, Australia is unlikely to be able to meet future emission reduction targets (Macintosh and Downie 2007). If CAG's vision for Canberra Airport is realised, aviation could pose a similar threat to the achievement of abatement targets for the ACT.

This paper considers whether the forecast expansion of Canberra Airport is consistent with the ACT Climate Change Strategy. To do this, the paper makes projections of the ACT's passenger-related aviation emissions over the period 2005 – 2050, compares the projections to the ACT Government's abatement target for 2050, and considers the implications for the strategy.

2. The ACT Climate Change Strategy

It is now widely accepted that human-induced climate change is occurring and that steps need to be taken to significantly reduce greenhouse gas emissions. Since 1950 average Australian temperatures have increased by 0.9°C. The CSIRO predicts that by 2030, average temperatures over Australia will be 1.0°C above 1990 levels (CSIRO 2007). If global emissions continue on their current trajectory, the CSIRO's projections suggest average temperatures over Australia will be between 1.5 – 2.8°C above 1990 levels in 2050 and 2.2 – 5.0°C above 1990 levels in 2070. Temperature increases of this magnitude could have many adverse affects on south-eastern Australia, including more frequent droughts and bushfires, declining water availability and quality, increases in climate-related morbidity and mortality, the inundation of low-lying coastal areas and the loss of biodiversity (CSIRO 2007).

In 2007, the ACT Government launched a Climate Change Strategy that sets out the plan of action for the Territory for addressing the threats posed by global warming.

[3] Aviation and emission statistics are generally reported on a financial year basis. In this paper, all references to years in the context of aviation and emission statistics refer to the financial year ending in the stated year unless otherwise indicated. For example, the reference to passenger movements in 1983 relates to movements in 1982-83.

The strategy is aimed at both emission abatement and promoting adaptation to the changing climatic conditions. It states:

> Our goal is to stabilise (and over time reduce) emissions, so as to prevent further and possibly catastrophic changes to our climate, and to prepare ourselves to deal with the changes now occurring and likely to occur over the next 30 to 50 years (DTMS 2007, p. 21).

The strategy also contains two emission reduction targets. They are as follows.

- By 2025, return the Territory's emissions to year 2000 levels (i.e. 4,059,000 tonnes of carbon dioxide equivalent (t CO_2-e)).

- By 2050, reduce the Territory's emissions by 60 per cent on 2000 levels (i.e. 1,623,400 t CO_2-e) (DTMS 2007).

To achieve these targets, the strategy outlines a number of principles and objectives to encourage and direct mitigation efforts. The strategy is also backed by an action plan for the period 2007 – 2011, which details 43 separate action items that are designed to assist in the achievement of the strategy's objectives.

3. Canberra Airport

Canberra Airport has experienced steady growth since it was privatised in 1998 (May and Hill 2006). According to the Bureau of Transport and Regional Economics (BTRE), between 1996 and 2006 the number of passengers passing through the airport increased from 1.75 million to 2.55 million, an increase of 46 per cent (BTRE 2007a). Consultants engaged by CAG have projected passenger numbers will grow from 2.69 million in 2007 to between 6.21 and 7.92 million in 2028. They also expect the number of annual aircraft movements to jump from 81,732 in 2006 to between 136,209 and 180,551 in 2028 (CIA 2007).

The increase in air traffic is being pursued by CAG as a means of increasing the output and profitability of its airport assets. CAG also believes expansion of the airport will bring economic benefits to the wider Canberra region. In the Preliminary Draft of the 2008 Master Plan, Canberra International Airport Pty Ltd (CIA), a related entity of CAG and the holder of the airport lease, states:

> Our vision is to develop Canberra International Airport as a first-class facility to serve the region's evolving transportation, business and development needs and to maximise the growth of a wide range of aeronautical and non-aeronautical businesses (CIA 2007, p. 9).

The airport's growth is expected to be driven by a number of factors. Increasing domestic demand for aviation services is an important pillar of the growth strategy. CAG also intends to develop Canberra Airport as an overflow for Sydney Airport as it reaches capacity. This includes a proposal to develop Canberra Airport as a 24 hour a day freight hub targeting Australian capital cities and New Zealand, thereby taking advantage of the curfew restrictions at Sydney Airport. Another driver of the airport's growth is expected to be international services. CAG is hoping to promote international flights to several locations in the Pacific region, including New Zealand, Bangkok, Hong Kong, Tokyo and Los Angeles (CAG 2005; CIA 2007).

To accommodate the growth in air traffic and to facilitate the development of international services, CAG is planning to invest in additional infrastructure at the airport. The development options being considered include:

- extension of the main runway (Runway 17/35);
- construction of a parallel runway to Runway 17/35;
- extension and strengthening of the cross runway (Runway 12/30);
- taxiway expansion;
- adjustment and augmentation of the Instrument Landing System and associated navigational aids;
- installation of a new Air Traffic Control tower; and
- expansion of the terminal building (CIA 2007).

It is anticipated that investments in aviation infrastructure will be complemented by expansion of the airport precinct and associated businesses. The Preliminary Draft 2008 Master Plan states that additional facilities could include structured car parks, hotels, showrooms, conference facilities, offices and food and retail outlets (CIA 2007).

4. Aviation emissions[4]

The main greenhouse gas emitted by aircraft is carbon dioxide (CO_2). CO_2 is a direct greenhouse gas that mixes well in the atmosphere and has a long atmospheric lifetime. It is the primary driver of human-induced climate change and its impacts on the climate system are relatively well-understood.

Other greenhouse gases emitted by aircraft include water vapour (H_2O), nitrogen oxides (NO_x) and volatile organic compounds (VOCs). The level of scientific understanding about the impacts of these so-called non-CO_2 aviation emissions is lower than that associated with CO_2. This is partly due to the fact that many of the gases have short atmospheric lifetimes and their impacts vary depending on when and where they are released. In particular, the release of several of these gases at altitude can magnify warming impacts on the climate (IPCC 1999).

In research on the impacts of aviation on the climate system, it is not uncommon for ‘uplift factors’ to be used to account for the effects of non-CO_2 emissions. CO_2 emissions from aviation are multiplied by the relevant uplift factor to provide an estimate of the total impact of aviation emissions. In 1999, the Intergovernmental Panel on Climate Change (IPCC) concluded in a special report on aviation that the

[4] This section draws on a more detailed discussion in Macintosh and Downie (2007).

total radiative forcing associated with aviation emissions was approximately two to four times larger (with a best estimate of 2.7 times larger) than the effects related to aviation CO_2 emissions alone (IPCC 1999). On this basis, several studies have applied uplift factors of between 2.5 and 2.7 in estimating aviation emissions and their contribution to climate change (Bows *et al.* 2005; DFT 2004; SCEA 2004). However, there is debate about whether uplift factors should be applied and, if so, which metric most accurately approximates the total climate impact of non-CO_2 emissions. Recent studies indicate that the appropriate uplift factor could range between 1.7 and 5.1 times aviation CO_2 emissions depending on the timescales of the analysis (Sausen *et al.* 2005; Foster *et al.* 2005).

In projecting aviation emissions, this paper uses an uplift factor of 1.7. This metric was adopted because the object was to use an uplift factor that provides an estimate of the impact of all aviation emissions expressed in CO_2-e, assuming the relevant global warming potentials are based on a period of 100 years. The 1.7 uplift factor is also the most conservative of the figures in the literature.

Most estimates of aviation's contribution to climate change understate its importance by failing to account for non-CO_2 emissions. For example, based on emissions of the six main direct greenhouse gases, the Stern Review estimates that aviation accounted for 1.6 per cent of global emissions in 2005 (Stern 2006). The same method suggests aviation is responsible for approximately two per cent of Australia's emissions. When uplift factors are used, aviation's contribution is larger, but it is still a small contributor to climate change. Using an uplift factor of 1.7 suggests aviation accounts for approximately 2.5 per cent of total global emissions and almost 4.0 per cent of Australian emissions. Although it is starting off a low base, there is concern that if the aviation sector is allowed to continue to grow under business-as-usual conditions it could become a major source of emissions by the middle of this century.

5. Projected ACT aviation emissions to 2050

CAG has an aggressive growth strategy for Canberra Airport that will see annual aircraft movements increase by around 250 per cent over the next 50 years. To date, no projections have been prepared on the possible magnitude of the ACT's aviation emissions in 2050 if these plans are put into effect. This section seeks to partly fill this void by projecting aviation emissions related to the scheduled passenger task in the ACT over the period 2005 – 2050 using CAG's data on the expected increases in aviation traffic. General aviation, freight and military flights were excluded because of data limitations. Due to the exclusion of these aviation services and the assumptions that have been adopted, the projections can be regarded as a lower bound estimate of total aviation emissions if CAG's plans are realised.

Domestic emissions – method

To estimate future scheduled passenger-related aviation emissions in the ACT over the period 2005 to 2050, an emission intensity method was used that relies on the application of the following equation.

$$EM = (PKM \times EI) \times UF$$

Where:

EM = CO_2-e emissions

PKM = scheduled domestic passenger kilometres (pkm)

EI = CO_2-e emissions (or CO_2 in uplifted scenarios) per pkm

UF = uplift factor

As the equation indicates, there are three inputs:

- the scheduled passenger task in passenger kilometres (pkm);
- emission intensity of the task, measured as emissions per pkm; and
- an uplift factor (where appropriate), to account for the impacts of non-CO_2 emissions.

Estimating the scheduled passenger task requires information on passenger numbers and the average voyage distance. Details on how the scheduled passenger estimates were devised are provided below.

- For 2005, 2006 and 2007, the passenger numbers were actual outbound domestic and regional scheduled passenger numbers obtained from the BTRE (2007a) and CAG (CIA 2007).

- For 2007 – 2028, the passenger numbers were based on the mid-range estimates of scheduled domestic and regional passenger numbers prepared by Airbiz and discussed in the Preliminary Draft 2008 Master Plan. The estimates in the draft Master Plan were halved to provide an approximation of the likely outbound traffic. Passenger numbers were assumed to grow in a linear manner between the specified years in the Master Plan (i.e. 2007, 2012, 2017, 2022 and 2028). The mid-range estimates do not account for the potential growth of Canberra Airport stemming from the overflow of Sydney airport, nor do they factor in the increases in services announced by Virgin and Qantas and the entry of Tiger Airways into the market (CIA 2007). Given the nature of CAG's plans for Canberra Airport, these estimates are considered to be conservative.

- Passenger forecasts have not been published for the period 2028 – 2050. However, CAG has published data prepared by Rehbein AOS Airport Consulting (2006) on the practical ultimate capacity of Canberra Airport, which it expects will be reached around 2050 (CAG 2005; CIA 2007). The data suggest the practical ultimate capacity of the airport is 282,120 fixed wing aircraft movements per annum, compromised of 224,734 scheduled domestic and regional, 25,106 international and 32,280 general, military and other miscellaneous movements. To devise an estimate of scheduled domestic outbound passengers for 2050, the estimated number of scheduled domestic and regional aircraft movements (i.e. 224,734) was multiplied by the estimated number of passengers per aircraft on scheduled flights in 2028 as detailed in the draft Master Plan (i.e. 76). The resulting number was then halved to provide an approximation of the outbound traffic.[5] Having obtained an estimate for 2050, passenger numbers were assumed to grow at a constant rate between 2028 and 2050.

The next step in the process was to devise an estimate of the average voyage distance for scheduled passengers at Canberra Airport. Data were obtained from Apelbaum Consulting Pty Ltd on the scheduled passenger task in the ACT in 2005 and 2006. These estimates were compiled on the basis of outbound traffic. The estimates were divided by the scheduled outbound passenger numbers at Canberra Airport from the BTRE (2007a) to provide an approximation of the average voyage distance in these years. Details of the estimates are provided in Table 1. It was assumed that the average voyage distance over the period 2007 – 2050 is the average of the distance in 2005 and 2006 (i.e. 561).[6]

Table 1 Average voyage distance, scheduled airlines, ACT, 2005 and 2006

Year	Scheduled passenger task (billion pkm)	Scheduled outbound passengers (million)	Average distance (km)
2005	0.70	1.24	565
2006	0.71	1.28	557

Sources: Apelbaum Consulting, pers. comms. (December 2007 and January 2008) and BTRE (2007a).

Having obtained relevant passenger and voyage distance data, the scheduled passenger task was calculated for the period 2005 – 2050. For 2005 and 2006, the actual scheduled passenger task data from Apelbaum Consulting was used. For all subsequent years, the passenger data derived from the information published by CAG was multiplied by the average voyage distance from 2005 and 2006 to provide a pkm estimate.

The emission intensity of domestic aviation services in the ACT over the period 2005 to 2050 was estimated using a three step process. Firstly, an estimate of domestic aviation emissions from scheduled flights in the ACT was devised for 2005. The Federal and Territory Governments do not currently publish data on aviation emissions in the ACT. This is due to the fact that aviation fuel sales in the ACT are not reported separately from those in New South Wales (aviation emissions are generally calculated on the basis of fuel uplifted in the relevant jurisdiction).[7] As a result, estimates of aviation emissions in NSW currently include emissions attributable to the ACT.

Due to this deficiency in the existing accounting frameworks, a proportion of the combined emissions for NSW and the ACT were allocated to the ACT on the basis of

[5] This is a conservative assumption because of the trend toward larger aircraft.
[6] This is a conservative assumption because the average voyage distance may increase as demand and services increase.
[7] In June 2007, the ACT Government introduced legislation for the compulsory reporting of fuel sales in the Territory. As a result, from June 2008 onwards it will be possible to calculate aviation emissions in the ACT on the basis of fuel uplifted (Alice D’Costa, Climate Change Unit, ACT Department of Territory and Municipal Services, pers. comms. 25 October 2007).

its share of the combined scheduled passenger task. Two sources of data on the combined emissions from scheduled services were considered: Apelbaum Consulting and the Australian Greenhouse Office (AGO).

Apelbaum Consulting estimates that full fuel cycle emissions from scheduled domestic flights in NSW and the ACT in 2005 were 1.85 million tonnes (Mt) CO_2-e, with CO_2 emissions of approximately 1.80 Mt.[8] The emission factors for aviation in Apelbaum Consulting (2007) suggest full fuel cycle accounting adds approximately 14 per cent to direct emission accounting (BTRE 2005). Adjusting the full fuel cycle data on this basis provides direct emission estimates of 1.62 Mt CO_2-e (1.57 Mt CO_2).

The AGO's estimates are lower than those derived from the Apelbaum Consulting numbers. Data from the Australian Greenhouse Emissions Information System (AGEIS), which is maintained by the AGO, suggest the combined NSW/ACT emissions from scheduled flights in 2005 were 1.03 Mt CO_2-e, with CO_2 emissions of 1.02 Mt (AGO 2007). To ensure conservative outputs, the lower AGO estimates were used.

Both the Apelbaum Consulting and AGO emission estimates are based on fuel uplifted and they do not allocate emissions between passenger and freight services. To account for the freight component, the AGO estimates were reduced by five per cent. This approximates the proportion of the total domestic scheduled aviation task (in pkm) that is attributable to freight and mail (Apelbaum Consulting 2007). This is a conservative assumption because most air freight at Canberra Airport is carried in the holds of passenger aircraft or on turboprop and piston engine aircraft (CIA 2007).

To allocate a proportion of the adjusted AGO emissions to the ACT, data were obtained from Apelbaum Consulting on the scheduled passenger aviation task in NSW and the ACT in 2005. These data indicate that the combined NSW/ACT scheduled passenger aviation task was 9.837 billion pkm, with 9.137 billion pkm in NSW and 0.70 billion pkm in the ACT.[9] By assuming emissions were proportional to the task, it was estimated that the ACT's scheduled passenger aviation emissions in 2005 were 69,449 t CO_2-e (68,781 t CO_2).

The second step in the process of devising emission intensity estimates was to calculate the intensity of the ACT's scheduled passenger aviation task in 2005 by dividing the estimated CO_2-e and CO_2 emissions by the passenger task. This provided emission intensity estimates for 2005 of 99 grams of CO_2-e per pkm and 98 g CO_2 per pkm.

The third step in the process involved calculating emission intensity estimates for the period 2006 – 2050. This was done on the basis that the emission intensity of the ACT's domestic passenger aviation task falls by 1.2 per cent per annum over the duration of this period due to changes in aircraft design, engine efficiency and air

[8] Apelbaum Consulting, pers. comms (December 2007 and January 2008).
[9] Apelbaum Consulting, pers. comms (December 2007 and January 2008).

traffic management. The 1.2 per cent annual rate of improvement is consistent with estimates devised by the IPCC (1999).[10]

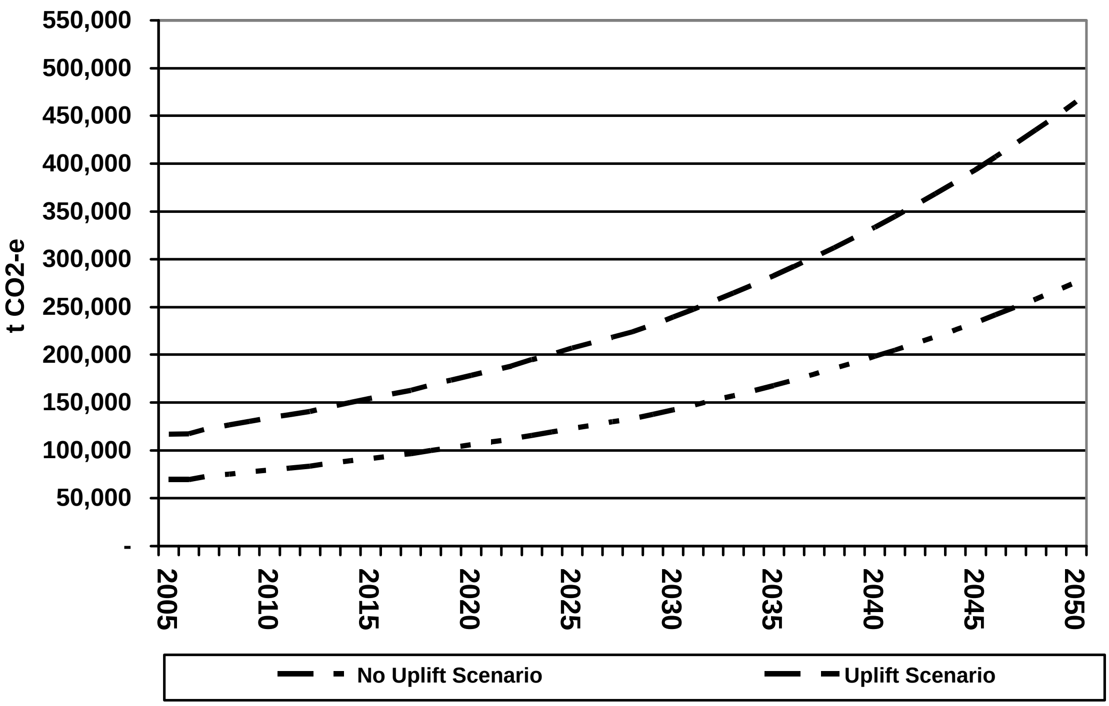
Two scenarios were developed to account for the different types of aviation emissions. The first, the No Uplift Scenario, was based solely on emissions of the six major direct greenhouse gases, measured in CO_2-e. No attempt was made to account for the atmospheric impacts of the non-CO_2 emissions. The second scenario, the Uplift Scenario, takes into account the full impact of aviation emissions using an uplift factor of 1.7, which is applied to the estimated CO_2 emissions.

Domestic emissions – results

Figure 1 plots the projected emission scenarios for scheduled domestic aviation in the ACT from 2005 to 2050. The Uplift Scenario is considered the best estimate because it accounts for the total impact of aviation emissions on the earth's climate system.

Under the No Uplift Scenario, aviation emissions increase from 69,449 to approximately 276,000 t CO_2-e between 2005 and 2050. Under the Uplift Scenario, domestic aviation emissions rise from 116,928 to approximately 465,000 t CO_2-e over this period, a 297 per cent increase.

Figure 1 Projected domestic passenger aviation emissions in the ACT, 2005 – 2050, t CO_2-e



[10] This figure is used widely in making long-range projections of aviation emissions. See, for example, Bows *et al.* (2005) and Macintosh and Downie (2007).

International emissions - method

A three step emission intensity method was used to estimate international aviation emissions associated with the scheduled passenger task. Firstly, international passenger-related aviation emissions at 2050 were estimated using the following formula.

EM = [(PKM x EI) x UF]/2

Where:

EM = CO_2-e emissions in 2050

PKM = international pkm in 2050

EI = CO_2-e emissions (or CO_2 in uplifted scenarios) per pkm in 2050

UF = uplift factor

Total international passengers at 2050 were estimated using the data prepared by Rehbein AOS Airport Consulting's for CAG on the international flights servicing Canberra Airport at ultimate capacity (R-AOS 2006). The data include expected aircraft movements, flight routes, and the types of planes servicing the routes. To devise an estimate of passenger numbers, the average load factor for international flights in Australia in 2007 (i.e. 75.6 per cent (BTRE 2007b))[11] was multiplied by the median passenger capacity of the listed aircraft, which in turn was multiplied by the projected number of movements of the relevant aircraft.[12] To calculate international pkm, the estimated number of passengers was multiplied by the median flight distance on the relevant routes. Details of the pkm estimates and related data are provided in Table 2.

[11] This is the latest year for which data were available.
[12] Most of the listed aircraft have a number of different seating configurations. The median passenger capacity refers to the middle number between the configurations with the highest and lowest maximum passenger capacities for each aircraft. The data on passenger capacity were obtained from Airbus (2007) and Boeing (2007).

Table 2 Expected international passenger kilometres (pkm) at Canberra International Airport by aircraft type, 2050

Aircraft type	Median passenger capacity	Origin/ Destination	Median flight distance (km)	Annual aircraft	Estimated passengers	Pkm (million)
B737-800	176	NZ/Pacific Islands	3,889	1450	192,383	748
B747-400	470	Los Angeles/Dubai	13,612	936	332,580	4,527
B747-400	470	Beijing	10,371	936	332,580	3,449
B747-400	470	Bangkok/Tokyo/ Seoul	9,353	2138	759,674	7,105
B777-300	459	Hong Kong/Tokyo/ Seoul	8,982	4422	1,534,452	13,783
B777-300	459	Singapore/ Kuala Lumpur/Bali	7,501	1106	383,786	2,879
A320	150	NZ/Pacific Islands	3,889	1460	165,564	644
A330	294	Singapore/ Kuala Lumpur/Bali	7,778	6918	1,537,622	11,960
A340	310	Tokyo/Seoul	10,927	5740	1,343,057	14,675
Totals	–	–	–	**25,106**	**6,581,697**	**59,770**

Source: Rehbein AOS Airport Consulting (2006), Boeing (2007) and Airbus (2007).

To devise emission intensity estimates for 2050, the emission intensity of the international passenger task in 2005 was estimated. Having obtained an estimate for 2005, it was assumed there will be a 1.2 per cent per annum improvement in emission intensity over the period 2005 – 2050 due to changes in aircraft, engine design and air traffic management (IPCC 1999).

As in the case of the domestic emission projections, two sources of data on the emissions from international aviation were considered: Apelbaum Consulting (2007) and the AGO. According to Apelbaum Consulting (2007), full fuel cycle CO_2-e and CO_2 emissions from international aviation in Australia in 2005 were 27.66 Mt CO_2-e and 26.86 Mt CO_2. These estimates are based on all fuel used in international aircraft servicing Australian routes, not just the fuel uplifted in Australia. To provide an estimate of direct emissions from international aviation, it was assumed full fuel cycle accounting adds 14 per cent to direct emissions. This provided an estimate of 24.26 Mt CO_2-e (23.56 Mt CO_2) for total direct international aviation emissions in 2005. To remove the freight component, the emission estimates were reduced by 30 per cent, which is an approximation of the proportion of the total international aviation task (in pkm) attributable to freight and mail (Apelbaum Consulting 2007). The final adjusted estimates were 16.98 Mt CO_2-e and 16.49 Mt CO_2.

The AGO estimates that Australia's international aviation emissions in 2005 were 6.83 Mt CO_2-e (6.77 CO_2) (AGO 2007). This estimate is based on the amount of fuel uplifted in Australia that is used in international aviation operations. Approximately 34 per cent of fuel used in Australia's international aviation task is uplifted in Australia (Apelbaum Consulting 2007). Accordingly, to devise an estimate of total direct emissions associated with the international task, the AGO numbers were multiplied 2.9. The freight component was then removed by subtracting 30 per cent, providing adjusted estimates of 13.94 Mt CO_2-e and 13.81 Mt CO_2. The lower AGO estimates were used in preference to those derived from the Apelbaum Consulting data to ensure conservative outputs.

To calculate the emission intensity of the international passenger aviation task in 2005, the emission estimates derived from the AGO data were divided by the scheduled international aviation passenger task in 2005, which was obtained from Apelbaum Consulting (2007). The emission intensity was then calculated for 2050 on the basis there is a 1.2 per cent per annum improvement in emission intensity over the period 2005 – 2050. The emission intensity estimates for 2005 and 2050 are shown in Table 3.

Table 3 Emission intensity of international aviation in Australia, emissions per pkm, 2005 and 2050

Year	Grams of CO_2-e per pkm	Grams of CO_2 per pkm
2005	107.38	106.37
2050	62.37	61.79

Sources: Apelbaum Consulting (2007) and AGO (2007).

Multiplying the emission intensity estimates by the passenger task derived from the Rehbein AOS Airport Consulting data provided an approximation of total emissions from international aircraft servicing Canberra Airport in 2050. The ACT's share of these emissions was assumed to be 50 per cent. There are a number of different methods for allocating aviation emissions between jurisdictions. The most widely used is to allocate emissions on the basis of where the fuel is uplifted. However, in the absence of fuel data, the division of emissions on a 50/50 basis between origin and destination is considered appropriate.[13]

The second step in the emission intensity method involved devising emission estimates for 2012, 2017, 2022 and 2028. The Preliminary Draft 2008 Master Plan contains data on the projected international passenger numbers for these years, enabling estimates to be calculated. The emission intensity formula outlined above was used for this purpose.

[13] Mark Hunstone, Australian Greenhouse Office, pers. comms. (24 October 2007).

To devise pkm estimates, the passenger numbers were allocated to the routes listed in Table 2 in accordance with the ratio of estimated passengers on the routes in 2050, excluding the proposed A340 Tokyo/Seoul routes. The A340 Tokyo/Seoul routes were omitted to account for the fact that the Preliminary Draft 2008 Master Plan suggests these services may only be a long term prospect (CIA 2007).[14] Having allocated the passengers to routes, the estimated pkms were obtained by multiplying the passenger numbers by the median flight distance on the routes. International emissions for 2012, 2017, 2022 and 2028 were then obtained by multiplying the pkm by an emission intensity estimate and then allocating half of the total emissions to the ACT.[15]

The final step in the process involved plotting an emissions trajectory over the period 2005 – 2050. Actual emissions were used for 2005, 2006 and 2007 (i.e. zero). For simplicity, it was assumed emissions follow a linear growth path between 2007, 2012, 2017, 2022, and 2028. Between 2028 and 2050, emissions were assumed to grow at a constant rate. As with domestic emissions, two scenarios were developed: the No Uplift Scenario and an Uplift Scenario. The No Uplift Scenario is based on emissions of the six major direct greenhouse gases. The Uplift Scenario uses an uplift factor of 1.7, which was applied to estimates of CO_2 emissions.

[14] The exclusion of the A340 Tokyo/Seoul routes also ensures more conservative outputs because they are longer routes. The Hong Kong/Tokyo/Seoul and Bangkok/Tokyo/Seoul routes were included as there was no way of separating the Honk Kong and Bangkok traffic.

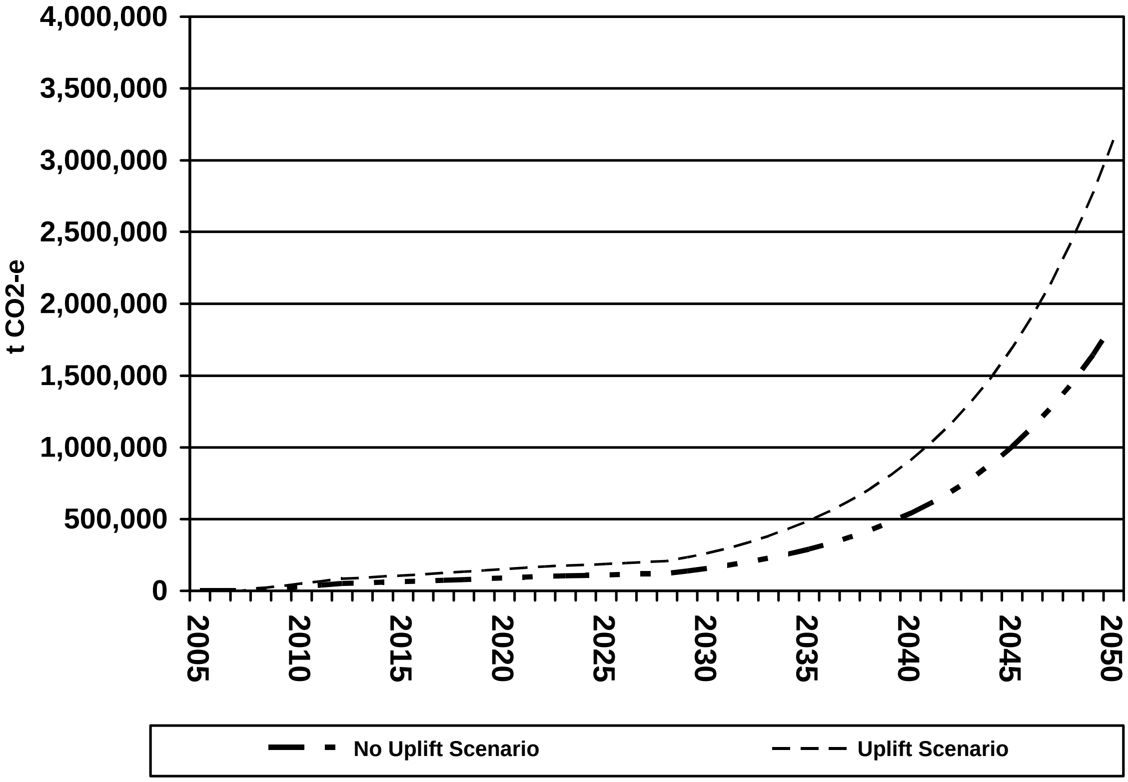
[15] The emission intensity estimates were obtained by adjusting the data from Apelbaum Consulting (2007) for 2005 on the basis of a 1.2 per cent per annum improvement in emission intensity over the period 2005 – 2050.

International emissions – results

Under the No Uplift Scenario, the ACT's international aviation emissions are projected to rise to 111,324 t CO_2-e in 2025 and reach 1.86 Mt CO_2-e in 2050 (see Figure 2). Under the Uplift Scenario, international emissions are expected to be 187,472 t CO_2-e in 2025 and 3.14 Mt CO_2-e in 2050.

Comparing Figures 1 and 2, it is clear that by 2050 emissions from international aviation at Canberra Airport will greatly exceed those from domestic aviation. International flights, involving larger planes over much longer distances, will generate emissions nearly seven times greater than domestic flights.

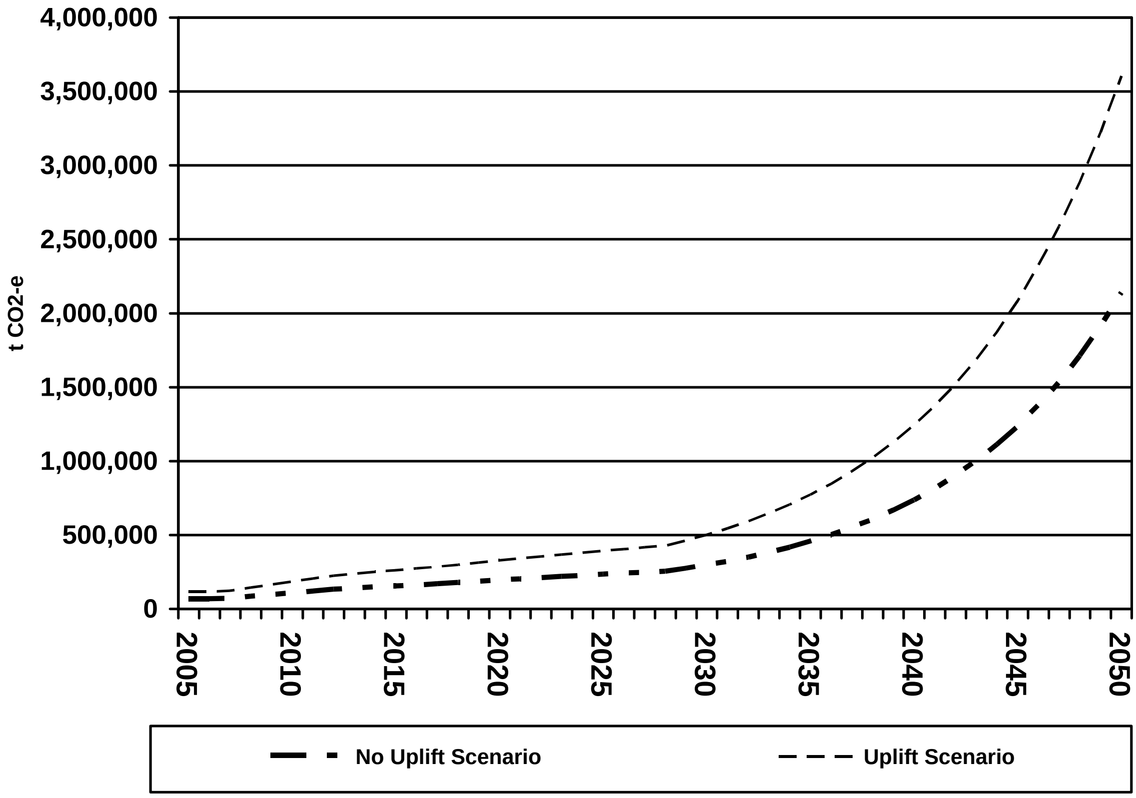
Figure 2 Projected growth in international passenger aviation emissions, 2005 to 2050, tonnes CO_2-e



Total projected aviation emissions

Figure 3 shows the growth in the ACT's total aviation emissions over the period 2005 to 2050, that is, emissions from both domestic and international flights. Under the No Uplift Scenario, total emissions increase from 69,449 t CO_2-e to 2.14 Mt CO_2-e in 2050. Under the Uplift Scenario, total aviation emissions rise from 116,928 t CO_2-e to 3.60 Mt CO_2-e. These projections suggest that if international services develop at Canberra Airport as expected, they will have a very significant impact on the growth of total aviation emissions in the ACT.

Figure 3 Projected growth in total passenger aviation emissions in the ACT to 2050, tonnes CO_2-e



6. Projected emissions versus desired emission targets

The available evidence indicates that if the Australian aviation sector continues to grow under business-as-usual conditions it will derail attempts to meet future national emission reduction targets (Macintosh and Downie 2007). Research on the European aviation sector has reached similar conclusions (RCEP 2002; Bishop and Grayling 2003; Bows *et al.* 2005; Wit *et al.* 2005; Bows and Anderson 2007; Stern 2007). The projected growth in aviation emissions associated with the growth of Canberra Airport and the ACT's passenger task suggests the same threat faces the ACT.

As discussed in Section 2, as part of its climate change strategy the ACT Government has established an interim target of stabilising the Territory's emissions at 2000 levels by 2025, or 4,059,000 t CO_2-e. It has also established a long-term target of reducing the Territory's emissions to 1,623,400 tonnes CO_2-e by 2050, a 60 per cent cut on 2000 levels (DTMS 2007). These targets do not include emissions from aviation.[16]

The exclusion of domestic aviation emissions was due to the problems associated with the accounting systems concerning fuel sales in the Territory. Presumably, when fuel sale data for the ACT become available in mid-2008, the targets will be amended to include a domestic aviation component.[17]

The exclusion of international aviation emissions from the ACT target reflects current practice under the IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006). The IPCC Guidelines treat international and domestic aviation emissions differently (IPCC 2006). Domestic aviation emissions are required to be included in national totals. In contrast, international aviation emissions are excluded from national totals. However, if fuel used in international aviation operations is sold in a country, the emissions associated with the burning of the fuel are required to be reported as a separate memo item. The effect of these provisions is that international aviation emissions are currently excluded from national emission targets under the Kyoto Protocol and there is uncertainty about whether they will be included in other policy targets at national and sub-national levels.

Given existing greenhouse accounting practices, it is arguable emissions from future international aviation operations at Canberra Airport should not be included in the reporting framework for the ACT's 2025 and 2050 targets. However, there is growing pressure for international aviation emissions to be included in national totals in the IPCC reporting system. If the existing situation continues, there is a risk international aviation operations could undermine the global abatement effort. The same applies in relation to policy targets set at national and sub-national levels. For this reason, there are strong grounds for including international aviation emissions at Canberra Airport in the ACT's greenhouse reporting framework.

If it is assumed both domestic and international aviation emissions are included in the reporting framework, the 2025 and 2050 targets should be adjusted to include an aviation component. To adjust the base year estimate, the total aviation emissions for NSW and the ACT in 2000 (i.e. 1.427 Mt CO_2-e) were obtained from the AGEIS (AGO 2007). This amount was then multiplied by the proportion of the total combined NSW/ACT aviation task in 2001 that was attributable to the Territory (i.e. 4.9 per cent), which was obtained from Apelbaum Consulting.[18] The resulting amount (i.e. 70,272 t CO_2-e) was multiplied by a 1.7 uplift factor then added to the year 2000 estimate provided in the climate change strategy. The adjusted year 2000 baseline derived by this method is approximately 4,178,000 t CO_2-e. Accordingly, the adjusted 2025 target is 4,178,000 t CO_2-e, while the 2050 target is approximately 1,670,000 t CO_2-e, 60 per cent below the 2000 levels.[19]

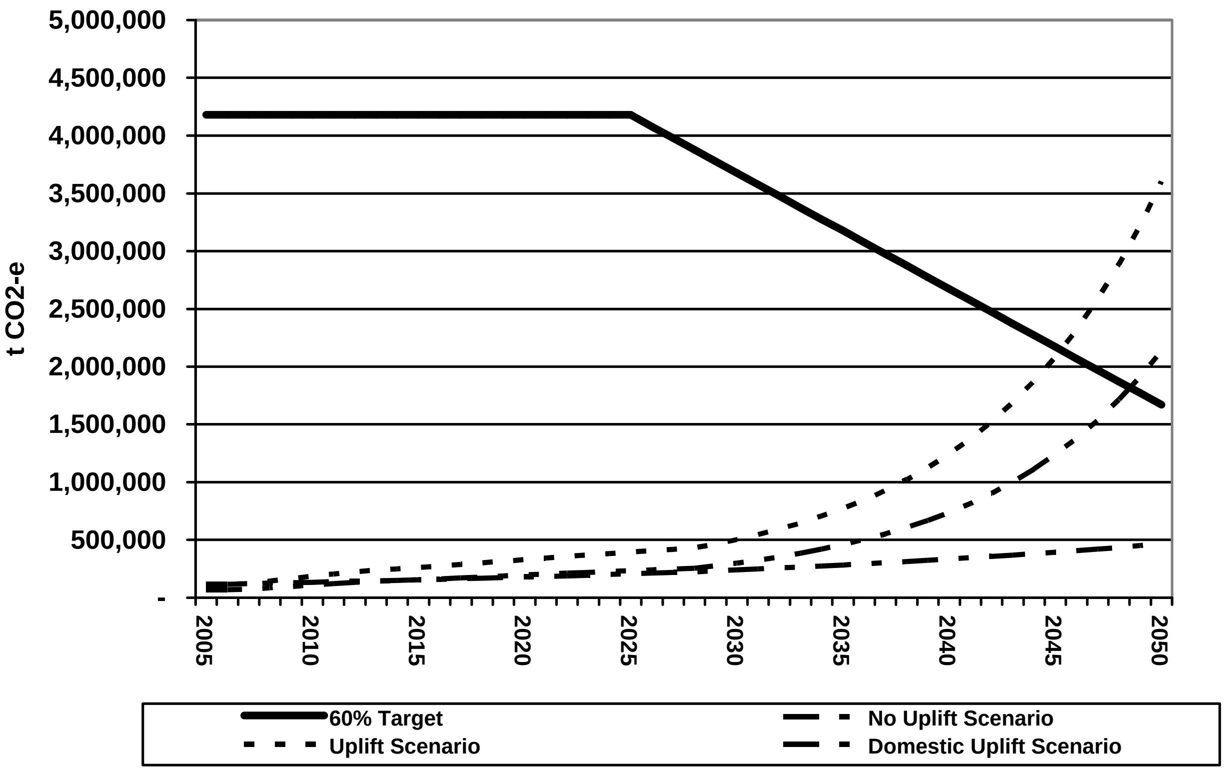
[16] Allen Traves, ACT Government, pers comms (19 December 2007).
[17] This will still be an approximation as the new data requirements will not apply retrospectively.
[18] Apelbaum Consulting, pers. comms. (7 December 2007). Relevant data were not available for 2000.
[19] If uplift scenarios and no uplift scenarios are used there should be two targets to account for the different accounting methods. For simplicity, only the higher uplift target was used. This also ensures more conservative outcomes.

Figure 4 plots the projected No Uplift Scenario and Uplift Scenario for total aviation emissions in the ACT alongside the Territory's emission target. The ACT emission target scenario assumes that emissions follow a linear path between 2025 and 2050.[20] In reality, a number of paths are possible for reaching the target. The domestic Uplift Scenario was also included to highlight the magnitude of the threat posed by aviation to the achievement of the ACT's greenhouse targets.

As shown in Figure 4, the project growth in aviation emissions is incompatible with the ACT's Climate Change Strategy. Under the No Uplift Scenario, aviation accounts for six per cent of the ACT's emissions in 2025. However, by 2050, they are projected to constitute 128 per cent of the ACT's total allowable emissions. Under the Uplift Scenario, the situation is significantly worse. Aviation is expected to account for nine per cent of the ACT's emissions in 2025. By 2050, they constitute 216 per cent of the ACT's target.

Even if the plans to develop international air services at Canberra Airport are not realised, the growth in domestic emissions will still pose a significant threat to the objectives of the Climate Change Strategy. Under the No Uplift Scenario, domestic emissions constitute 17 per cent of the target in 2050. When the impacts of the non-CO_2 emissions are taken into consideration via the Uplift Scenario, aviation's share of the target in 2050 rises to 28 per cent.

Figure 4 Projected passenger aviation emissions versus emission target in the ACT, to 2050, tonnes CO_2-e



[20] No attempt was made to forecast the ACT's emissions over the period 2005 – 2025. A flat line was used for the purpose of illustration only.

7. Implications

The ACT Government has set the Territory a target of reducing greenhouse gas emissions to 60 per cent below 2000 levels by 2050. If CAG's plans for Canberra Airport are realised, and aviation is included in the accounting framework under the Climate Change Strategy, this target is likely to be unachievable.

The projections published by, or prepared for, CAG and its related entities indicate it is expecting annual scheduled domestic flight movements to rise from almost 40,000 in 2006 to over 80,000 in 2028. By 2050, it expects this number to be around 220,000. If this occurs, the emissions associated with the ACT's domestic passenger task are expected to increase by almost 300 per cent between 2005 and 2050, rising from approximately 69,000 to 276,000 t CO_2-e. When non- CO_2 emissions are included through the use of an uplift factor, domestic aviation emissions rise from approximately 117,000 to 465,000 t CO_2-e over this period.

With the development of international services at Canberra airport, the increase in the ACT's passenger-related aviation emissions would be more dramatic. In the No Uplift Scenario, combined domestic and international emissions rise from 69,000 t CO_2-e in 2005 to 2.14 Mt CO_2-e in 2050. At this level, aviation emissions would constitute 128 per cent of the Territory's long-term emission reduction target. Under the Uplift Scenario, total aviation emissions in 2050 are 3.60 Mt CO_2-e, 216 per cent of the Territory's allowable emissions.

These emission projections are deliberately conservative. In particular, they are confined to passenger-related emissions from scheduled flights. Freight, general aviation and military emissions are all excluded. The inclusion of these aspects of the aviation task would significantly increase the projected emissions.

There is a possibility technological innovation could ameliorate aviation's contribution to climate change. In the projections, innovation is accounted for through the use of a 1.2 per cent per annum improvement in emission intensity. As the results indicate, the emission increases driven by rising demand for air services are likely to far outweigh the cuts brought about by design and operational improvements. For the projected growth in demand to be compatible with emission reduction objectives, there would have to be a technological breakthrough that fundamentally altered modern aircraft and engine design. This is possible. However, the evidence suggests it is unlikely (IPCC 1999; RCEP 2002; Peeters *et al.* 2005). Moreover, even if unforeseen technological solutions emerge, it will take decades for them to be implemented. The absence of technological options means that demand for air transport will have to be constrained if climate change objectives are going to be met.

To limit demand and promote technological innovation, domestic and international aviation emissions (confined to CO_2 emissions and emissions of the other five main direct greenhouse gases) should be included in the proposed national emissions trading scheme. The inclusion of international aviation emissions in the scheme should preferably be done in collaboration with the International Civil Aviation Organization (ICAO) and the recently announced Group on International Aviation and Climate Change (ICAO 2007). The design of the scheme should also be consistent with the proposal to include international aviation emissions in the

European Union's emission trading scheme (European Commission 2006). Ensuring consistency between the schemes will enable them to be linked in the long term and promote greater certainty in the aviation industry.

The inclusion of aviation emissions in the emissions trading scheme will not be sufficient to achieve the desired environmental outcomes. Additional measures will be necessary to control non-CO_2 emissions. These measures could include non-CO_2 emission taxes and emission standards for new aircraft and engines.

Prior to the emissions trading scheme reaching maturity, there is a risk of unsustainable investments being made in the aviation industry. This could result in assets being stranded when emission caps are introduced and subsequently tightened. The resulting financial losses and employment impacts could create political barriers to the introduction of effective greenhouse policies.

To reduce these risks, the Federal Government should consider the immediate introduction of a flat-rate greenhouse charge on all domestic flights. This would dampen demand and provide a signal to the market of the changes that are likely to occur after the emissions trading scheme commences. New airport developments and airport master plans should also be subject to formal statutory environmental assessment procedures that require the evaluation of the greenhouse implications of the relevant actions and related increases in aviation traffic.

References

Australian Greenhouse Office (AGO) 2007, ‘Australian Greenhouse Emissions Information System’, <http://www.ageis.greenhouse.gov.au/GGIDMUserFunc/indexUser.asp> (28 December 2007).

BBC News 2006, ‘Branson makes $3bn climate pledge’, <http://news.bbc.co.uk/1/hi/business/5368194.stm> (12 May 2007).

Bishop, S. and Grayling, T. 2003, *The Sky’s the Limit; Policies for sustainable aviation*, Institute for Public Policy Research, London.

Boeing 2007, ‘Technical information’, <http://www.boeing.com/commercial/737family/specs.html> (5 November 2007).

Bows, A., Upham, P. and Anderson, K. 2005, *Growth scenarios for EU & UK aviation: contradictions with climate policy*, report for the Friends of the Earth Trust ltd, Tyndall Centre for Climate Change, Manchester.

Bows, A. and Anderson, K. 2007, ‘Policy clash: Can projected aviation growth be reconciled with the UK Government’s 60% carbon-reduction target?’, *Transport Policy*, Vol. 14, pp. 103 – 110.

Bureau of Transport and Regional Economics (BTRE) 2002, *Greenhouse gas emissions from transport: Australian trends to 2020,* Report 107, Commonwealth of Australia, November, Canberra.

Bureau of Transport and Regional Economics (BTRE) 2005, *Greenhouse gas emissions from Australian transport: base case projections to 2020*, report for the Australian Greenhouse Office, Commonwealth of Australia, August, Canberra.

Bureau of Transport and Regional Economics (BTRE) 2006, *Airline industry monthly summaries, by industry sector*, Commonwealth of Australia, Canberra (available at: <http://www.btre.gov.au/statistics/xls/Monthly_airline_performance.xls> (15 March 2007)).

Bureau of Transport and Regional Economics (BTRE) 2007a, *Aviation statistics: airport traffic data 1995-96 to 2005-06*, Commonwealth of Australia, March, Canberra.

Bureau of Transport and Regional Economics (BTRE) 2007b, *Australian Domestic Airline Activity – Time series*, *Monthly Airline Performance*, Commonwealth of Australia, October, Canberra.

Canberra Airport Group (CAG) 2005, *Canberra International Airport 2005 Master Plan*, February, Canberra.

Canberra International Airport Pty Ltd (CIA) 2002, *Preliminary Version Draft Minor Variation Canberra International Airport Year 2020 Master Plan*, February, Canberra.

Canberra International Airport Pty Ltd (CIA) 2007, *Canberra International Airport 2008 Master Plan*, Preliminary Draft, November, Canberra.

CSIRO 2007, *Climate change in Australia*, Technical Report, Canberra.

Department of the Environment and Heritage (DEH) 2006, *AGO Factors and Methods Workbook*, Commonwealth of Australia, Canberra.

Department of the Environment and Water Resources (DEWR) 2007, *Australia's National Greenhouse Accounts*, Commonwealth of Australia, Canberra (available at: < http://www.greenhouse.gov.au/inventory/index.html> (3 April 2007)).

Department of Territory and Municipal Services (DTMS) 2007, *Weathering the change: the ACT climate change strategy 2007-2025*, ACT Government, Canberra.

Department for Transport (UK) (DFT) 2004, *Aviation and Global Warming*, UK Government, England.

European Commission 2006, *Proposal for a Directive of the European Parliament and of the Council amending Directive 2003/87/EC so as to include aviation activities in the scheme for greenhouse gas emission allowance trading within the Community*, COM(2006) 818, EC, 20 December, Brussels.

Forster, P., Shine, K. and Stuber, N. 2006, 'It is premature to include non-CO2 effects of aviation in emission trading schemes', *Atmospheric Environment*, Vol. 40, pp. 1117 – 1121.

International Civil Aviation Organization (ICAO) 2007, *Sharp focus on Safety and Environmental Protection in 2007*, ICAO News Release, PIO 14/07, December, Canada.

Intergovernmental Panel on Climate Change (IPCC) 1999, *Aviation and the global atmosphere*, special report, Cambridge University Press, England.

Intergovernmental Panel on Climate Change (IPCC) 2006, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, Institute for Global Environmental Strategies, Japan (available at: http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm (28 August 2007)).

Intergovernmental Panel on Climate Change (IPCC) 2007, *Climate Change 2007 – The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the IPCC*, Cambridge University Press, England.

Macintosh, A. and Downie, C. 2007, *A Flight Risk? Aviation and climate change in Australia*, The Australia Institute, Discussion Paper No. 94, May, Canberra.

May, M. and Hill, S. 2006, 'Questioning airport expansion – A case study of Canberra International Airport', *Journal of Transport Geography*, Vol. 14, pp. 437-450.

Newton, P. and Falk, R. 1997, *DTI Forecast of Fuel Consumption and Emissions from Civil Aircraft in 2050 Based on ANCAT/EC2 1992 Data*, Department of Trade and Industry (UK), 13 November, London, United Kingdom.

Peeters, P., Middel, J. and Hoolhorst, A. 2005, *Fuel efficiency of commercial aircraft: An overview of historical and future trends*, National Aerospace Laboratory NLR, The Netherlands.

Rehbein AOS Airport Consulting (R-AOS) 2006, *Canberra International Airport Practical Ultimate Capacity ANEF*, December, Canberra.

Royal Commission on Environmental Pollution (RCEP) 2002, *The Environmental Effects of Civil Aircraft in Flight*, Government of the United Kingdom, November, London.

Sausen, R., Isaken, I., Grewe, V., Hauglustaine, D., Lee, D., Myhre, G., Kohler, M., Pitari, G., Schumann, U. Stordal, F., and Zerefos, C. 2005, 'Aviation radiative forcing in 2000: an update on IPCC (1999)', *Meteorologische Zeitschrift*, Vol. 14, No. 4, August.

Select Committee on Environmental Audit (SCEA) 2004, *Third Report of Session 2003-04: Pre-Budget Report 2003 – Aviation Follow-up*, House of Commons, Government of the United Kingdom, 16 March, England.

Stern, N. 2007, *The Economics of Climate Change: The Stern Review*, Cambridge University Press, January, Cambridge.

Wit, R., Boon, B., Velzen, A., Cames, M., Deuber, O. and Lee, D. 2005, *Giving wings to emission trading: Inclusion of aviation into the European Emissions Trading System - design and impacts*, report for the European Commission, CE Delft, July, The Netherlands.