

Analysing International Tourist Flows to Estimate Energy Use Associated with Air Travel

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Tourism is a major global industry and air travel is an increasingly vital component of international tourism. This paper examines the neglected relationship between tourism and aviation with regard to global environmental impacts, including energy use and greenhouse gas emissions. Based on visitor arrival data collected by Statistics New Zealand, it estimates a total energy use of 27.8 PJ resulting from international passenger air travel to New Zealand, which would increase national energy use by 6% if international air travel were included in national inventories. This energy use translates into additional carbon dioxide emissions of 1.9 million tonnes. These estimates are discussed in terms of a tourist's 'energy bill', national and international climate change policies, and with regard to the concept of sustainable tourism development.

Introduction

Since 1960, international air travel (revenue passenger kilometres) has grown steadily by about 9% per annum (OECD, 1997). This growth is expected to continue at around 5% per year (Airbus and Boeing, cited in Umweltbundesamt, 1999). International and long-haul air travel in particular are predicted to increase considerably (Oppermann & Cooper, 1999; Schafer & Victor, 1999), with regional traffic flows for flights within Asia, between Asia and Oceania or Europe, and flights between North America and Asia/Oceania becoming increasingly important (Penner *et al.*, 1999). There is a trend towards longer trips, with an extension of average passenger trip length by 43% in the last two decades (OECD, 1997). Schafer and Victor (1999) argue that transport, as a result of this growing mobility demand and a fixed time budget, will ultimately be satisfied by aircraft and high-speed trains.

Tourism, in particular international tourism, plays a major role in the growth of air travel. Globally, international tourism is not only one of the fastest growing industries, but now also the third biggest industry behind petroleum and the automobile (Collier, 1999). The World Tourism Organisation (WTO) (1998) reported average growth rates of 4% in the last decade. In 1996, the 597 million tourists (WTO, 1998) constituted almost 50% of the 1390 million air passengers using the world's airlines in the same year (ICAO,¹ 1998). A tourist is generally defined as any person travelling to spend more than 24 hours and less than a year out of his or her usual environment (WTO, 1999). The boost in tourism resulting from such factors as an increase in disposable income and leisure time, along

with strong competition among airlines and a considerable drop in airfares, has led to mutually stimulating growth in both the air transport and the tourism sectors. However, despite being a major global industrial sector, the air travel component of international tourism has not gained much attention in tourism studies. The air travel of tourists has been analysed with regard to its economic importance for regional development, for example for Zimbabwe (Turton & Mutambirwa, 1996), Cairns in Australia (Prideaux, 2000), and south-east Asia (Bowen, 2000). In the case of small-island developing states, Abeyratne (1999) pointed out that promoting air travel to islands induces growing tourist flows that need to be carefully managed with regard to the three dimensions of sustainability: economic, social, and environmental. Environmental impacts of air travel itself have been discussed from a more general perspective (e.g. Price & Probert, 1995), without particular reference to tourism. A comprehensive discussion of the externalities of aviation, such as air pollution, noise, accidents, and congestion, is provided by Janić (1999), but a systematic inclusion of environmental impacts of air travel, in particular energy use and greenhouse gas emissions, in the discussion about sustainable tourism development is lacking, or 'virtually excluded' (Gössling, 2000: 410).

Since the energy use involved with air travel to a particular destination has not been published so far, there is no basis on which to discuss and compare the dimensions of the resulting impact. To fill this gap, and to provide a first basis for further discussions in this field, this study quantifies the total energy use and carbon dioxide (CO₂) emissions associated with international passenger air travel to (and from) New Zealand. The procedure of estimating international visitor flows based on arrival cards filled out at New Zealand's Customs and Immigration will be presented in detail to allow for further methodological improvements in this area. Finally, the results will be discussed with regard to a tourist's 'energy bill', national and international climate policies, and the concept of sustainable tourism development.

Energy Use and Greenhouse Gas Emissions

Travelling by air requires considerable amounts of energy and releases greenhouse gases into the atmosphere.² In a report on aviation and the atmosphere by the Intergovernmental Panel on Climate Change (IPCC) it was estimated that aviation accounts for 2–3% of the world's total use of fossil fuels, with more than 80% consumed by civil aviation (Penner *et al.*, 1999). Olsthoorn (2001) estimated an increase in jet-fuel consumption and associated emissions by a factor of between 3 and 6 until 2050, depending upon different scenarios (e.g. economic growth, energy taxes). Accordingly, aviation's contribution to global anthropogenic CO₂ emissions is forecast to grow to 3–7% by 2050 (Penner *et al.*, 1999). The effect of CO₂ is well understood, as it contributes directly to the warming of the atmosphere depending on its atmospheric concentration. Other greenhouse gases (mainly NO_x) influence the atmosphere indirectly by a complex interaction with other compounds, and it is difficult to quantify their contribution to global warming (Penner *et al.*, 1999). Uncertainty also results from the increased effectiveness of emissions at an altitude of 9 to 12 kilometres, due to longer atmospheric residence times in these upper troposphere layers. It is

assumed that the accumulative effect of all aircraft emissions is two to four times larger than CO₂ emissions alone (Greenpeace, 1996; Olsthoorn, 2001). Apart from greenhouse gases, aircraft also emit soot mass, sulphate aerosols, and water vapour in the tropopause. Water vapour forms on particles and builds up to visible line clouds, the so-called contrails. It has been observed that aerosols indirectly affect cirrus cloud cover throughout the atmosphere and that contrails cause a positive radiative forcing, thus also contributing to the greenhouse effect (Penner *et al.*, 1999). However, the overall impact of particles and contrails is not yet fully understood.

Destination New Zealand

Situated in the South Pacific with its nearest neighbour, Australia, being at a flight distance of 2.5 hours, New Zealand is an isolated and geographically remote island group away from the main international airline routes. Air travel costs are an important factor in travel decisions (Crouch, 1994). In the past, fares to New Zealand were relatively high due to low passenger volumes and, hence, interest by international airlines to serve this country was low. The launch of a competitor to the international carrier Air New Zealand on the Trans-Tasman route to Australia in 1995 induced a price war with dramatic decreases in air fares. As will be described below, this process of price reduction has spread to other routes. Not only New Zealand residents increased their travelling overseas (Oppermann & Cooper, 1999), but international tourists also benefited from favourable airfares and more direct flights from Asian hubs. Consequently, New Zealand has developed into a popular tourist destination, positioning itself in the international tourism market, where travel distance and price no longer constitute a major barrier for international tourists.

In recent years, tourism growth rates have reached up to 11.7% per annum (Collier, 1999). In 2000, New Zealand received more than 1.8 million international visitors (Statistics New Zealand, 2001a), of which 90% match the WTO's (1999) definition of a tourist. Of all visitors in 2000, 99% arrived by air (Statistics New Zealand, 2001a). Except for visitors from Australia and some Pacific Islands, this involves a long-distance flight of more than five hours. In 1993, visitors to New Zealand represented only 0.2% of the world's total visitor arrivals (WTO, 1998). However, it was estimated that in the same year, New Zealand captured 2.1% of the world long-distance travel market (Collier, 1999).

To become more competitive on the international market, New Zealand liberalised its aviation policies, mainly by giving access to foreign carriers, and thus enhancing the network and national economic competitiveness. Part of this development was the joining of New Zealand's flag carrier, Air New Zealand, to the world's largest air alliance, Star Alliance, in 1999. Being in an alliance with other strong carriers, such as Air Canada, Lufthansa, SAS, Thai Airways, United, and VARIG, attracts more traffic from around the world to the airline's primary hub (Bowen, 2000). The main gateway of New Zealand is Auckland, which is currently scheduled by 31 international airlines with a total number of 76 international flights per day and eight million passengers per year (Auckland International Airport, 2001).³ In addition to Auckland, there are five other gateways with Christchurch (seven direct services to international destinations) and

Wellington (three international services) being the largest. The liberalisation of international air services will continue to constitute an important issue of government policy with the aim of maximising the economic benefits of air travel and transport (Ministry of Transport, 1998). Accordingly, the recently released *New Zealand Tourism Strategy 2010* targets 3.2 million visitors in 2010 (Tourism Strategy Group, 2001). Simultaneously, however, the current Government devoted itself to lead the world in climate-change policy and to ratify the Kyoto Protocol by mid-2002 (Ministry for the Environment, 2001). This involves decreasing the current total CO₂ emissions of 30,389 kilo tonnes (in 1999) (Ministry of Economic Development, 2000a) to 1990 levels of 25,485 kilo tonnes.

Method

The following analysis uses data on visitor arrivals in 1999 recorded by Statistics New Zealand (2000a), and combines them with information on routings and mileage obtained by major airlines (Air New Zealand, Qantas, Thai Airways, United Airlines).

Retracing visitor flows

Every passenger disembarking in New Zealand is obliged to fill out an arrival card and give information on their nationality and the port of last embarkation. Since the data are actual totals, the sampling error is assessed to be less than 1% for major origin markets (Travel & Tourism Intelligence, 1999). Generally, all passengers travelling for longer than 12 hours would report an airport other than their airport of first departure (country of origin), as aircraft have a maximum range of 12 to 13 hours flying time.

Two different sets of data can be generated based on the information provided by the arrival cards. First, the total number of visitor arrivals broken down by nationality at each of the three main international airports, Auckland, Christchurch, and Wellington can be determined (other international airports are of minor significance, and visitor numbers are added to the geographically closest major gateway, e.g. Hamilton's totals are added to Auckland). Based on this, the arrival number of each 'nationality' can be converted into a share (in percentage) of the three airports of the nation's total visitor flow. For example, 78.5% of all British visitors arrive in Auckland, while 16.9% arrive in Christchurch and the remaining 4.6% in Wellington.

Since visitors choose different routes to travel to New Zealand, information on the country of origin and the port of arrival is not sufficient to obtain a complete picture of international tourist flows. The port of last embarkation reported by each visitor gives an indication of the actual travel route. This information is provided in the second data set, where each nation's total visitor numbers at different ports of last embarkation are compiled. These are often the large airport hubs in south-east Asia: Singapore, Bangkok, Kuala Lumpur, or Hong Kong.

By linking the two data sets, it was possible to estimate likely passenger movements to New Zealand for the year 1999. All visitors were presumed to have ultimately arrived from their respective home countries via the biggest gateway (e.g. United Kingdom: London; Japan: Tokyo). This was also presumed in a

study on Norwegian travel (Høyer, 2000). For most countries this should not affect the total travel distance to New Zealand considerably, especially if the distance between different potential gateways is small compared with the distance between the country of origin and New Zealand. For example, there are a number of direct flights between various cities in Japan and New Zealand that differ less than 5% in their distance. However, bigger countries with large tourist flows to New Zealand, such as Australia, the United States and Canada, were analysed in more detail to account for differing travel distances to New Zealand from different regions within each country. Since visitor arrivals from these three countries are recorded at a state level, visitor flows could be defined for different starting points (e.g. California: Los Angeles; New South Wales: Sydney). Nations with less than 100 arrivals in 1999 were not considered.

Countries of origin with more than 20,000 arrivals to New Zealand (major markets) in 1999 were split into two or three routes, depending on the degree of variation in arrival numbers at different ports of last embarkation. For European countries this procedure allows for accounting for at least one route via Asia and one via the United States. Asian routes either continue directly to New Zealand or lead there via Australia (Sydney).

Visitors from the United Kingdom, Germany, and Japan were divided into three geographic flows, whereas those from the United States, Korea, Canada, Hong Kong, China, and Thailand were split into two flows. Despite having visitor arrivals less than 20,000 in 1999, Indian and South African flows were also split in two, as two equivalent travel choices could be identified. Australia is unusual in that most Australians travel directly to New Zealand. To account for the complete travel distance, domestic flights that connect to an international flight (e.g. from Perth to Sydney) were included. This procedure was also applied for the United States and Canada.

Passenger numbers of last ports of embarkation other than the ones identified as main flows were added to the geographically closest main tourist flow of the specific nation. For example, in the German case Singapore was identified as the most frequented hub and therefore represents other Asian routes, for example via Bangkok or Hong Kong. Adding up all visitor numbers at Asian airports of last embarkation reveals that 86% of German visitors flew via Asia, while 14% took the western route (for example, via Chicago, Honolulu or Fiji), represented by Los Angeles. The German flow via Asia was further split into a direct flow to New Zealand, and one leading via Sydney to New Zealand. Each of the three German flows was finally disaggregated into three arrival flows (if larger than 100) to the main international airports. Of each German visitor flow, 76% were assumed to have arrived in Auckland, 20% in Christchurch, and 4% in Wellington. All other nations' visitor flows were split in the same way according to the specific arrival share at the New Zealand main airports. In cases where no direct link between the last port of embarkation and the New Zealand gateway exists (e.g. Bangkok–Christchurch) a domestic flight from Auckland to the gateway was added. This approximates best to the total distance flown to the actual arrival airport.

For the purpose of this study, no distinction was made between multi- and single-destination travellers. This is relevant for the allocation of greenhouse gas emissions discussed later.

Calculation of distance and energy use

Most airways release information on routings and the corresponding mileage, and thus the mileage for a given itinerary can be readily estimated. Considering all identified routes for each nation the average travel distance from the country of origin to New Zealand was calculated. It is important to note that the procedure of identifying main gateways and main routes is a conservative approach in that it does not include individual routings that may deviate considerably from the identified flows. For example, 525 British visitors (0.3%) arrived in New Zealand via Buenos Aires, which is a longer route than the identified ones via Los Angeles and Singapore. Consequently, the described methodologies underestimate slightly the average travel distance, and thus energy use.

The average distance for each nation was converted into energy use per passenger by multiplying it with the energy intensity (energy use per passenger kilometre that takes into account average load factors and an average freight- to-passenger ratio) of a long-distance flight. This is reported to be 1.75 megajoules⁴ (MJ) of secondary energy (excluding energy used to extract, refine, and transport fuels) for modern aircraft (Lenzen, 1999). British Airways and Lufthansa report overall energy intensities of 2.03 and 1.86 MJ per passenger kilometre (Green Globe, 2000). The energy consumption given by Lenzen (1999) includes an average number of stops during long-distance flights, which is a relevant factor, as each landing and take-off cycle generally increases the energy consumption by about 1000 MJ per passenger (Hofstetter, 1992). To convert energy consumption into CO₂ emissions, a factor of 69 g/MJ for kerosene was applied (Baines, 1993; Ministry of Economic Development, 2000a).

In addition to energy use associated with travel from countries of origin, it is of interest to analyse travel flows on the last travel legs to New Zealand. This has implications for policies on the allocation of emissions, as will be discussed below. To estimate the energy use associated with the final network segment most accurately (e.g. Sydney to Auckland), the total visitor numbers, regardless of nationality at different ports of last embarkation, were analysed. Again, the distance for each flight sector was drawn from airlines' mileage tables. In most cases this referred to a flight from an overseas airport to Auckland. However, Christchurch and Wellington are directly linked with seven and three, respectively, overseas airports. Since the data provided by Statistics New Zealand (2000) give aggregated totals for arrivals at New Zealand airports and departures at last ports of embarkation, it is not possible to identify visitor numbers from a specific overseas port to a specific New Zealand arrival port. In these cases, an average distance from the overseas airport to New Zealand was calculated. For example, the mileage between Singapore and New Zealand is calculated as the average of the Singapore to Auckland and the Singapore to Christchurch distance. For Australian airports (Sydney, Melbourne, and Brisbane) this affects the distance only slightly (around 5%). The final travel distance, along with the visitor numbers at each airport of last embarkation and the energy factors given above, allowed for an estimate of energy use and CO₂ emissions for each last network segment.

Results

Energy use and country of origin

The procedure described in the methodology section splits the total of 1,591,650 (air) visitors into 346 visitor flow segments from 90 countries of origin. The minimum flying distance is from the Norfolk Islands (1091 km one way), and the furthest travel distance is from Ireland (21,434 km one way via Asia). On average, visitors arriving in New Zealand in 1999 travelled for 12,915 kilometres. Table 1 compiles the total visitor numbers arriving by air in 1999 (Statistics New Zealand, 2000a), the average flying distance for countries of origin, the associated energy use and CO₂ emissions. Clearly, tourism involves return travel and the figures presented in Table 1 need to be doubled to obtain the full amount of energy use and emissions associated with each trip. Due to the geographical distance, European tourists consume most energy by travelling to New Zealand. Interestingly,

Table 1 Arrival numbers for main countries of origin, average flying distance, energy use and CO₂ emissions for 1999

<i>Country of origin</i>	<i>Total air arrivals</i>	<i>One-way distance (km)</i>	<i>Energy use per visitor (MJ)</i>	<i>CO₂ per visitor (tonnes)</i>	<i>Energy use by country (PJ)</i>	<i>CO₂ per country (kilo tonnes)</i>
Australia	521,912	3,446	6,030	0.42	3.14	210
USA	173,182	11,146	19,500	1.4	3.37	230
United Kingdom	167,202	19,955	34,900	2.4	5.83	400
Japan	146,953	9,931	17,400	1.2	2.55	180
Germany	45,603	20,701	36,200	2.5	1.65	110
Korea	43,386	10,684	18,700	1.3	0.811	56
Taiwan	40,186	9,579	16,800	1.2	0.675	46
Singapore	33,873	8,514	14,900	1.0	0.505	35
Canada	32,864	15,172	26,600	1.8	0.874	60
Hong Kong	29,665	9,808	17,200	1.2	0.510	35
Thailand	23,233	10,257	18,000	1.2	0.418	29
China	22,978	13,874	24,300	1.7	0.558	39
Netherlands	19,394	19,077	33,400	2.3	0.648	45
Malaysia	17,161	8,755	15,300	1.1	0.263	18
South Africa	14,832	17,001	29,800	2.1	0.442	30
Fiji	14,151	2,218	3,880	0.27	0.055	3.5
Samoa	12,837	2,928	5,120	0.35	0.066	4.8
Switzerland	12,061	18,721	32,800	2.3	0.396	28
Other countries	220,177	(av.) 13,208	(av.) 23,100	(av.) 1.6	5.01	350
Total	1,591,650				27.8	1,900

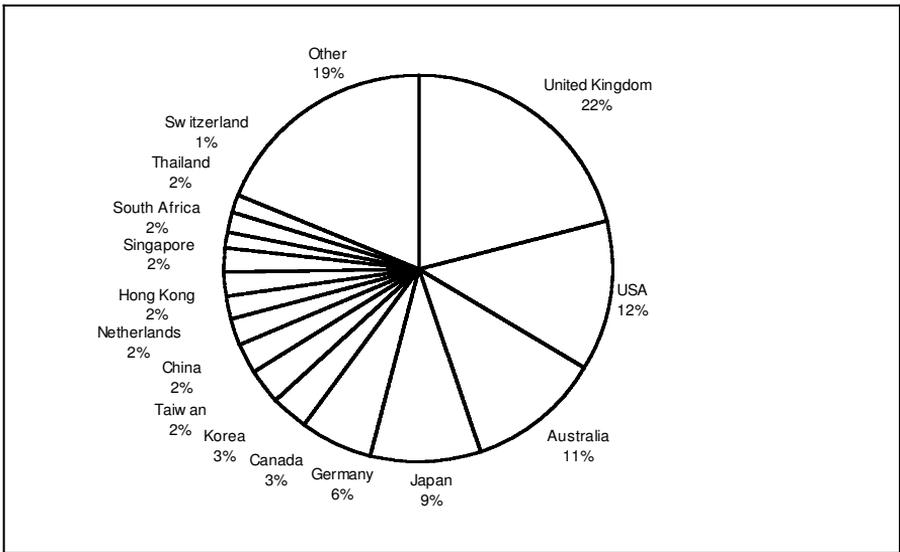


Figure 1 Origin countries' share of total energy use associated with international flights to New Zealand

visitors from South Africa also consume a large amount of energy of 27,800 MJ (one way), which is explained by the indirect route via Hong Kong travelled by 40% of South African visitors. This leads to the emission of more than two tonnes (4 tonnes for the return trip) of CO₂, only exceeded by British, Germans, Dutch, and visitors from other European countries. With an average travel distance of 3446 km, Australians consume least of the major markets (except for the smaller markets of the Pacific Islands), and produce less than one tonne of CO₂ for the return trip to New Zealand.

Apart from the energy use associated with individual travel to New Zealand, it is interesting to analyse the contribution of different nationalities. For this purpose, each country of origin's specific energy use for travelling to New Zealand was multiplied with the country's total arrival numbers by air. It appears that four countries account for more than half of the total energy consumption of 27.8 petajoules (PJ) (and 1900 kilo tonnes of CO₂), namely the United Kingdom, USA, Australia, and Japan. Figure 1 displays each nation's share in the total energy use associated with international air travel to New Zealand. Australia, while constituting 33% of all air-visitor arrivals, contributes only 11% to the total energy use associated with international air arrivals. In contrast, the proportions of visitor numbers from the UK and Germany (11% and 2.9% respectively) is lower than the proportions of energy consumption from the two countries (22% and 6% respectively). The remaining 85 countries of origin not displayed in Figure 1 consume together 5.1 PJ (19%) for their trip to New Zealand (10 PJ for the return trips).

Energy use and flight sector

The analysis of the last port of embarkation reveals the most frequently used flight sectors to New Zealand. More than half of all visitors (52%) travelled from

Table 2 Visitor arrivals, distances and resulting energy use and CO₂ emission for the last network segment to New Zealand

<i>Last port of embarkation</i>	<i>Visitor numbers</i>	<i>Distance (km)</i>	<i>Total energy use (PJ)</i>	<i>CO₂ emissions (kilo tonnes)</i>
Sydney	466,133	2,170	1.77	120
Melbourne	193,241	2,550	0.862	60
Brisbane	152,580	2,433	0.650	45
Los Angeles	144,904	10,488	2.66	180
Singapore	134,120	8,410	1.98	140
Tokyo	113,089	9,150	1.81	130
Hong Kong	60,051	9,233	0.970	67
Jakarta/Denpasar	56,170	7,506	0.738	51
Seoul	48,058	9,973	0.839	58
Fiji	44,103	2,158	0.167	11
Kuala Lumpur	30,844	8,825	0.476	33
Taipei	22,010	8,950	0.345	24
London	19,357	18,364	0.622	43
Honolulu	19,355	1,089	0.369	3
Other ports	87,635	(av.) 12,780*	1.96	140
Total	1,591,650		15.9	1,100

* This figure is large due to the false reporting of last ports of embarkation (e.g. Frankfurt or London)

or via Australia (Sydney, Melbourne, Brisbane, Cairns). The second and third largest flows arrived from Los Angeles (9.0%) and Singapore (8.3%). The picture changes, however, for concomitant energy consumption. The visitor flow from Australia to New Zealand is equivalent to an energy use of 3.5 PJ or 22% of the total energy use of 15.9 PJ (arrival only) (Table 2). Flights from Los Angeles to Auckland contribute 17% to the total energy use, and flights from Singapore and Tokyo to New Zealand make up 12% and 11%, respectively. Table 2 also presents CO₂ emissions associated with last network segments to New Zealand. The total amount of CO₂ emitted on the last flight sectors to New Zealand equals 1.1 million tonnes (one way). The last network segment contributes with 58% of the total CO₂ emissions of 1.8 million tonnes.

Discussion

The implications of energy use and CO₂ emissions resulting from air travel to New Zealand are discussed below on an individual basis, from a national and from a global perspective. More emphasis is put on energy use than on emissions, due to the uncertainty associated with the accumulated contribution of aviation to the greenhouse effect. In this discussion only CO₂ emissions will be

considered; however, it is important to point out that this is a conservative approach and the impacts on the atmosphere are possibly considerably underestimated.

The tourist's energy account

On a global average, the per capita emission of CO₂ as a result from all fossil fuel combustion (not just travel) amounts to 4.0 tonnes of carbon per year. In developed countries this figure rises to 10.3 tonnes, with a range between 5.5 to 20.2 tonnes (IPCC, 1995). New Zealand emits 8.0 tonnes of CO₂ per capita and year (Ministry for the Environment, 1997). Biesiot and Noorman (1999) calculated that a continuous energy use of 1–1.5 kW per capita can be maintained sustainably, which translates into 31,500 to 47,300 MJ or 2.2 to 3.3 tonnes CO₂ per person per year. This estimate is based on the global capacity of renewable energy sources allocated equally to the earth's projected population of 8 to 10 billion in 2050. Visitors from Europe and South Africa consume their budget of 2.3 tonnes CO₂ in total by their (one-way) trip to New Zealand. In a study on travel patterns in Sweden, Carlsson-Kanyama and Linden (1999) estimated a sustainable level of energy consumption⁵ for travel of 11,000 MJ (0.7 tonnes CO₂) per person per year. Considering the energy figures presented in Table 1, almost all visitors completely exhaust this budget by a single return flight to New Zealand.

In addition to the energy use associated with travelling to the destination, there is also considerable energy use within the country. The average energy use of an international tourist within New Zealand, including the transport and accommodation sectors, and visitor attractions, amounts to approximately 7290 MJ (circa 0.5 tonnes CO₂ when all energy demand is met with fossil fuels) (Becken *et al.*, 2001). Hence, even visitors from Fiji, who generally use the least amount of energy to travel to New Zealand, would exceed the sustainable limit of 11,000 MJ. Based on such an energy audit, any visit to New Zealand must be considered as unsustainable, given current technology.

However, tourism is not only seen as being socially and economically beneficial for both travellers and hosts, but it also constitutes a form of land use that has the potential to safeguard and conserve the very resource on which tourism builds. 'Use it or lose it' became a common expression in tourism studies (Wolters, 1999), meaning that tourism may be a useful tool to safeguard nature, cultural and social provision. Therefore, a pragmatic approach that allows for limited travel needs to be considered. Rather than measuring the total energy use associated with a trip, an indicator of energy intensity, such as energy use for the international flight per day, could be developed. Consequently, a longer stay would decrease the average daily energy use of the flight and increase the ratio of economic benefit for New Zealand (tourist spends) to the 'invested energy'. For example, a visitor from Australia would need to stay in New Zealand for at least 92 days (ignoring energy use within New Zealand) to meet the criteria of sustainability (based on a sustainable energy use of roughly 130 MJ/day), whereas a Japanese visitor would have to stay for at least 134 days. This principle is in line with ecotourism ideals of longer, more intensive (in the sense of experience), but less frequent holidays (Wolters, 1999).

National perspectives

Allocating emissions

The neglecting of energy use associated with international tourism can partly be attributed to complex political reasons. At present, the United Nations Framework Convention of Climate Change does not cover international aviation in its policy guidelines. The *Guidelines for National Greenhouse Gas Inventories* released by the IPCC (1996) advise including international air transport in the so-called international bunker fuels, which are reported separately and excluded from national totals. Generally, energy use and aircraft emissions are only regulated for domestic flights and the landing and take-off phase up to an altitude of 900 metres (Green Globe, 2000; Olsthoorn, 2001). Internationally, there have been several suggestions to allocate air traffic emissions, ranging from 'no national allocation at all' to an 'allocation to the nationality of the airline' or the 'country of departure or arrival' (ICAO, 2001). The New Zealand Ministry of Transport (1995) investigated the following allocation options:

- emissions from fuel burned within New Zealand's 200 km economic zone;
- emissions from fuel purchased within New Zealand;
- a half share of the fuel consumed between New Zealand and the first/last port of call overseas;
- a half share of the fuel consumed between New Zealand and the origin or destination port.

The suggestion of fuel consumed in the economic zone of 200 km of New Zealand is not investigated any further, as the major proportions of international flights would remain uncontrolled. The three other options result in very different energy use and emission scenarios. The least energy use allocated to New Zealand results from sharing the consumption (of international visitors) with the last/next port of embarkation. Assuming the same routing for arrival and departure, a half share of energy use for 1999 would amount to 15.9 PJ or 1.1 million tonnes CO₂. The fuel purchased as international bunker fuels for aviation amounted to 25.6 PJ⁶ (1.8 million tonnes CO₂) in 1999 (Ministry of Economic Development, 2000b). The largest amount of energy (27.8 PJ) allocated and the emission of 1.9 million tonnes of CO₂ occurs when energy and emissions are shared between the country of origin and New Zealand.

Different countries are likely to favour different allocation scenarios. Main generating countries, such as Germany or Japan, will probably be opposed to the principle of allocating emissions to the country of origin (the nationality principle, as described in Knisch & Reichmuth, 1996). This option would lead to a considerable increase in national greenhouse gas emissions without a direct economic benefit, since about half of tourists' expenditure remains at the destination (Arbeitsgruppe Ökotourismus, 1995). For the same reason it is conceivable that top tourism destinations, for example small island states, would benefit from the 'nationality principle'. The alternative of allocating emissions to countries of airline registration would result in considerable problems for airline hubs, especially for small countries, such as Singapore, with large hub-based airlines. In the case of New Zealand, where international arrivals and the departures of New Zealanders are within a similar range (1.6 million compared with

1.3 million), the option of fuel purchased within the country or the half share between New Zealand and the next port of embarkation seems acceptable. Again, several factors need to be considered, such as the possibly larger travel distance of visitors to New Zealand compared with outbound travel of New Zealanders (primarily to Australia).

It has become evident that international agreement will be difficult to achieve. As outlined in the Kyoto protocol, it is the role of the ICAO to implement appropriate mechanisms that allocate and limit greenhouse gas emissions from international aviation (ICAO, 2001).

Future options for New Zealand

While contributing directly to New Zealand's GDP at 4.9% (Statistics New Zealand, 2001b), tourism is also responsible for a considerable consumption of energy, especially if international air travel were included in national inventories. Reductions in energy use from international travel could be achieved by promoting markets that are geographically close to New Zealand (Australia and the Pacific Islands) and by generally increasing the average length of stay. This, however, needs to be investigated in more detail, as different types of tourists are likely to have different travel styles with characteristic energy consumption patterns. Another option would be to discourage the increasing outbound travel of New Zealanders by promoting domestic holidays, and thus shifting the focus away from international visitors. Finally, New Zealand could investigate the potential of cruising tourism, which presently makes up only 1% of visitor arrivals (Statistics New Zealand, 2001a). However, there is little understanding of this market in the Pacific, and a closer examination of environmental impacts of cruising tourism is yet to be undertaken.

Further inventories of emissions resulting from international air travel to New Zealand will have to account for 'trip chaining', that is, tourists who travel from one country to another (Lue *et al.*, 1993). New Zealand is a popular stop-over for round-the-world travellers and is part of a 'multi-destination area loop' defined by Oppermann (1995). According to Oppermann, 13% of all tourists to Australia visit New Zealand on the same trip. Depending on the allocation principle, this would reduce New Zealand's share of total energy costs associated with air travel. Much research on carbon sequestration through the plantation of native trees was initiated in the last year. As a result of great uncertainties in this field the option of offsetting carbon emissions is not discussed any further in this context.

Measures to reduce emissions globally

Technical progress and increase in efficiency have been promoted as the most convenient means to reducing environmental impacts. In fact, since 1976, the aviation industry has doubled fuel efficiency (Green Globe, 2000), and it is believed that future improvements have the potential to decrease the fuel consumption by a further 8–10% (Penner *et al.*, 1999). Whereas the chances of replacing jet fuels with renewable energy sources are slim, much increase in efficiency could be gained from improved operational management. This means, for example, increasing the average occupancy across the global fleet (currently at 66% (Green Globe, 2000), comparing favourably to other modes of transport).

Other options in this field are better air traffic management to avoid congestion and to optimise routings or the operation of bigger planes. Better operational practices are estimated to reduce the energy consumption between 8% and 18% (Penner *et al.*, 1999). It has been shown in this paper that visitors from South Africa frequently used the route via Hong Kong (19,935 km compared with 13,166 km via Sydney), resulting in an elevated energy use. This is induced by cheaper airfares (that do not reflect real costs) via the Asian hubs, compared with the Australian route.

Clearly, there is a need for further economic regulations. Possible options are the regulation of aircraft emissions, removal of subsidies, market-based options, such as charges and taxes, emission trading, voluntary agreements, and substitution of aviation by other modes of transport (Penner *et al.*, 1999). However, few of these instruments have been tested in aviation, and a macroeconomic analysis of effects is, therefore, required. Generally, the IPCC recognises that most of these options will increase airline costs, and, thus reduce demand for air travel. It is believed that an international framework could address mechanisms for internalising the environmental costs of aviation (Janic, 1999) through fiscal or regulatory policies. For this purpose, the OECD (1997) suggests a further harmonisation of international environmental standards under the auspices of the ICAO (as already indicated in the Kyoto protocol) to avoid inequality between airlines and between airports. The first step in this direction is the monetary assessment of external costs associated with air travel. There are various estimates for the marginal costs of CO₂ emissions, ranging from \$5 to \$125 per tonne of carbon (US\$) (Department of the Environment, Transport and the Regions, 2001; Frankhauser, 1994). These costs could be accounted for through fuel taxes. The introduction of such taxes, however, is one of the most controversially discussed measures. For example, Olsthoom (2001) calculated that a carbon tax would only achieve minor reductions in emissions. In contrast, Abeyratne (1993) reported that fuel costs represent 10–25% of an airline's variable costs and that any tax imposed on fuels would have considerable, detrimental effects on overall costs. This is confirmed by Crouch (1994), who found that long-haul tourism is more sensitive to transportation costs than tourism to closer destinations. According to this, countries that depend on long-haul travel will suffer most as a consequence of increased airfares.

Sustainable tourism?

Numerous studies have investigated the areas of sustainable tourism or sustainable tourism development (e.g. Hall & Lew, 1998). Key points in this context are ecological and social sustainability, and equity, both now and in the future (Høyer, 2000). The growing awareness of sustainability issues was accompanied by a boom in ecotourism as responsible tourism to natural areas that both conserves the environment and improves the well-being of local people (Ecotourism Society, 1997). According to this definition, it is not surprising that most ecotourism guidelines and projects focus on local impacts rather than on global effects. Transport induces broader impacts on the environment that are often considered as being 'beyond the scope' of ecotourism discussions (Buckley, 2001: 379).

While the conflict between sustainable development and tourist transport is generally poorly investigated (Hall, 1999; Høyer, 2000), the interface of air travel and the sustainability of tourism has been almost completely overlooked in previous research. Høyer (2000) points out that tourism, if aimed at sustainability, needs to undergo a complete change by complying in the first instance with the criteria of sustainable mobility. These criteria include, according to the Centre for Sustainable Transportation in Canada (1997), aspects of equal access needs of individuals and societies, accordance with human and ecosystem health, affordability and efficiency, and a minimisation of resource use. Long-distance air travel fails with regard to the aspects of health and resource use. Moreover, the principle of a fair distribution of the used resources is not met by global air travel, as only a minority of the world's population can afford to fly. In fact, only 6.5% (313 million passengers) of the population participate in air travel (Greenpeace, 1996), generating some 206 million tonnes of CO₂ in 1995 (Olsthoorn, 2001).

To meet criteria of sustainability, Høyer (2000) suggested to reducing 'aeromobility' and to alter travel behaviour towards locally oriented and non-motorised travel styles. In the case of remote destinations, such as New Zealand, this shift would clearly result in decreased visitor volumes. This is often in conflict with economic expectations attached to tourism. To comply with sustainability criteria, while keeping or increasing visitor volumes, the only feasible option appears to be the creation of carbon sinks and offsetting emissions. These ideas are already considered by several environmental associations that offer web-based 'carbon-calculators' to determine emissions associated with travel and the number of trees to be planted (e.g. American Forest, 2001). Gössling (2000) calculated an area of almost 30,000 km² that would need to be afforested each year to offset global emissions resulting from tourist air travel. However, the creation of carbon sinks is conceived as a preliminary measure that cannot substitute for structural changes and more permanent options (see also Noble & Scholes, 2001). Future research on sustainable tourism is challenged by the obvious conflict between promoting sound tourism at the destination and minimising impacts associated with travel to and from the destination.

Conclusion

From an individual, a national and a global viewpoint, international tourism and air travel are critical factors in achieving global sustainability. Apart from unsustainable energy use, the main detrimental effect of air travel is the emission of greenhouse gases. Clearly, remote countries that are focusing on tourism as a profitable and expanding industry, such as New Zealand, are in a delicate situation. The energy use of up to 27.8 PJ resulting from international air travel to New Zealand is comparable to the agricultural sector's energy use. In the *New Zealand Tourism Strategy 2010*, New Zealand demonstrates its awareness of environmental impacts caused by tourism, including the use of resources and the impacts of greenhouse gas emissions (Tourism Strategy Group, 2001). However, this awareness has so far not extended to the significant effects of international air transport. The country continues to increase visitor numbers and maximise benefits. The promotion of long-haul tourism is questionable, particularly,

because New Zealand markets itself as green destination with a recently launched global campaign of '100% pure New Zealand' (Tourism New Zealand, 2000).

Clearly, air traffic will be prevalent and will continue playing an integral role in many countries' tourism development. However, countries that depend strongly on air transport, such as New Zealand, may gain advantage by analysing their situation in terms of emissions ahead of time and taking precautionary measures to reduce these emissions.

There are several options to improve the environmental record of international travel, and thus reduce emissions. These include increasing the average length of tourist stay thus potentially decreasing the frequency of long-haul journeys, promoting domestic tourism, and increasing promotion efforts in countries that are geographically close to the destination.

The relative importance of leisure air travel to the total emission of greenhouse gases, both on a national and global scale, emphasises the necessity to include emissions from aviation in national accounts. Globally, regulatory options such as emission controls and taxes will lead to an increase in air fares, and thus may reduce visitor volumes.

Future research on sustainable tourism will need to broaden the perspective from local impacts to global ones by taking account of the so-far ignored impacts of air travel.

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Notes

1. The International Civil Aviation Authority (ICAO) is a United Nations agency with responsibility to develop standards and practices for international civil aviation.
2. Greenhouse gases are implicated in the phenomenon known as global warming, with implications for future climatic stability and sea levels. Key greenhouse gases include: carbon dioxide (CO₂), formed in the combustion of all fossil fuels, the most significant greenhouse gas; nitrogen oxides (NO_x), a collective name for various compounds of oxygen and nitrogen. They are formed in all combustion, and in aircraft engines because the high temperature and pressure cause the atmospheric nitrogen and oxygen to react with each other, mainly during take-off and ascent when the engine temperature is at a maximum. At low levels, NO_x gases are converted into nitric acids, which can contribute to the acidification of soils. At higher levels NO_x gases helps form ozone, (O₃), a highly effective greenhouse gas. Nitrous oxide (N₂O), a greenhouse gas formed through combustion, is broken down in the atmosphere into carbon monoxide and nitrogen oxides (based on definitions given in the SAS Environmental Report, 1997, Stockholm).
3. For comparison: in 1997 Kuala Lumpur airport reached a passenger volume of 17 million while Changi airport in Singapore plans for a projected volume of 64 million passengers in 2003 (Bowen, 2000).
4. One megajoule (MJ) equals 10⁶ joules; 1 petajoule (PJ) equals 10¹⁵ joules or 10⁹ megajoules.

5. In this study sustainable development comprises a long-term accordance between human activities and nature, the preservation of resources for future generations, and an equal share of these resources.
6. This includes all outbound travel (1.28 million short-term departures of New Zealanders in 1999 (Statistics New Zealand, 2000a) and returning overseas visitors).

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