THE IMPACT OF TOURISM ON CLIMATE CHANGE

Paul Peeters [a*]

Centre for Sustainable Tourism and Transport, NHV University for Applied Sciences, Breda, Netherlands

Abstract – The impact of tourism activities on climate change are not very evenly distributed over the different kinds of tourism. Main determinants are the distance between the destination and the homes of the tourists, the transport mode choice and the length of stay. Overall impact of tourism is between 4% and 10% globally, but can be as high as 20% for developed economies. Almost 90% of all tourism greenhouse gas emissions are generated by transport in general and some 70-80% of this relates to air transport in particular, while road transport is still the main transport mode for tourism (in number of trips). Generally tourists tend to choose more often for air transport, destinations at longer distances and shorter stays plus increasing number of trips. All of these choices direct to a reduction of the eco-efficiency of tourism. Some further prospects for technological innovation in air transport exist, but progress will not be large enough to compensate for the growth of air transport volume.

Keywords –climate change, tourism, air transport, mitigation, radiative forcing.

1 Introduction

The relation between climate change and tourism is twofold: climate change impacts on tourism and tourism impact climate change. The first relation may ask for adaptation measures, like shifting destinations, seasons and activities and investing in new air condition systems. Adaptation will be dealt with in several other papers in this publication. The second relation may ask for mitigation measures aimed at reducing greenhouse gas (GHG) emissions. Also mitigation policies in other sectors may have consequences for tourism as well and require also adaptation. An example may be measures aimed at reducing emissions by transport or the consumption of energy for heating or cooling accommodations. Such measures may change the cost of several resources for the tourism industry, asking for adaptation measures and investments regarding activities, transport and destination choices. This paper aims to give a short overview of the magnitude of the impact of tourism on climate change and some general remarks on mitigation and adaptation-to-mitigation.

The most important GHG emission is carbon dioxide (CO_2), important that it is responsible for most radiative forcing (RF) caused by humans and responsible for the increase in average temperature. Carbon dioxide is emitted in tourism through the operation of accommodations (heating, cooling, washing, cooking, etc), activities (energy use for transportation of tourists from their accommodations to the sites of activities, for operating restaurants, bars, disco's, cinemas, cable-cars, scenic tours, et cetera) and transport between the tourists homes and the destination areas (by car, coach, train, ferry, aircraft, et cetera). Recent research shows that rather large uncertainties exist on the global GHG emissions of the tourism industry. Tourism is often described as the largest economic sector. According to the World Travel & Tourism Council (WTTC et al. 2007) the contribution of the 'travel & tourism industry' to world GDP was 3.6% in 2006. This includes leisure, business and VFR (visiting friends and relatives) and both domestic and international tourism and a large share of day-leisure visits (to museums, leisure parks, nature, et cetera). If also the supplying industry that is associated with non-visitor services, manufacture of transport vehicles and investments are accounted for (the 'travel & tourism economy'), this share increases to 10.2%.

An important issue is the impact of non-carbon contributions to climate change. For the world economy these emissions add 40% to the contribution in Global warming potential of CO_2 emissions alone (an 'equivalence factor' of 1.4, see also Gössling et al. 2005). For the EU economy a factor 1.17 has been published by the European Commission (COM 2007). For road, rail and sea transport an equivalence factor of 1.05 has been found, meaning CO_2 is here the main contributor to global warming. However, air transport forms an exception as it emits not only CO_2, but also other gases causing direct and indirect. The main indirect impact is the contribution to the forming of contrails (condensation stripes) at cruising altitude and the non-carbon radiative change in the year 2000 almost equals the total long term impact of cumulative CO_2 emissions by aviation since 1940 (see Sausen et al. 2005). This is too large to ignore, but finding a metric for this impact is rather difficult (see §2).

Global atmospheric concentrations of carbon dioxide (CO_2) should be kept below 450 ppmv (Graßl et al. 2003, Schellnhuber et al. 2006). In order to achieve this, a reduction of GHG emissions by about 80% is required by 2050 for developed economies, while at the same time room for development for developing countries is created. Assuming that emissions should be reduced on an equal basis for each sector, the tourism sector faces substantial reduction demands, while currently being characterized by rapid growth of emissions.

* *Corresponding author: Paul Peeters: Center for Sustainable Tourism and Transport, Breda University of Applied Sciences, P.O. Box 3917, 4800 DX Breda, The Netherlands. Email: peeters.p@nhtv.nl.*

2 GHG emissions from tourism

The impacts of aviation on climate change are not only from carbon dioxide emissions, but stem also from NO_x emissions and impacts like the forming of contrails (condense lines at cruising altitude) and contrail induced cirrus. For non-aviation sectors the radiative forcing caused by non-carbon emissions (and excluding impacts of land-use changes) is 17 % (COM 2007). For aviation these non-carbon impacts on radiative forcing have been estimated defining a Radiative Forcing Index (RFI, the ratio between all current radiative forcing RF, historically caused by aviation and the RF from all aviation CO_2 emissions since 1940 (Prather et al. 1999). The latest update for this factor is for the year 2000 and amounts to 1.9 (Sausen et al. 2005). The problem with RFI is that it is based on historic emissions, while CO_2 eq. Refer to the future impact (normally 100 years in advance) of GHG emissions compared to the impact of CO_2 emissions, using the Global Warming Potential as a metric (Shine et al. 2005). For aviation GWP is not appropriate as it considers well-mixed gases that stay at least for about a decade in the atmosphere. Still Forster et al. (2006) defined an emission weighting factor (EWF) and calculated this at 1.7 for a 100 year period. Comparing this factor with the overall factor of 1.17 as mentioned above, it is clear the shares of aviation will rise more than those of the global emissions and thus the moment at which aviation takes 100% of all emissions will shift substantially forward in time.

From recent work presented at the e-CLAT conference on Climate Change Mitigation and Tourism, June 2006 in Westelbeers, the Netherlands, the relation between RFI, aviation emission growth and global emissions scenario's has been established (Peeters et al. 2007, in press). Generally it appears RFI will increase with time when the aviation emissions growth is above 2% per year and will decrease if it is lower. Furthermore the RFI is lower for global low CO_2 concentration scenarios. The differences emerge because the carbon related radiative forcing is largely cumulative, while the non-carbon impacts are more or less instantaneous (the main part of the impact disappears within a day, the remainder within less then ten years). Figure 1 shows the relationships. The B2 scenario results is lower CO_2 concentrations in the atmosphere as the IS92a scenario (both are IPCC SRES scenarios, IPCC 2000).

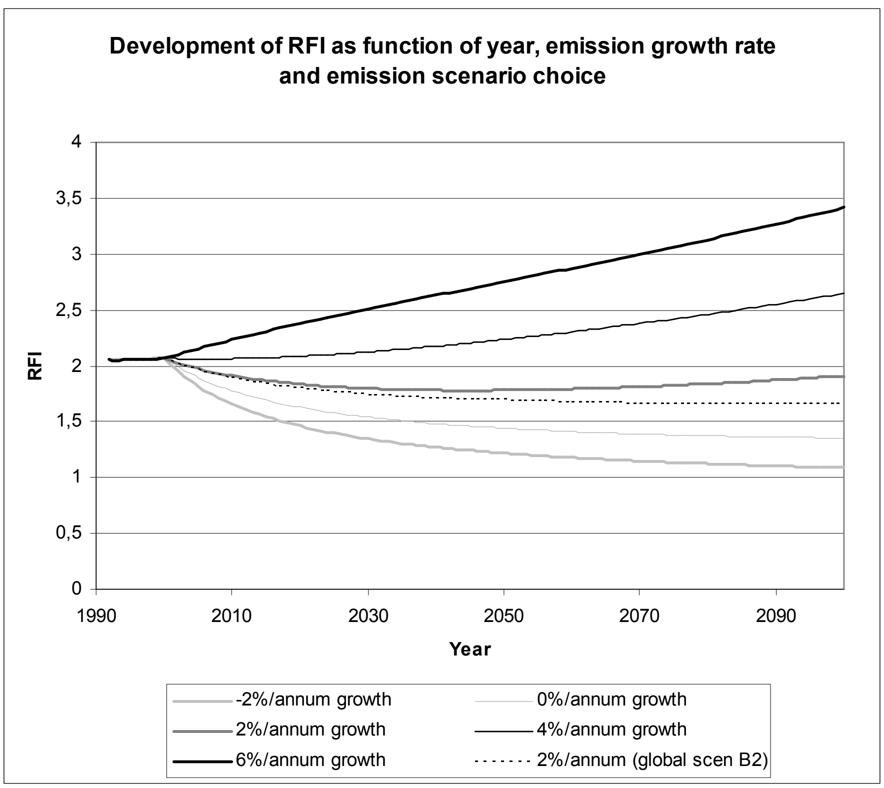

Figure 1: the relations between RFI (excluding the impact of cirrus), future year, aviation emission growth rates and global emissions scenario (all aviation growth scenarios are combined with the IS92a (except for the dotted line showing the impact of the lower emissions background scenario B2; based on data by Penner et al. 1999, Sausen et al. 2005).

As shown in §1 rather large uncertainties still exist on the extend and distribution of the GHG-emissions of the tourism industry as we will describe in this paper. Following numbers give some feeling of the extend of the share of the travel & tourism industry to climate change:

- World wide: 4-10% in 2000 (historical contribution radiative forcing, thus based on the RFI metric, RFI=2.7)

- In the developed world: 10-20% in 2000 (GHG emissions, RFI=2.7)
- In an unsustainable future (+3-5 ºC) world wide: 10-20% of radiative forcing in 2050
- In a sustainable future (with less than +2 ºC): 50-100% of radiative forcing in 2050 (see also paper by Bows, Anderson & Peeters in this publication).

From the above data it is easily seen that the eco-efficiency of the travel & tourism industry (in € contribution to GDP per ton greenhouse gas emissions) is about half of the world economy average as the global share of emissions is between 4-10% is two times the share in GDP of 3.6% (see also Gössling et al. 2005).

Now we have some idea of the total share of GHG emissions of tourism it is time to consider the shares of the different ingredients of tourism: accommodations, activities and transport. Worldwide data are not systematically available. The best available estimate is given by Gössling (2002). Based on this assessment, but correcting for an apparently low estimate of global number of accommodations and at the same time including business travel by air, Figure 2 has been drawn. The figure shows that OD-transport (between the homes of the tourists and their destinations) to a large extend determines the total impact of tourism on global warming[1].

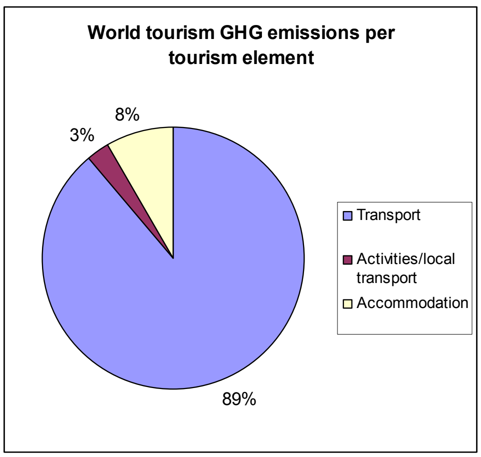

Figure 2: shares of GHG emissions (RFI=2.7) per element of tourism (based on data by Boeing 2005, Gössling 2002, Peeters et al. 2007b).

The next issue to discuss is, if *climate change* is the main environmental problem of tourism transport. To give an answer we need to find a common indicator for all environmental costs of tourism. External costs are such an indicator (see for definition in Schipper 1999). Figure 3 shows the external costs for tourism O/D transport for all tourism trips (domestic, intra-EU and intercontinental) taken by the EU-25 citizens in 2000.

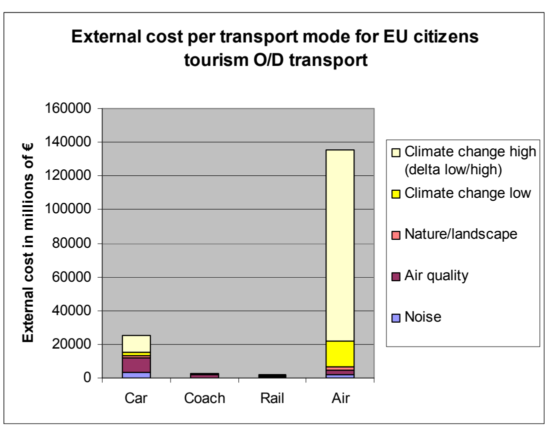

Figure 3: External cost of all tourism O/D transport by all citizens of the European Union (based on Peeters et al. 2004).

[1] *With a RFI of 1.9 (Sausen, R., Isaksen, I., Grewe, V., Hauglustaine, D., Lee, D. S., Myhre, G., Köhler, M. O., Pitari, G., Schumann, U., Stordal, F. & Zerefos, C. (2005) Aviation radiative forcing in 2000: An update on IPCC (1999). Meteorologische Zeitschrift, 14 (4), 555-561.), the share of transport would reduce to 87%.*

Obviously climate change is the most important externality even at the lower limit of cost estimates per ton greenhouse gas emissions. Therefore focus on transport is when assessing the impacts of tourism on global warming and the options for mitigation. Figure 3 also shows that air transport has a disproportionate share of the external cost of global warming. Let us therefore more closely consider the modal shares for tourism transport. Figure 4 shows the modal split for number of trips, kilometres travelled and GHG emissions for all tourism trips by EU25 citizens. It is clear that in both 2000 and 2020 the car is the backbone of tourism as it serves more than half of all trips. However in terms of traffic - number of kilometres travelled - the aircraft takes the main share now and in 2020. The consequence of this is that air travel, though responsible for just 20% of all trips has a share of the GHG emissions of 75% in 2000 and even 85% in 2020.

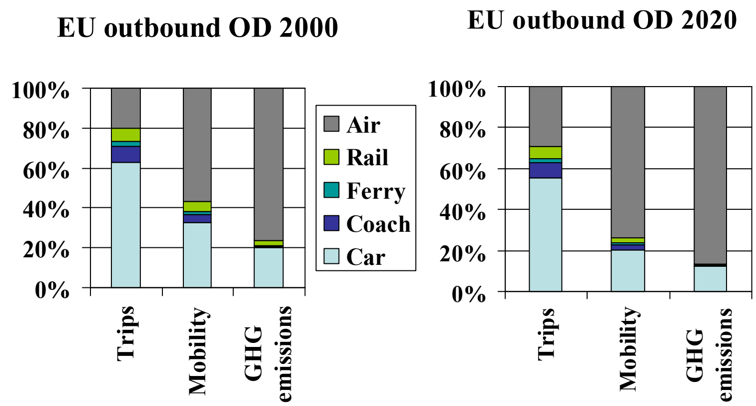

Figure 4: modal split for trips, mobility and GHG emissions of all tourism trips by EU25 citizens (thus including domestic, intra-EU25 and intercontinental) in 2000 and a forecast for 2020 (using RFI=2.7; based on Peeters et al. 2004).

What Figure 4 does not show is the growth between 2000 and 2020. The number of trips may grow by 57% between 2000 and 2020, however, the growth pace of traffic is much larger, with 122%. Due to technological development of fuel efficiency the GHG-emissions will increase a bit less: 90% between 2000 and 2020.

Another issue is to understand individual tourists and the consequences of their behaviour on global warming. Why do they behave in the way that can be observed and why are they behaving more and more towards increased greenhouse gas emissions per night? Figure 4 shows the personal impact - in terms of emissions per tourist day - of the individual choices for transport mode and length of stay (LOS).

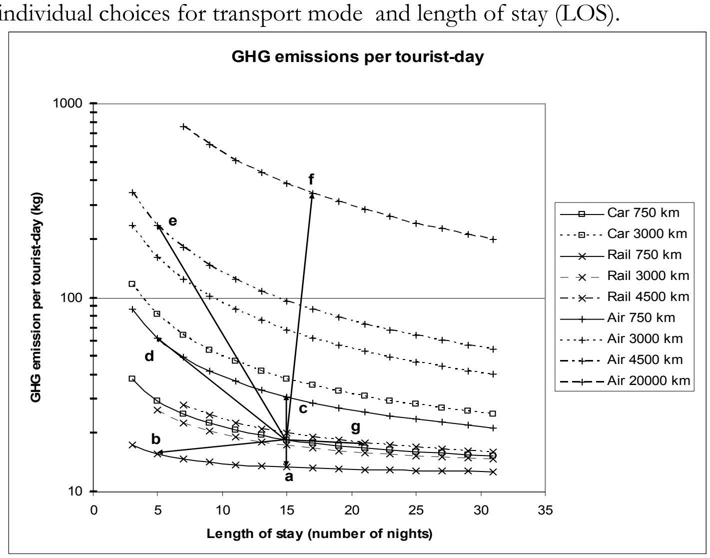

Figure 5: GHG emissions per tourist-day as function of length of stay and O/D transport mode, assuming constant average emissions for accommodation and activities (RFI=2.7; Peeters et al. 2007a)..

Note that the y-axis is logarithmic. The arrows show 'scenarios' for travel choices that deviate from the most common tourist trip (the *mode* trip), covering a return distance of between 500 and 1000 km by car and with a length of stay of 15 days. A large share of EU tourism trips fall into this category. The arrows represent scenarios of changed choice for the mode family. Scenario a shows that favouring rail over the car would result in 28% reduction of emissions for an otherwise identical holiday trip. Scenario b reveals that favouring the train over the car would, even at an average stay of only 5 days, still result in 16% lower emissions. Favouring the aircraft over the car would lead to an increase of 66% of emissions per day for an otherwise identical two-week trip (scenario c). For a shorter trip, the use of the aircraft would make the trip's eco-efficiency even less favourable, leading to a factor 3.3 higher emissions (scenario d). This factor increases to 12.7, if the distance to the destination for such a short trip (5 days) is quadrupled (scenario e). A choice for a long-haul destination leads to a factor of 17.6 increase (scenario f). Finally, in scenario g, increasing the LOS to 21 days, while favouring the train over the car, can even at six times the return distance (4500 km) result in slightly lower (4%) emissions. In conclusion: the options for the mode family to increase the emissions per tourist-day appear to be much more abundant than the options to reduce them. Furthermore the potential increases are far larger than the potential reductions.

Conclusions: the main source of GHG emissions related to tourism is air transport. Air travel is also the fastest growing part of tourism. And in the current situation individuals have more options to increase than to decrease their emissions. In both global and individual perspectives aviation plays an important role in the growth of GHG emissions. So when looking at mitigation of GHG emissions emphasis should be put on the role aviation in tourism.

3 Some mitigation basics

The amount of GHG emissions is determined by the volume of tourism times the average emission factor. The volume comprises first of all the number of kilometres travelled and thus not just the number of trips or the length of stay (LOS). The emission factor is a function of the energy efficiency and fuel used for the transport system, state of technology of the transport systems and the operational efficiency (like seat occupation rate, directness of routes, travel speed). For accommodations it is technically feasible to reduce emissions to zero (see for example Bode et al. 2003). In the world of building the technology to store heat in the summer while cooling a building and to use this stored heat in winter has been proven to make heating and air conditioning almost carbon neutral. Also the options to reduce emissions at electrical power stations (solar energy, wind energy, water power, combined heat and power, CO_2 sequestration) are more abundant and much cheaper than for mobile, oil based GHG sources like cars, coaches and aircraft.

For leisure activities it is paramount to consider energy use and emissions at the design phase of development. The difference between the energy consumption of a scenic walk or a scenic helicopter flight is two orders of magnitude. Generally activities comprising air based tours or a relatively large amount of high power per seat vehicle kilometres have large impacts on GHG emissions and climate change. Also indoor activities at inappropriate climates/seasons (like skating or skiing halls in high summer or hot deserts or a tropical swimming paradise at high latitudes or in winter) require generally large amounts of energy per visitor-hour. The second option for mitigation with leisure activities is increasing energy efficiency, using electricity from the grid and/or (local) sustainable energy sources and for example replacing aircraft or helicopters with blimps/airships for scenic flights.

The best and cheapest technical prospects for zero emissions are found with electric rail transport, because such transport systems rely on static power stations. For such power stations the cost of reducing GHG emissions are far lower than for mobile emission sources like cars. At this time both Swedish and Swiss rail systems are almost zero emissions as they make use of their own water power stations. All electrically driven Austrian railways run for 100% on green electricity, thus saving large amounts of CO_2 emissions and at the same time reducing several other environmental impacts. Other railway companies in Europe could easily chance their power policy and change to 'green' or 'nature' power, thus within years achieving near-zero emissions. Add to this the high energy efficiency of rail (technically five to ten times more energy efficient than the competing modes if the system is used intelligently), and it is clear renewed development of rail travel poses an important chance to reduce tourism caused global warming.

For car transport, the backbone of tourism, options to reduce GHG emissions are increasing the energy efficiency, using bio-fuels or a combination of solar energy – hydrogen – fuel cells. These are all relatively expensive options that can only be realised in the medium long term. A complication is that other fuels generally lead to replacing the problems from the user phase to the production of the fuel (bio-fuels) or energy required to produce the fuel (hydrogen) or both. The tourism sector may help to increase the rate of introduction of new technology by restricting access by cars with 'old' technology in favour of cars with 'new' technology (like favouring hybrids in distributing scarce parking capacity). Some tourism villages in the Alps are successfully experimenting with such schemes. Nevertheless, a shift from car to rail helps to reduce emissions and can be achieved with micro-measures at the tour operator and destination level (like in Werfenweng, Austria or other 'Pearls of the Alps').

Than we come to air transport technology. In the current literature it is assumed that fuel consumption per seat kilometre of new aircraft designs will reduce at a fixed rate per year. Values found are between 0.5% and 1.3% (Penner et al. 1999: Table 9-15). Fleet-wise the development is higher with rates between 1.0% up to 1.8% and a most common one of 1.4% (Penner et al. 1999: 5). However recent research shows that such an exponential function does not fit historical development of both piston and jet powered airliners (Peeters et al. 2006, Peeters et al. 2005). The annual decrease itself decreases per year (see Figure 6). Fuel efficiency using the 1.4% figure would yield 43% lower fuel consumption per seat kilometre between 2000 and 2040. The new method, using a sigmoidal model, yields numbers of 16%, 28% and 35% for the same period (for respectively US fleet, all new aircraft, new long haul aircraft only), significantly lower. For longer periods the differences increase further. More on this in the paper by Bows, Anderson and Peeters.

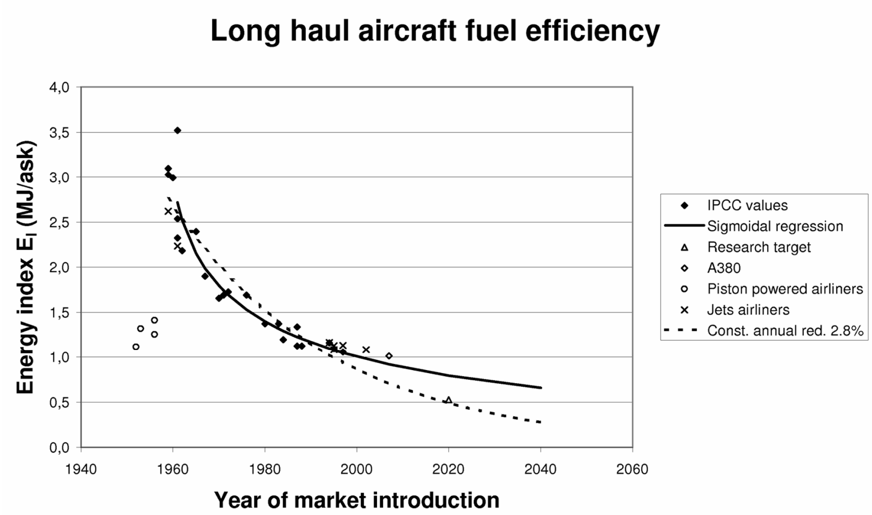

Figure 6: example of the development of fuel efficiency of long haul jets showing that conventional exponential methods cannot fit the historical development in a proper way.

An elegant way to reduce the impact of greenhouse gas emissions from aviation seems to plant trees, that withdraw the carbon dioxide from the atmosphere, schemes like Climate Care and Trees-for-travel. The prospects for this will be discussed by Gössling in a separate paper (see also an overview in Gössling et al. 2007). The main problems with such schemes are their credibility and their scalability. The amount of space required for compensating aviation alone is huge and space is scarce. Actually, if all emissions by aviation are to be compensated in this way, by 2050 50-100% of all space for sequestration of CO_2 by forestry projects will have been used up, that is, the total amount of carbon sequestered by the maximum available forest land of 700 Mha will have been emitted by aviation alone. As the capacity to compensate is a scarce good, decisions to use it for one sector has implications for the non-use in other sectors. Therefore it has to be discussed if compensation schemes should not be used first for primary needs (food, housing, daily transport) in stead of luxuries like frequent long haul travel. Furthermore a conflict in interests between Western tourists and developing countries can not be ruled out, as the tourists claim a large share of these compensation grounds next to the already large areas required for resorts, beaches, second homes and nature reserves.

Related is the emergence of use of bio fuel for transportation. Also this option is a scarce good and cannot satisfy current energy needs let alone unlimited growing needs in the future. Palm tree fields grow currently at the cost of tropical forests. Poor Mexicans are faced with doubling the cost of their food, mainly maize, to some extend caused by the increasing demand of maize for bio-fuels on the world market. On the other hand will farmers in poor countries see more benefit from the maize they produce.

Transport volume can partly be reduced independently of the economic prospects of tourism. This subject will be dealt with by the paper by Peter Burns and Lyn Bibbings. Technically spoken these are not necessarily damaging for the tourism sector: the number of nights can be kept constant while at the same time reducing emissions if length of stay is increased or at least current trend of reducing LOS is brought to a halt. Current practice of offering tours and travel products at a 'price from ..' means that the lowest price is associated with the shortest travel. Advertising the lowest price per day would invert this to the longest stay on offer. This may have some influence on product choice. Another way to reduce transport volume is a shift to nearer destinations. Currently most tourism is domestic/short haul (for EU25 citizens 55% of domestic, and only 5% intercontinental). But long haul tourism is growing at double the rate of short haul tourism. We need to reconsider why people are travelling further and further away for doing essentially the same things (lying on beaches, hiking, 'being away from it all'). And why long haul tourism products are marketed with more rigour – i.e. using more expensive communication through radio and television - than domestic or short haul products.

To help tour operators and travel agencies to reduce the GHG emissions of their products, global warming might be included in CSR (Corporate Social Responsibility) reporting schemes. Obviously this is not common practice. Even public 'sustainable' tourism websites like Responsible Travel (www.responsibletravel.com) almost ignore the global warming side of the products offered on the site. The world first seems a small Travel agency of the Youth Department of Dutch NIVON that shows the ecological footprint per night for all holidays on offer at the website in the main overview of the product (so next to price, number nights, travel dates, etcetera). Ecological footprint is largely determined by GHG emissions.

4 Conclusions

From the above the following is concluded:

- The tourism and travel sector contributes currently a higher share to climate change than (directly) to the global economy and is thus a relatively eco-inefficient sector with respect to global warming.
- The tourism & travel sector develops towards a higher dependency on high energy transport and activities and more luxurious accommodations, thus further decreasing the eco-efficiency.
- Air transport causes an increasing share of all tourism & travel related global warming, a share that is currently already over 60%.
- Most tourism trips are relatively eco-efficient as 80% of the trips (by rail, coach and car) cause just about 20% of the GHG emissions.
- The number of choice options for individual mode travellers to increase their personal contribution to global warming per travel day are a magnitude of order larger and several times more numerous than options to reduce this personal contribution.
- Technology reducing GHG emissions and increasing energy efficiency offers the best opportunities for accommodations and rail transport. For road transport fuel efficiency and alternative fuels remain the best solution, apart from modal shift to rail.
- Air transport prospects for further increasing fuel efficiency are relatively low because the technology of jet aircraft has become already more or less mature. Alternative fuels will not be introduced on a large scale within the next three to five decades, unless strong government incentives are given.

Generally it is clear that only a small part of all tourism is responsible for the main share of GHG emissions. This means that mitigation can be directed mainly at this smaller part of tourism, leaving the main part more or less unaffected. This reduces the problem. Unfortunately the current trends show an increase of the share of tourism with high GHG emissions, complication mitigation through volumetric measures.

References

Bode, S., Hapke, J. & Zisler, S. (2003) Need and options for a regenerative energy supply in holiday facilities. *Tourism Management,* 24**,** 257-266.

Boeing (2005) *Current market outlook 2005*. Seattle: Boeing Commercial Airplanes. Marketing.

COM (2007) *Limiting global climate change to 2 degrees Celsius: the way ahead for 2020 and beyond. Final edition.* Commission of the European Communities.

Forster, P. M. d. F., Shine, K. P. & Stuber, N. (2006) It is premature to include non-CO_2 effects of aviation in emission trading schemes. *Atmospheric Environment,* 40 (6)**,** 1117-1121.

Gössling, S. (2002) Global environmental consequences of tourism. *Global environmental change part A,* 12 (4)**,** 283-302.

Gössling, S., Broderick, J., Upham, P., Ceron, J.-P., Dubois, G., Peeters, P. & Strasdas, W. (2007) Voluntary carbon-offsetting schemes for aviation: Efficiency, credibility and sustainable tourism. *Journal of Sustainable Tourism,* 15 (3)**,** in press.

Gössling, S., Peeters, P. M., Ceron, J.-P., Dubois, G., Patterson, T. & Richardson, R. B. (2005) The eco-efficiency of tourism. *Ecological Economics,* 54 (4)**,** 417– 434.

Graßl, H., Kokott, J., Kulessa, M., Luther, J., Nuscheler, F., Sauerborn, R., Schellnhuber, H.-J., Schubert, R. & Schulze, E.-D. (2003) *Climate protection strategies for the first Century: Kyoto and beyond. Special Report.* Berlin: WBGU.

IPCC (2000) *Special report on emission scenarios.* Online documents at URL http://www.grida.no/climate/ipcc/emission/index.htm [03-03-2006].

Peeters, P., Williams, V. & Gössling, S. (2007, in press) Air transport greenhouse gas emissions. IN Peeters, P. M., Amelung, B., Becken, S., Ceron, J.-P., Dubois, G. & Gössling, S. (Eds.) *Tourism and Climate Change Mitigation. Methods, greenhouse gas reductions and policies*. Westelbeers (NL), NHTV.

Peeters, P. M., van Egmond, T. & Visser, N. (2004) *European tourism, transport and environment. Final Version.* Breda: NHTV CSTT.

Peeters, P. M., Gössling, S. & Becken, S. (2007a) Innovation towards tourism sustainability: climate change and aviation. *Journal of Innovation and Sustainable Development,* 1 (3)**,** 184-200.

Peeters, P. M. & Middel, J. (2006) Historical and future development of air transport fuel efficiency. *Transport and Climate Change (TAC) Conference*, 25-29 June 2006. Oxford.

Peeters, P. M., Middel, J. & Hoolhorst, A. (2005) *Fuel efficiency of commercial aircraft. An overview of historical and future trends.* NLR-CR-2005-669 Amsterdam: Peeters Advies/National Aerospace Laboratory NLR.

Peeters, P. M., Szimba, E. & Duijnisveld, M. (2007b) Major environmental impacts of European tourist transport. *Journal of Transport Geography,* ?? (??)**,** in press.

Penner, J. E., Lister, D. H., Griggs, D. J., Dokken, D. J. & McFarland, M. (Eds.) (1999) *Aviation and the global atmosphere; a special report of IPCC working groups I and III,* Cambridge, Cambridge University Press.

Prather, M. & Sausen, R. (1999) Potential climate change from aviation. IN Penner, J. E., Lister, D. H., Griggs, D. J., Dokken, D. J. & McFarland, M. (Eds.) *Aviation and the global atmosphere; a special report of IPCC working groups I and III*, 185-215. Cambridge, Cambridge University Press.

Sausen, R., Isaksen, I., Grewe, V., Hauglustaine, D., Lee, D. S., Myhre, G., Köhler, M. O., Pitari, G., Schumann, U., Stordal, F. & Zerefos, C. (2005) Aviation radiative forcing in 2000: An update on IPCC (1999). *Meteorologische Zeitschrift,* 14 (4), 555-561.

Schellnhuber, J., Cramer, W., Nakicenovic, N., Wigley, T. & Yohe, G. (Eds.) (2006) *Avoiding Dangerous Climate Change* Cambridge, Cambridge University Press.

Schipper, Y. (1999) *Market structures and environmental costs in aviation. A welfare analisys of European air transport reform.* proefschrift Amsterdam: Vrije Universiteit Tinbergen Institute Research Series.

Shine, K. P., Fuglestvedt, J. S., Hailemariam, K. & Stuber, N. (2005) Alternatives to the global warming potential for comparing climate impacts of emissions of greenhouse gases. *Climate Change,* 68, 281-302.

WTTC & Accenture (2007) *World travel & tourism climbing to new heights. The 2006 travel & tourism economic research.* Online documents at [28-01-2007].