Voluntary Carbon Offsetting Schemes for Aviation: Efficiency, Credibility and Sustainable Tourism

Stefan Gössling
Department of Service Management, Lund University, Helsingborg, Sweden, and Western Norway Research Institute

John Broderick, Paul Upham
Tyndall Centre for Climate Change Research, The University of Manchester and Manchester Business School, UK

Jean-Paul Ceron
CRIDEAU, Université de Limoges, France

Ghislain Dubois
Tourisme Environnement Consultants (TEC), Marseille, France

Paul Peeters
Centre for Sustainable Tourism and Transport, NHTV Breda University of Applied Sciences, The Netherlands

Wolfgang Strasdas
Sustainable Tourism Management, University of Applied Sciences Eberswalde, Germany

Tourism is becoming increasingly dependent on air transport. Recent scientific work has pointed out the significant and growing contribution of air transport to greenhouse gas (GHG) emissions. Obligations to reduce GHG emissions under the Kyoto Protocol and post-Kyoto instruments might make transport more expensive or even restricted in the future. This paper examines these questions and the issues raised by the increasing number of organisations offering voluntary carbon offsetting schemes as a means of compensating for emissions of GHGs, mostly from transport, which could help to stabilise or reduce emissions. There are substantial differences between the approaches chosen by these organisations in terms of their calculation of emissions, compensation measures, price levels, company structures and evaluation processes. The paper discusses these differences and their consequences for the efficiency and credibility of voluntary carbon offsetting schemes. Within this increasingly contested area, there is general agreement that increased clarity and regulation is required.

doi: 10.2167/jost758.0

Keywords: aviation, carbon offsetting schemes, greenhouse gas emissions, Kyoto, sustainable transport, sustainable tourism

Introduction

It is now widely recognised that the transport sector accounts for a large and growing share of emissions in industrialised countries. Recent mobility studies, which have focused on global transport sectors: aviation (Åkerman, 2005), regional or national leisure mobility (Åkerman & Höjer, 2006; Ceron & Dubois, 2006; Chatterjee & Gordon, 2006; Peeters & Schouten, 2006), European leisure mobility (Peeters *et al.*, 2004, 2007a) and aviation in the European Union (EU) (Bows *et al.*, 2006a), all indicate that there are growing gaps between current mobility trends and sustainable transport scenarios. These studies also show that air travel contributes, by far, the largest proportion of the growth of greenhouse gas (GHG) emissions in the transport sector. Aviation now accounts for 3.4–6.8% (Gössling & Peeters, 2007) of all emissions of GHG. While these figures may be debated, there is agreement that growth rates in aviation's fuel use are considerable and in the order of 3% per year globally, and an observed 4.3% per year within the EU25 in the period 1990–2003 (Commission of the European Communities, 2005; T&E, 2006; see also Gössling & Peeters, 2007, for emissions from aviation in contrast to other transport sectors). This is highly problematic given the commitment of the EU to reduce its emissions of GHG by 8% in 2008–2012 (base year 1990; EEA, 2006), with even more drastic reductions needed by 2020 and 2050 (Graßl *et al.*, 2003; Meinshausen, 2005; Schellnhuber *et al.*, 2006). A reduction of emissions throughout all sectors (transport, housing, food, industry, etc.) would then also apply to the transport sector, demanding a reversal of observed growth trends or, if transport is allowed a softer treatment than other sectors, over-proportionally large reductions in other sectors (cf. Ceron & Dubois, 2007).

The tourism industry is heavily and increasingly dependent on air transport. Its future depends on finding ways to reduce GHG emissions, if possible without reducing tourism's activities. Equally, the future credibility of the concept of sustainable tourism depends on finding ways of reducing tourism's GHG emissions and their contribution to global warming.

Various measures are currently under general discussion for reducing the contribution of the transport sector and aviation in particular, to global warming. These include governmental command-and-control measures (emission trading schemes, emission taxes, fuel taxes or value-added taxes), technological change (improved fuel efficiency, alternative fuels) and structural change (restructuring public transport, changing flight altitudes and flight corridors, capacity management, air traffic management) (Peeters *et al.*, 2006). The combined potential of these measures is substantial (Åkerman & Höjer, 2006; Peeters *et al.*, 2006). However, they are for various, mainly political and constitutional reasons, not likely to be implemented at the high level required to reverse the trend of growing emissions. Technological change in the aviation sector, for instance, is contributing to relative efficiency gains, which are nevertheless outpaced by the rapid growth in air travel. Governmental command-and-control measures, even though in principle supported by the public (European Commission [EC], 2005; IPSOS Mori, 2006), are opposed by the aviation industry and its organisations (Gössling & Peeters, 2007), and are currently not likely to make significant contributions to reduction goals.

In recent years, a growing number of companies (for profit) and charities (not for profit) have started to offer voluntary compensation schemes to those who are aware of the environmental consequences of aviation but do not want to, or are not able to, forego flying altogether. These organisations, known as carbon offsetting organisations, because they seek to offset the GHG carbon dioxide (CO_2), are seen as a swift way forward to solve the GHG problems of the aviation and, therefore, the tourism industry. They are characterised by substantial differences in their approaches to calculate and compensate for emissions, their price levels and their accountability. These differences, in turn, affect the efficiency and credibility of voluntary carbon offsetting schemes. This paper explains the voluntary carbon offsetting market for aviation, along with an analysis of business strategies and achieved carbon savings. Recommendations for structural change in this sector are made, and future research needs are outlined.

Many technical terms are involved in this discussion: a glossary is provided at the end of this paper (Appendix 1).

Transport Emissions

Globally, transport accounts for about 24–28% of all energy-related CO_2 emissions (life cycle basis, Fulton & Eads, 2004: 11). Aviation accounts for about 3.4% of all emissions of CO_2 (Gössling & Peeters, 2007). One of the main contributors to these emissions is air transport for tourism. Although air transport accounts for only 20% of all tourism trips by EU citizens (domestic and international), it causes 75% of all GHG emissions of all EU tourism transport (in 2000, Peeters *et al.*, 2007a). Global emissions from all transport grow in the order of 2% per year (WBCSD, 2004).

Within the transport sector, air travel is of major importance for several reasons. First, only a minor share (<2%) of the global population uses air travel for international transport (calculation based on WTO, 2005).[1] Second, emissions from air travel are particularly harmful because they are released in the upper troposphere and lower stratosphere, where they have a larger impact on cloudiness and ozone generation (Sausen *et al.*, 2005), both important factors contributing to radiative forcing and thus global warming. Emissions from air travel may be between a confirmed minimum of 1.9 and up to 5.1 times as environmentally harmful in terms of their contribution to global warming as emissions from surface bound traffic (per unit of fuel burnt; see references and detailed discussion below). Considering these impacts, the contribution of aviation to global warming may be in the order of up to 9% (T&E, 2006). Third, technological progress in the aviation sector is slow. Even though the potential to reduce specific fuel consumption of the most efficient aircraft is estimated to be in the order of 28–35% by 2040 (Peeters & Middel, 2006), relative efficiency gains are outpaced by absolute growth in this sector.

Aviation is thus a significant and increasingly important contributor to global warming. Despite this, international aviation is currently not included in the Kyoto Protocol, and emissions from international flights are not accounted for in national GHG inventories. Aviation is also exempted from most fuel taxes (Gössling & Peeters, 2007), though the European Parliament voted on 4 July 2006 to introduce a tax on aviation fuel for flights originating from the 25 member states of the EU, while proposing to simultaneously remove value-added tax exemptions. The EC has said that it would prefer to include emissions from all the aircraft departing from EU airports (not just intra-EU flights) in the EU Emissions Trading Scheme (EU ETS), and stated the intention to bring a legislative proposal on this by the end of 2006 (Commission of the European Communities, 2005). On 20 December 2006, the EC did indeed table a proposal to integrate European airlines into the EU carbon-trading scheme as of 2011 (EURACTIV, 2007). The proposal provides for aviation to be brought into the EU ETS in two stages. From the start of 2011, emissions from all the domestic and international flights between EU airports will be covered. From the start of 2012, emissions from all the international flights departing from or landing at EU airports will also be included.

Rising GHG emissions from transport need to be seen in the context of the GHG emission reductions required to limit mean global surface warming to 2°C higher than pre-industrial temperatures, an objective adopted by the EC in 1996. Only at levels of around 400 ppmv CO_2 equivalent are the risks of overshooting a 2°C target low enough that its achievement can be termed 'likely' (Meinshausen, 2006). Even the less stringent scenario of an atmospheric concentration of 450 ppmv of CO_2 or 550 ppmv of CO_2-e (EEA, 2005) would require an 80% reduction in CO_2 emissions for the EU25 by 2050 equivalent to an annual reduction in EU CO_2 emissions of 4% per annum from 2010–2050. Policymakers have neglected the urgent need for GHG emissions reductions for so long that even this weaker target will now be difficult to meet without near-term changes in both behaviour and technologies. If EU aircraft emissions grow at recent and then moderate rates, then shortly after 2050 they would exceed the EU's 2050 carbon emissions budget for 450 ppmv CO_2 as shown in Figure 1 (Bows *et al.*, 2005). From 2050, almost no growth in EU carbon emissions by other sectors would be possible. Figure 1 compares this scenario of EU aviation emissions with a 450 ppmv CO_2 budget for the EU; however, without considering a Radiative Forcing Index (RFI) (cf. Bows *et al.*, 2006a, 2006b; radiative forcing indices are discussed further below). Note that omitting RFI, while scientifically justifiable, gives a conservative indication of the warming effects of aviation emissions. Using the same values and assumptions as in Figure 1, applying the IPCC (1999) mean RFI factor of 2.7 brings forward the date at which non-aviation sectors in the EU would need to be carbon neutral to 2017 and the date at which aviation emissions exceed the entire EU 450 ppmv budget to 2040 (Anderson *et al.*, 2006).

Carbon Markets

The carbon market consists of regulatory and voluntary regimes. Regulatory regimes exist under the Kyoto Protocol (2008–2012), based on carbon trading through the Clean Development Mechanism (CDM) and Joint Implementation (JI) schemes. Within the EU, the EU Emissions Trading Scheme (EU ETS 2005–2007) constitutes the largest multi-country, multi-sector carbon emission trading scheme in the world, with over 9400 of the largest emitters of CO_2 having reported their compliance status by mid-2006 (EC, 2006). The system allows importing carbon credits from CDM and JI carried out elsewhere, i.e. outside the EU. Companies exceeding their carbon allowances can buy Certified Emissions

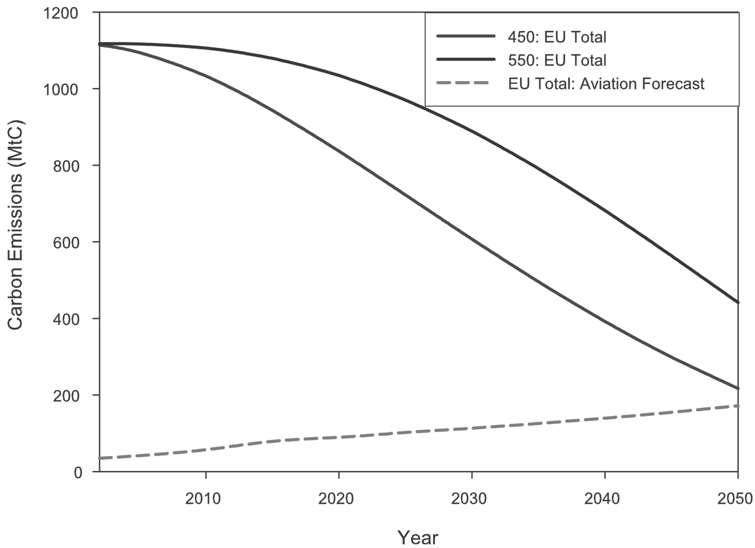
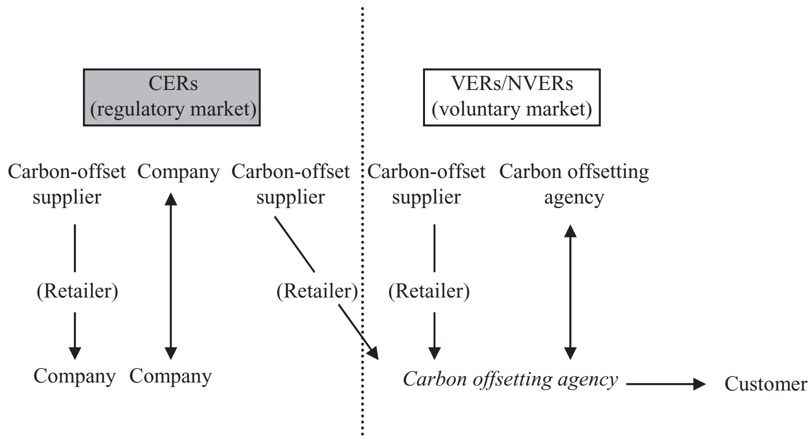


Figure 1 Contraction and convergence profiles for EU25 compared with aviation carbon emissions. *Explanatory note*: The *upper line* shows the contracting carbon emissions total for the EU as a whole, for a 550 ppmv scenario; the *middle line* shows the contracting carbon emissions total for the EU as a whole, for a 450 ppmv scenario; the *rising dashed line* shows EU aircraft carbon emissions (not including a RFI), under a 'business as usual' scenario that accounts for anticipated efficiencies and the moderation of air traffic growth rates from 2015 onwards.
Source: Bows *et al.* (2005)

Reductions (CERs, through CDM) or Emission Reduction Units (ERU, through JI) from carbon offset suppliers (eventually via retailers), with 1 CER/ERU corresponding to 1 ton of CO_2. CERs/ERUs have to be approved by the CDM Executive Board and/or the JI authority in charge (for a more detailed discussion, see Taiyab, 2006). Alternatively, companies can avoid carbon offset suppliers/retailers and develop their own projects. Should these projects generate emissions reductions exceeding the amount needed by the company, they can be sold in the regulatory carbon market (Figure 2, left-hand side).

Voluntary carbon offsetting organisations can also buy CERs, but they engage more often in the trade of verified emissions reductions (VER), and what is here termed non-verified emissions reductions (NVERs, see right-hand side of Figure 2). VERs are generated through non-CDM projects verified through an external auditing process, i.e. projects not seeking CDM registration, thus being outside the regulatory carbon market (Taiyab, 2006). Note that VERs are counted as national emission reductions, unless these projects are carried out in countries not obliged to reduce emissions under the Kyoto Protocol. NVERs, in contrast, are non-verified emission offsets generated through non-CDM projects. These are usually assessed through self-developed standards, i.e. organisations follow their own procedures for evaluation. Once again, there are two options in the market: voluntary carbon offsetting organisations can buy VERs/NVERs through retailers from carbon offset suppliers, or they can implement their own projects and sell emissions reductions exceeding their own demand to other organisations. Arrow directions indicate that CERs, VERs and



CER: Certified Emissions Reduction
VER: Verified Emissions Reduction
NVER: Non-verified Emissions Reduction

Figure 2 Overview of the carbon market

NVERs are taken out of the market for compensation (arrow head down), or, if generated by the organisation through its own projects, can be sold in the respective regulatory/voluntary markets (arrow head up and down).

Carbon markets are theoretically efficient options to achieve reductions in emissions, as players in the market will seek to achieve emissions reductions at the lowest cost. However, there are several potentially problematic aspects that deserve discussion. First, CERs are usually generated through large scale CDM projects. Such schemes are often industrial and carried out in only a few countries; India, Brazil, Mexico and China together host 71.5% of projects (UNFCC, 2007), thus making a limited contribution to sustainable development in terms of local livelihood improvements as well as a geographical distribution of investment benefits among countries (Taiyab, 2006).

In response to these criticisms of CDM-generated CERs, the World Wide Fund for Nature and a number of other non-governmental organisations have developed 'The Gold Standard' setting out more stringent criteria (The Gold Standard, 2006). It includes stricter screens for additionality and sustainability at project inception, for example permitting renewable energy projects but excluding forestry, and requires Environmental Impact Assessments and local stakeholder consultation. Mandatory, independent monitoring of sustainable development benefits during project operation are also intended to improve outcomes. Validation and verification has to be carried out by independent UNFCCC-accredited bodies (The Gold Standard, 2006), which is currently not the case in general. Gold Standard protocols have also been developed for both Small Scale and VER projects. A number of other standards for VERs are in development and will be discussed later in the 'Efficiency and Credibility of Offsetting Schemes' section; however, it is interesting to note that at the time of writing, the UK Government is expected to announce its own 'best practice' guidelines recommending that offsets be purchased from the compliance market, i.e. CDM CERs or European EUAs. If this formal connection between voluntary purchasers and the regulated markets proves to be influential, then there are serious implications for VER suppliers.

One of the most important and contentious aspects of carbon offsets is the principle of additionality. The concept is central because it relates to the issue of whether any emissions can truly be said to be 'offset' by a project. In the context of voluntary offsetting schemes, additionality has several implications. First, schemes need to ensure that emission reductions are additional, i.e. that they would not have occurred without financial support. For instance, emission reductions from building a wind farm should only be counted if (1) the wind farm had not been built without the financial support from voluntary carbon offset schemes and (2) an equal quantity of electricity is no longer produced from non-renewable fossil fuels (coal, oil and gas). Individuals, organisations or businesses can purchase the amount of GHG emissions neutralised, measured as the projected GHG emissions that would have occurred if the project had not been established (Taiyab, 2006). It should be noted that this emissions offset is specifically associated with the project. It should not be understood to imply that net emissions in that country will necessarily decrease. As development is stimulated via offsets projects, it is more likely that national emissions will increase, in aggregate (see also Alfredsson, 2002). What is being offset or avoided are the emissions of an assumed, alternative, less benign development pathway.

The principle of additionality also deserves discussion in the context of the regulatory regime, as VERs generated in countries obliged under the Kyoto Protocol to reduce emissions will help the regulatory market to achieve its emission goals. There are only two ways to avoid this problem: by selling VERs generated in countries not bound to reduce emissions under the Kyoto Protocol, or by selling CERs from the regulatory market for retirement in the voluntary market. As yet, the additionality problem of selling VERs generated in countries obliged under the Kyoto Protocol to reduce emissions is not necessarily acknowledged in voluntary markets. Besides considering additionality, projects also have to ensure that savings of GHG are permanent.

From a more general point of view, it is also important to note that carbon offsetting organisations offer to neutralise emissions caused by consumption in one sector (i.e. a flight) through compensation in another sector (e.g. afforestation, renewable energy). The system is thus built on a continuous process of reducing emissions in the non-transport sectors, implying that limits will be reached at some stage – either because of spatial constraints (i.e. the area available for afforestation will be filled completely by aviation alone in 2050 if all aviation-related climate impacts are compensated through afforestation; see Boon *et al.*, 2006) or because of physical or economic constraints (efficiency improvements becoming increasingly difficult and costly). Furthermore, as the contraction and convergence curves for EU25 emission targets and aviation emissions in Figure 1 show, aviation will soon fill the complete allowable emissions, which means that even if other sectors are all zero-emission, aviation will not be able to find enough compensation for its own growth.

Large scale offsets based around tree-planting schemes would have the biggest disadvantages, as the main land area for planting is in developing countries. The implication is that for the lifestyle of only a part of the developed minority of the world, very large areas would be forested in perpetuity, without the local population necessarily having much control over this. This cannot be seen as sustainable, as the possibilities to develop will be limited for future generations in the developing countries for the benefit of sustaining current developed minorities. So both the place and time constraints of sustainable development (i.e. we should not export current problems to the future and/or somewhere else) would not be met. Moreover, voluntary compensation schemes have also been criticised for creating and fostering the idea that there are simple solutions to unsustainable lifestyles. Also, they could increase the likelihood of international flights not being included in post-Kyoto climate agreements, due to airlines arguing that they are already doing everything they can – a situation that would not lead to the innovations towards efficiency required of the sector (cf. Peeters *et al.*, 2007b). On the other hand, credible compensation schemes may have an educational effect and contribute to create more carbon conscious societies by offering acceptable solutions to travellers and the tourism industry, who may otherwise reject restrictions to air travel for economic or other reasons. In particular, projects implemented to reduce energy use or to establish renewable energy sources can have positive effects.

Efficiency and Credibility of Offsetting Schemes

In the past five years, voluntary offsetting schemes, addressing individuals, organisations and industry, have rapidly grown in number (Lecocq & Capoor, 2005; Sterk & Bunse, 2004). Reasons to engage in voluntary schemes can range from personal goals to reduce one's impact on the environment, to public and governmental expectations for companies to engage in environmental management (e.g. Lynes & Dredge, 2006). A wide range of companies including British Airways (BA)[2] are already participating in these schemes, which have become increasingly known because of the involvement of international stars such as the Rolling Stones (Taiyab, 2006) or international events seeking to achieve carbon neutrality, such as the World Soccer Championship, 2006 (Öko-Institut, 2006), contributing to broad media coverage.

During research for this paper, 50 organisations offering carbon offsets were identified through reviews of various reports (e.g. Gössling, 2006; Taiyab, 2006) and an extensive search on the Internet in September and October 2006. This does not include a number of other actors in the voluntary carbon market. For instance, the Swedish Naturskyddsföreningen (Swedish Society for Nature Conservation) has asked its members and the public to buy European Allowance Units (EUAs) with the goal to remove them from the market. Other organisations such as the Solar Electric Light Fund encourage the public to make donations to offset emissions, rather than offering a specific carbon reduction service. There are also a number of commercial carbon brokers such as Natsource (US), matching buyers and sellers for CDM and JI projects. The following analysis considers only voluntary carbon offsetting organisations offering aviation-specific offsets; the number of such organisations included in this article is 41, even though there might be more that have remained unidentified. All information provided in Table 1 was gathered by a search of organisations' websites.

Where the data were not available online, email contact was made and followed up by brief telephone interviews if a representative was available. Nevertheless, some organisations were not willing or not in a position to provide data with respect to some criteria, as indicated in Table 1. The Table is a summary of the data gathered during this study. Further information is available to download at http://www.tyndall.ac.uk/publications/journal_papers.shtml.

Growth of the voluntary carbon offsetting market

Figure 3 illustrates the growth of organisations in the voluntary carbon offsetting market (data for 40 organisations available). Up to 2000, there were only six organisations offering voluntary offsetting schemes. However, numbers have increased continuously, with most starting up only recently: out of 40, 17 commenced sales of offsets in 2005–2006. It is also worth noting that a number of carbon offsetting operations have been started by organisations working with carbon sequestration (e.g. forestry) for many years, and which have recently developed this as a voluntary carbon offsetting service. The focus of offsetting services is generally diversified. Of those considered in this analysis of aviation-focused offsetting schemes, only four of those examined exclusively provide offsets to account for aviation emissions. Most also offer to 'neutralise' emissions caused by, for instance, other transport, households, waste, electricity, heating, food or even diapers.

The analysis also shows that there are regional clusters of carbon offsetting organisations, with none based in a developing country. The broad majority

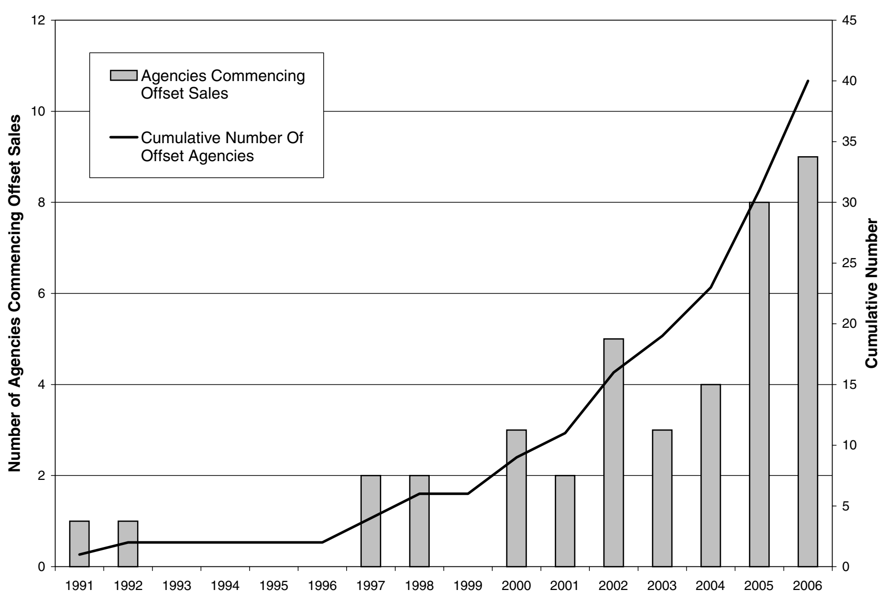


Figure 3 Number of organisations commencing voluntary carbon offset sales from 1991 to 2006

Table 1 Voluntary carbon offsetting organisations offering aviation-specific offsets

Company	*Base*	*Offset sales commence*	*Offset project types**					*Forestry horizon*	*AMS to BCN return flight*		*% invested*	*CER*	*VER*	*Annual Report*	*For profit*
			F	*R*	*EE*	*CCX*	*O*		*t CO_2-e*	*Price (€)*					
American Forests	USA	2000	×					15	0.32	3.96**	–	N	N	Y	N
Atmosfair	DEU	2005		×	×		×	N/A	0.60	12.00	>80	Y	N	Y	N
Bonneville Environmental Foundation	USA	1998		×				N/A	1.00	15.84**	40	N	Y	N	N
C-Change Trust	UK	2006	×					40	0.27	4.05	75	N	N	N/A	N
Carbon Balanced (World Land Trust)	UK	2000	×					20	0.45	4.98	85	N	N	Y	N
Carbon Clear	UK	2005	×					10	0.50	6.68	70	N	N	N	Y
Carbon Footprint	UK	2005	×			×		100	≈0.73	14.85		N	Y	N	Y
Carbon Fund Foundation	USA	2004	×	×		×		Lifetime	0.44	1.92	93	N	Y	N	N
Carbon Neutral	AUS	2002	×					30	0.88	17.58**	52	N	N	Y	N
Carbon Neutral Newcastle	UK	2002	×	×	×			99	≈0.6	13.37	75	N	Y	N	N
Carbon Planet	AUS	2005	×					100	≈1	13.48	57	N	Y	N	Y
Carbon Zero	CAN	2006	×	×	×			80	0.34	5.22	75	N	Y	N/A	Y
Carbonozero	PRT	2005	×					30	0.84	20.33	61	N	Y	N	Y
CeroCO_2	ESP	2005	×	×	×		×	20	0.79	7.94	–	N	Y	N	N
Climat Mundi	FRA	2006		×	×			N/A	0.73	14.52	70	N	Y	N/A	Y
Climate Care	UK	1998	×	×	×			100	0.30	3.39	60	N	Y	Y	Y
Climate Friendly	AUS	2004		×				N/A	0.80	9.91	65	N	Y	Y	Y
Carbon Counter (Climate Trust)	USA	2003	×	×	×			50 or 99	0.45	3.61	60	N	Y	N	N
CO_2balance	UK	2003	×	×				50	0.37	13.36**	90	N	Y	N	Y
CO_2Solidaire (GERES)	FRA	2006		×				N/A	0.67	17.00	≈100	N	Y	N/A	N
Conservation International	USA	2006					×	Lifetime	≈0.5	3.96	85	N	N	Y	N
Easy Trees	UK	2003	×					40	1.50	14.85	N/A	N	N	N	Y
Friends of Conservation	UK	2004	×		×			20	0.44	7.43**	100	N	N	N	N

Table 1 (contd)

Company	*Base*	*Offset sales commence*	*Offset project types**					*Forestry horizon*	*AMS to BCN return flight*		*% invested*	*CER*	*VER*	*Annual Report*	*For profit*
			F	*R*	*EE*	*CCX*	*O*		*t CO_2-e*	*Price (€)*					
Green Fleet	AUS	1997	×					Lifetime	0.90	5.52	>70	N	N	Y	N
Green My Flight	CAN	2006		×				N/A	0.34	5.89	75	N	Y	N/A	Y
Green Seat	NLD	2005	×					100	0.55	10.23	N/A	Y	Y	Y	N
Grow A Forest	UK	2005	×					–	0.27	13.35**	–	N	N	N	N
Ebex21 (Landcare Research)	NZ	2002	×					3	0.36	4.11	77	N	Y	Y	Y
Moor Trees	UK	2006	×					100	0.39	14.85	90	N	N	Y***	N
My Climate	CHE	2002		×	×			N/A	0.74	18.00	80	Y	Y	Y	N
Native Energy	USA	2001		×			×	N/A	0.72	9.50**	–	N	Y	N	Y
Offsetters	CAN	–		×	×			N/A	0.30	3.99	–	–	–	–	N
Prima Klima Weltweit	DEU	1991	×					30 or 50	0.44	3.29	90	N	Y	N	N
Terrapass	USA	2004		×		×	×	N/A	0.31	7.88	–	N	Y	Y	Y
The Carbon Neutral Company	UK	1997	×	×	×			typically 100	0.40	5.54	60	N	Y	Y	Y
The Conservation Fund	USA	2000	×					Lifetime	0.35	5.07	–	N	Y	Y	N
Tree Canada	CAN	1992	×					80, 20, 10 or 1	0.34	5.61	80	N	N	Y	N
Tree Flights	UK	2006	×					Lifetime	€14 fee per flight		65	N	N	N/A	Y
Trees for Life	UK	2002	×					Lifetime	Estimate	5.57	80	N	N	N	N
Trees for Travel	NLD	2001	×					100	1.25	17.00	≈75	Y	Y	Y	N
Vancouver Renewable Energy Cooperative	CAN	2006		×				N/A	No calculator		90	N	N	N/A	N

Note. –, information not available or not disclosed; N/A, not applicable.
*F: forestry; R: renewables; EE: energy efficiency; CCX: retired credits from Chicago Climate Exchange; O: Other.
**Minimum amount.
***Does not include offset information.

are located in North America, Australia/New Zealand and Europe. The United Kingdom, with 14 organisations, is the country with the largest single number. Regarding the geographic distribution of offsetting schemes, there is considerable variation. Of 41 organisations providing information, 23 sell emissions reductions generated domestically, while 10 generate these in developing countries and 8 in a combination of projects 'at home' and in developing countries. Overall, carbon reduction projects are carried out in an estimated 30–40 different countries.

Strasdas (2006) lists several preconditions for credible and efficient compensation schemes. Regarding credibility, it has to be made sure that emissions are compensated on a 1:1 basis (i.e. fully). This involves the correct calculation of emissions, based on adequate aviation data, and the consideration of warming effects by non-CO_2 GHG. Efficiency relates to the potential of compensation projects to actually achieve 'neutralisation' of emissions. Verification mechanisms should be in place to guarantee customers that these conditions are being met.

Calculating emissions

The quantities of GHG released from transport, as well as their contribution to global warming, will necessarily be estimated rather than measured. At the most basic level, this is due to the infeasibility of measuring the emissions of individual vehicles, be they surface vehicles or aircraft. Emissions estimates for the purposes of offsets thus assume average operating conditions and typical engine sizes, allowing emission factors to be applied as multipliers to the distance travelled. At the most detailed level, a more accurate calculation would have to consider the type of aircraft used by the traveller, its fuel use, occupancy rate, route, cruising altitude, the time of the day flown and even particular weather conditions, such as the presence of supersaturated zones. All of these factors will ultimately affect the individual traveller's contribution to climate change (IPCC, 1999). Such a complex calculation process is for various reasons unfeasible, and most compensation companies thus use simplified factors. These can affect the accuracy of results. For instance, as shown in Table 1, the amount of CO_2-e emissions calculated for a flight from Amsterdam to Barcelona can vary by at least a factor of 3 between companies.

For instance, even though most UK-based organisations use the Department of Environment, Food and Rural Affairs' (DEFRA) average per pkm emission factors, the results of their online calculators are not necessarily the same. For instance, while C-Change Trust (UK) calculates emissions of 0.27 t CO_2-e for a Amsterdam – Barcelona flight based on DEFRA's averages, The Carbon Neutral Company (UK) arrives at 0.39 t CO_2-e. Note that the per passenger emissions estimates will, by definition, be sensitive to aircraft load factor, type, age, operational procedures and capacity assumptions. Compounding this potential for error is the uncertainty as to how best to account for the additional warming effects of non-CO_2 emissions, relative to CO_2, expressed as a multiplier in the RFI (see glossary). While IPCC (1999) estimated the mean net effects of these to be 2.7 times higher than those of CO_2, an estimate since lowered to 1.9 by research under the TRADEOFF (2006) project (Sausen *et al.*, 2005), these RFI multipliers do not include contrail-induced cirrus cloud. Including these impacts may substantially increase the RFI to a theoretical maximum of 5.1. However, it should be noted that not only is an accurate RFI value unknown, but that the calculation appropriate for indicating these warming effects is keenly debated, due to their region-specific effects and, as with other GHGs, their substantially differing lifetimes (e.g. Shine *et al.*, 2005). Furthermore, the above multipliers refer to the radiative forcing of historic (long-lived) CO_2 emissions and current (short-lived) non-CO_2 impacts, while for the purpose of compensation, the impact of 1 t of GHG emitted now, for future radiative forcing, should be accounted for (see Forster *et al.*, 2006; Peeters *et al.*, 2006; Wit *et al.*, 2005). As it is impractical to try to account for all factors mentioned above, most schemes use travel distance and a standard emissions factor for calculation. Out of 41, five considered here offer basic estimates for travellers relating to short, medium or long haul flights rather than calculating emissions for a specific journey.

As shown in Table 2, out of 35 organisations with online calculators, exactly half currently use no RFI to account for non-CO_2 effects (where no information concerning the RFI was given [three companies], this was interpreted as an RFI equalling 1). One quarter uses RFI 2.0, and five companies use RFIs of 2.7 or 3.0. Four other companies have customised their RFI, i.e. they allow the customer to decide to include a higher/lower RFI. The use of different RFI standards heavily influences the calculation of the amount of CO_2-e generated by a given flight, even though it does not necessarily explain differences in emissions calculated for a given flight. For instance, emissions calculated for a flight from Amsterdam to Barcelona can vary between 0.3 t CO_2-e (Climate Care, UK) and 0.74 t CO_2-e (My Climate, Switzerland), even though both companies claim to use an identical RFI of 2.0 in this particular case.

The use of RFI also seems unrelated to the total costs of compensation for a specific flight (Figure 4), with costs for offsetting 1 t of CO_2-e varying between €2.38 (American Forests, US) and €37.13 (Moor Trees, UK), representing a factor-15 price difference. The price difference becomes even greater when calculated per flight. For instance, offsetting a short distance flight from Amsterdam to Barcelona (2600 pkm return distance) is offered at prices ranging between €1.92 (Carbon Fund Foundation, US) and €20.33 (Carbonozero, Portugal) and may be influenced by minimum charges applied by the provider. In effect, compensation by an 'expensive' organisation using a RFI of 1.0 might thus be offered at the same price as compensation by a 'cheap' organisation using a RFI of 3.0. The prices of compensation might thus rather depend on the time horizons over

Table 2 Number of voluntary carbon offsetting organisations applying specific RFI

RFI 1.0	17
RFI 2.0*	9
RFI 2.7	3
RFI 3.0	2
RFI customised	4
Total	35

*Including two organisations using RFIs of 1.9 and 2.16, respectively.

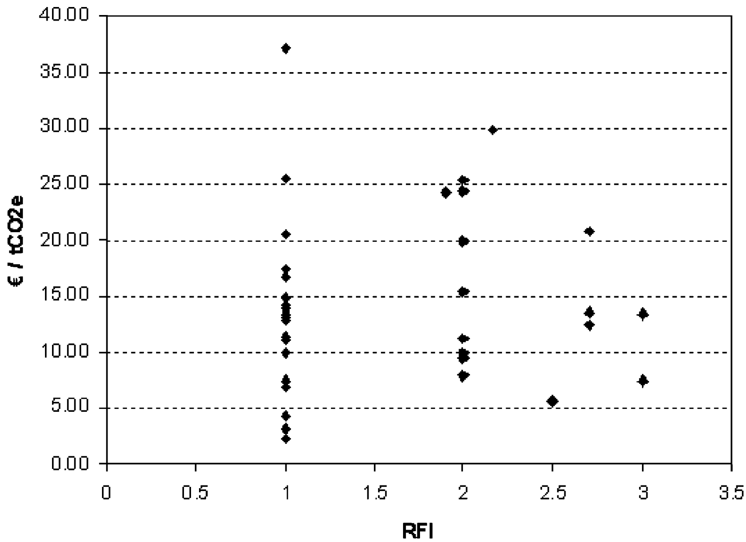


Figure 4 Comparison of prices (€ per ton CO_2-e) and RFI

which projects are calculated, the validity and reliability of projects, administrative costs or profit margins taken out by profit entities (out of 41 organisations, 16 are for profit), than on the choice of an RFI. The share of payments invested in offsetting projects can vary between 40% (Bonneville Environmental Foundation, US) and a claimed 100% (Friends of Conservation, UK). Note that most companies do not provide information on the share of investments in relation to payments made; however, for newly started and small companies, administrative costs will heavily influence results. Note as well that out of 41 organisations, only 16 had accessible annual reports, even though this might be due to the fact that 17 organisations were founded in 2005 or 2006. For those provided, the details and assurances vary considerably particularly if offsetting is not the primary activity of the organisation.

Compensation measures

Compensation schemes support mainly two project categories: biological 'sinks' where carbon is sequestered in biomass through afforestation or reforestation (here summarised as forestry) or emissions savings, where energy-efficiency gains or replacement of fossil fuels by renewable energy sources reduces GHG emissions from a business-as-usual baseline. Companies also engage in buying offsets from the Chicago Climate Exchange (www.chicagoclimatex.com), and practice a wide range of other measures, such as methane capture, forest and biodiversity conservation, or projects focusing on climate change adaptation. However, as Table 3 shows, most of the voluntary carbon offsetting organisations identified focus entirely or partially on forestry projects. Less than 25% focus entirely on renewable energy and energy efficiency projects.

To include forestry in regulatory offsetting schemes is possible because of article 3.3 of the Kyoto Protocol, which states that countries have to account for emissions and the sequestration of afforestation (newly planted areas),

Table 3 Focus on project categories among voluntary carbon offsetting organisations

Forestry	20*
Forestry, Renewables, Energy efficiency	11**
Renewables, Energy efficiency	10
Total	41

*Including Conservation International (entirely conservation projects, i.e. 'avoided deforestation').
**Including three companies buying credits from the Chicago Climate Exchange. As these can comprise forestry projects, the companies are included in the mixed category.

reforestation (previously planted, cut down and replanted areas) and deforestation. More specifically, the Marrakesh Accords allow the inclusion of afforestation and reforestation activities as sink projects within the CDM (Marrakesh Accords, 2001). Tree planting appears popular among customers. One reason for this could be that forests are important places for recreation in industrialised countries. Tropical forests, on the other hand, refer to Western concepts of natural, unsullied environments, and the diversity of life. Trees are thus generally seen as something positive, appealing to common aesthetics. While forestry projects can have a number of advantages, such as their potential to contribute to local development processes, biodiversity management, and to raise awareness of climate change, there are also a number of problems. For instance, Gössling (2000) calculated that offsetting global aviation's GHG emissions for the year 2000 (leisure tourism only) would require an area of about 28,800 km^2. An area of similar size (growing by about 3% per year) would have to be afforested each year, indicating the scale at which forestry projects would have to be operated (see also Boon *et al.*, 2006). Furthermore, unless carbon stored in trees is not used for the production of biofuels to substitute for fossil fuels (Read & Lermitt, 2005), the area used for afforestation would also have to be set aside infinitely. This might be even more problematic given that forests will increasingly be at risk (fire, drought etc.) because of climate change (Ceron & Dubois, 2007). Moreover, monocultures for fuel production would only support low levels of biodiversity, and the effectiveness of afforestation must be assessed, particularly in developing countries, against political stability, social and other environmental aspects (Bäckstrand & Lovbrand, 2006; Benitez *et al.*, 2006; Brown & Corbera, 2003; Jackson *et al.*, 2005; Reich *et al.*, 2006). Finally, forestry and biomass production can entail significant energy inputs and related GHG emissions that should be deducted from the carbon stored, to only consider net gains (Holden & Høyer, 2005).

In comparison, ecoefficiency measures have the goal of achieving the same output in terms of production or service at a lower input of energy or materials (for a case study of tourism, see Gössling *et al.*, 2005). Investments in ecoefficiency measures would thus seek to reduce the amount of emissions caused by a particular mobility pattern or journey through reductions in energy use and associated emissions in other sectors. Likewise, exchanging existent energy structures based on the use of fossil fuels in favour of those based on renewable ones might have a range of development advantages.

Temporal aspects of compensation projects

Another aspect of fundamental importance in the calculation process is the period over which compensation companies calculate their offsets. All carbon released at present will lead to additional build-up of CO_2 in the atmosphere, while compensation measures, such as forestry, will lead to sequestration over time. As Table 1 shows, some companies seek to 'neutralise' emissions through forestry projects during the same year they occur, while others calculate sequestration over 100 years (i.e. the assumed lifetime of a tree). Clearly, such differences in the time horizon chosen not only have consequences for CO_2 concentrations in the atmosphere, but also influence prices for offsetting. Furthermore, carbon sequestration will depend on the tree species planted, soil conditions and climate, thus varying between geographical regions. It thus seems clear that the integration of proper timeframes for various compensation projects (particularly forestry, but also for renewable energy and energy efficiency) is paramount. A simple model in the context of forestry projects illustrates this (Figure 5).

One of the major questions in the context of afforestation schemes is the question of the size of the area that needs to be afforested in order to offset 1 t of carbon. Since emissions are released over hours, but sequestered over the lifetime of a tree, the interval between emission and storage determines the build-up of additional atmospheric carbon. Gössling (2000) used three carbon storage scenarios (10, 20 and 40 years), based on the assumption that fuel demand of leisure air travel was in the order of 80.5 Mt in 2000, increasing by 3.9%. Note that current growth in fuel use worldwide is somewhat lower in the order of 3% per annum; however, European growth in fuel use in 1990–2003 was 4.3% per annum (Commission of the European Communities, 2005). The RFI used in Gössling's (2000) model was 2.7. In scenario A, emissions accumulated between 2000 and 2015 (S), are offset until 2017/18 (S′), in scenario B until 2023/24 (S″) and in scenario C until 2032/33 (S‴). As shown in Figure 5, the rate of carbon

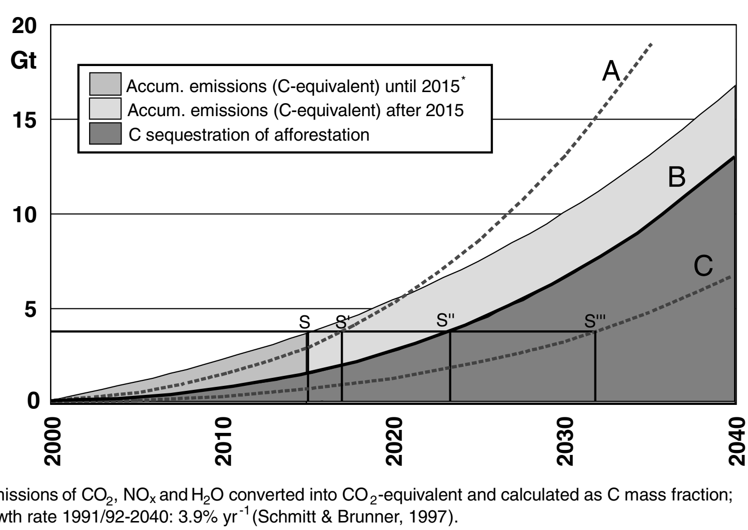


Figure 5 Carbon accumulation through afforestation over time.
Source: Gössling (2000)

sequestration in trees in scenario A (fast sequestration) soon passes the rate of atmospheric accumulation, while in scenario C (slow sequestration), sequestration of carbon follows emissions slowly, leading to an increasing build-up of carbon in the atmosphere. It was concluded that emissions should be sequestered within a period of 20 years, as the carbon increment would follow emissions slowly over time. While the model is simplified, using RFI as a constant parameter (Peeters *et al.*, 2006; Sausen *et al.*, 2005), it nevertheless shows that the consideration of time horizons is significant for future build-up of CO_2 concentrations. The model also shows that using forestry sequestration horizons of 100 years is unfeasible, which is recognised in the Marrakesh Accords (2001) and addressed through complex guidelines regarding forestry CDM, but disregarded by organisations in the voluntary carbon market.

Emissions compensated

Clearly, the total amount of emissions offset through voluntary schemes is as yet negligible. Of those companies reporting amounts offset (16 of 41), as yet, only a few have achieved considerable reductions. Based on an aggregation of existing company figures, it is estimated that the total amount of carbon offsets from all voluntary carbon offsetting organisations (aviation) did not exceed 200,000 t CO_2-e in 2005 (see also Clean Air-Cool Planet, 2006). This can be compared to (1) the regulatory market, where an estimated 107 million t CO_2-e were traded in 2004 (Lecocq & Capoor, 2005), (2) overall emissions from aviation in the order of some 800 million t CO_2 and (3) global emissions of CO_2 in the order of 23 Gt. The voluntary carbon offsetting market is thus, in volume terms, in an early development phase, with a growth factor of 400 needed to become significant – i.e. achieving a 10% reduction of GHG emissions from aviation.

Credibility

Companies sell CERs, VERs or NVERs, which are generated through their own or third party projects. The most common standard is the VER, generated through own projects. A wide variety of auditors are involved in accreditation, making it difficult to understand the standards used for VERs. While some companies state that they do not go through auditing to save money, there are also a number of companies providing very general information that verification is based on an 'external auditing'. For individual customers, it is currently next to impossible to judge the real value of the credits they buy. Formal certification does indeed increase transaction costs. While carbon credits certified under the Gold Standard may cost around €20 per ton of CO_2-e, NVERs through forestry may cost one tenth of this amount. Clearly, the credibility of current audit practices is variable and price in an increasingly competitive compensation market may be a driving force behind this. Efforts to regulate the generation and trade of VERs are proposed from a number of sources. The Gold Standard and UK Government recommendations have previously been mentioned, whilst the NGO, The Climate Group, is developing its own Voluntary Carbon Standard (VCS) with the International Emissions Trading Association and World Economic Forum. The VCS is less prescriptive of project type and sustainability criteria than are others, the main intention being to provide comparable auditing standards and a central registry of Voluntary Carbon Units (VCUs) to prevent double selling (The Climate Group, 2006). It is not clear how the various proposals will interact in the marketplace and what, if any, legislation may develop.

Discussion and Conclusions

Aviation is of central importance for international tourism, as some 42% of all international tourist arrivals are now by air, corresponding to 286 million passengers (in 2003; WTO, 2005). This perspective, however, only represents the share of tourism by the relatively wealthy. In terms of all domestic and international tourism worldwide, the significance of aviation as a means of transport is far lower. Our estimate is that aviation is the transport mode for less than 10% of all tourist trips (>24 h). Nevertheless, the importance of aviation for international tourism is expected to increase, with a trend towards more frequent and longer air travel. For instance, within the EU, average distances covered by air are predicted to increase from about 1150 km in 2000 to about 1600–1700 km per tourist in 2020 (Peeters *et al.*, 2004). Consequently, impacts related to aviation-based tourism will increase, raising the question of the potential of voluntary carbon offsetting schemes in mitigating these.

Voluntary carbon offsetting schemes seem increasingly popular, with a rapidly growing number of such organisations, possibly also in anticipation of compulsory carbon trading for aviation in the future. However, as this study reveals, there are substantial differences between organisations with respect to emission calculation processes, compensation measures, prices charged and verification processes. This has consequences for the efficiency and credibility of voluntary offsetting schemes: it would not be surprising if customers do not know how to choose between the widely different options and simply choose the least costly. Out of 41 companies, only a few (such as Atmosfair, Germany) seem to use a scientifically sound and holistic approach to compensation. Gaining credibility calls for the establishment of common standards for the calculation of emissions, and in particular a common RFI, as well as the measurement of emissions reductions, essentially following UNFCCC CDM procedures. Companies should also be required to inform customers about alternatives to frequent air travel, such as adopting different travel habits or using ground transportation where feasible. The objective should be to reach both common calculation standards and communication messages.

Companies using common standards, notably integrating a minimum RFI and identical offsetting periods, could then carry a common label, such as an extended version of the Gold Standard. This would improve their credibility and the market in general, making it easier for the customer to distinguish reliable and credible companies from those with ambivalent standards. The criteria for choosing a suitable compensation organisation might then rather be the portfolio offered, such as projects in developing countries versus at home, energy efficiency versus renewable energy, or large-scale versus small-scale projects. The price charged to compensate 1 t of CO_2-e would then obviously be relevant, forcing companies to offer efficient solutions. This might in particular affect for-profit entities seeking to compensate at low, profit-maximising costs, based on more ambivalent projects.

At this early stage in the development of the offsets market, it is unclear whether voluntary carbon offsets could make a significant contribution to making tourism more sustainable. Voluntary compensation is still far from firmly rooted in the tourism industry and among travellers, though there are some positive trends. In Germany, *forum anders reisen* (www.forumandersreisen.de), an association of over 100 small special-interest tour operators, advertise the possibility of voluntary carbon compensation to their customers, and some operators have integrated it into their booking procedures. Similar initiatives are under discussion in the British tourism industry and within the ecotourism community. Nevertheless, voluntary emissions reductions need to increase by at least a factor of 400 to become relevant, even to achieve a 10% reduction of GHG emissions from aviation. If this is to be achieved, a sizeable proportion of the travelling public, airlines, tour operators and typical long-haul destinations would have to become a part of voluntary compensation schemes in the short term. It should also be clear that offsets are environmentally risky options that do nothing to directly reduce aviation emissions. If not presented as a temporary or complementary strategy, offsets carry the political risk of encouraging people to believe that they need not change their behaviour, thus creating irreversibility in current consumption and production patterns. Moreover, if emissions from aviation are allowed to grow on the basis of concomitant offsets in other sectors, this will reduce the number of options available for future reductions in these sectors at comparably low costs. Given the need for more drastic emissions reductions in the post-Kyoto period, such an approach could increase the future costs of offsets while reducing the margins of reductions that can be achieved through technology. Finally, one of the main disadvantages of a voluntary approach is that it gives limited incentive to airlines to increase their fuel efficiency; clearly, such incentives can be created by emission taxes and levies, or regulated, tightly capped carbon trade systems. Such a cap could be implemented separately for the aviation sector, with no option to buy emissions rights from other sectors, as there is otherwise a risk that the sector will increase its contribution to global warming by acquiring carbon credits not considering the non-CO_2 effects of aviation emissions (Lee & Sausen, 2000). Moreover, aviation might be able to afford buying permits at a price and to an extent that could choke the possibility for other sectors to do so, jeopardising the flexibility tradable permits are supposed to introduce (Godard, 2006).

In conclusion, voluntary carbon offsetting schemes remain an ambiguous solution to aviation's environmental impacts, and therefore, an ambiguous tool for sustainable tourism management. Arguably, in view of the strong growth in this sector, technological *and* behavioural change will be necessary to bring aviation onto a sustainable emissions path, with behavioural change having the more important role to play. An optimal approach might be to combine compulsory, non-tradable caps on aviation-related emissions with voluntary schemes. Caps would guarantee the primary goal that emissions from this sector could be stabilised. Voluntary offsets, if meeting credibility and efficiency standards, could then contribute to further emissions reductions in this sector. These reductions could be minor, if schemes continue to operate at current scales, or substantial, if they were applied throughout the sector.

The paper has also revealed substantial future research needs. First, voluntary offsetting schemes are as yet little explored, particularly with respect to the efficiency and credibility of calculation standards and compensation projects, as well as the verification standards of different auditors. Research is needed to identify these, and to 'audit the auditors', as there seem to be considerable differences in the approaches taken. In this respect, voluntary carbon offsetting is strikingly similar to the proliferation of certifications for sustainable tourism itself, where common global standards are also being sought. Second, voluntary offset schemes are currently of minor importance for reducing emissions. Research is thus needed to analyse the potential market for voluntary offsetting schemes, for instance with regard to customer acceptance of opt-out or obligatory compensation schemes for aviation. Third, we need to better understand the consequences of voluntary compensation projects for energy efficiency improvements, the development of prices for compensation and the contribution of these projects to sustainable development. For instance, should travellers offset their emissions nationally, this could have substantial consequences for the restructuring of national energy infrastructures in industrialised countries, potentially leading to considerable employment opportunities. Fourth, the interaction of voluntary and regulatory markets deserves to be analysed. Currently, some compensation organisations engage in regulatory markets, which could, in the future, have consequences for the development and price levels in these markets. Fifth, research could help various compensation mechanisms converge in terms of standards and communication. Sixth, the philosophical and ethical dimensions of compensation schemes deserve attention. Voluntary compensation is generally understood as a means to maintain current mobility patterns. Clearly, such a view ignores aspects of intra- and intergenerational equity. Several compensation schemes suggest that energy intensive lifestyles in Western societies can be continued with 'a good conscience' through compensation in low income countries. This raises another question: while investments in low income countries might be more efficient, this obscures the awareness of the long term costs of becoming sustainable in industrialised countries. For instance, would all citizens of one country invest only in national compensation projects, spatial constraints (e.g. in the case of afforestation) and financial constraints (higher costs for compensation associated with higher efficiencies) would become more obvious. While this might affect the willingness to participate in voluntary compensation schemes, it might also generate greater awareness of the impact of contemporary lifestyles in western societies. National projects are currently not feasible, though, because voluntary offsets affect the regulatory markets. Research would thus have to be carried out in order to understand how these problems can be resolved. Finally, there is a need to understand how voluntary carbon offsetting schemes can be established on a broader basis. For instance, in the UK, the tourism industry has started to engage in the Tourism Industry Carbon Offset Service (TICOS), which will have the goal to collect about €11.00 per ton of CO_2 from air travellers to invest in voluntary carbon offsets. However, it is unclear of how travellers will accept the scheme in general (cf. Becken, 2004), whether the fee is optimal and whether this can be replicated on a global scale.

Correspondence

Any correspondence should be directed to Dr. Stefan Gössling, Department of Service Management, Lund University, Box 882, 251 08 Helsingborg, Sweden (stefan.gossling@msm.lu.se).

Notes

1. According to WTO, there were 291.2 million international tourist arrivals by air in 2000. Given a world population of 6.135 billion in 2000, this translates to a statistical use of aviation by 4.7% of the global population (international travel). However, a large number of travellers participate in multiple journeys by air (e.g. Gössling *et al.*, 2006; Peeters *et al.*, 2006). Assuming that, on average, 2.5 international journeys are made per international tourist, less than 2% of the world's population would participate in air travel over national borders.
2. BA joined the UK Government's voluntary emissions trading scheme that was launched in April 2002 and which will cease (in terms of 'final reconciliation') in March 2007 (DEFRA, 2004).

References

Åkerman, J. (2005) Sustainable air transport – on track in 2050. *Transportation Research, Part D* 10, 111–126.

Åkerman, J. and Höjer, M. (2006) How much transport can the climate stand? Sweden on a sustainable path in 2050. *Energy Policy* 34, 1944–1957.

Alfredsson, E. (2002) Green consumption, energy use and carbon dioxide emissions. Unpublished dissertation, Department of Geography, Umeå University.

Anderson, K., Bows, A. and Upham, P. (2006) Growth scenarios for EU and UK aviation: Contradictions with climate policy. Tyndall Centre for Climate Change Research Working Paper 84. http://www.tyndall.ac.uk/publications/working_papers/wp84_summary.shtml.

Bäckstrand, K. and Lovbrand, E. (2006) Planting trees to mitigate climate change: Contested discourses of ecological modernization, green governmentality and civic environmentalism. *Global Environmental Politics* 6 (1), 50–75.

Becken, S. (2004) How tourists and tourism experts perceive climate change and carbon-offsetting schemes. *Journal of Sustainable Tourism* 12 (4), 332–345.

Benitez, P., McCallum, I., Obersteiner, M. and Yamagata, Y. (2006) Global potential for carbon sequestration: Geographical distribution, country risk and policy implications. *Ecological Economics* 60 (3), 572–583.

Boon, B.H., Schroten, A. and Kampman, B. (2006) Compensation schemes for air transport. Proceedings of the Tourism and Climate Change Mitigation Conference, 11–14 June 2006, Westelbeers, The Netherlands.

Bows, A., Upham, P. and Anderson, K. (2005) Growth scenarios for EU and UK aviation: Contradictions with climate policy, Tyndall Centre report for Friends of the Earth, The University of Manchester. http://www.foe.co.uk/resource/reports/aviation_tyndall_summary.pdf#search=%22%22Growth%20Scenarios%20for% 20EU%20and % 20UK% 20aviation% 3A% 20contradictions%20with%20climate%20policy%22%22. Accessed 30.10.06.

Bows, A., Upham, P. and Anderson, K. (2006a) Growth scenarios for EU and UK aviation: Contradictions with climate policy. Tyndall Centre Working Paper 84. http://www.tyndall.ac.uk/publications/working_papers/wp84.pdf. Accessed 30.10.06.

Bows, A., Anderson, K. and Upham, P. (2006b) Contraction and convergence: UK carbon emissions and the implications for UK air traffic. Technical report, Tyndall Centre for Climate Change. http://www.tyndall.ac.uk/research/theme2/final_reports/t3_23.pdf. Accessed 30.10.06.

Brown, K. and Corbera, E. (2003) Exploring equity and sustainable development in the new carbon economy. *Climate Policy* 3 (1), 41–56.

Ceron, J.P. and Dubois, G. (2006) Demain le voyage. La mobilité de tourisme et de loisirs des Français face au développement durable. Research report for PREDIT, p. 182.

Ceron, J.P. and Dubois, G. (2007) Limits to tourism? A backcasting scenario for a sustainable mobility in 2050. In P. Burns and M. Novelli (eds) *Tourism and Mobility*. Amsterdam: Elsevier/Butterworth-Heinemann.

Chatterjee, K. and Gordon, A. (2006) Planning for an unpredictable future: Transport in Great Britain in 2030. *Transport Policy* 13 (3), 254–264.

Clean Air-Cool Planet (2006) *A Consumers' Guide to Retail Carbon Offset Providers*. Portsmouth, NH: Clean Air-Cool Planet.

Commission of the European Communities (2005) Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions. Reducing the climate change impact of aviation SEC (2005) 1184, Brussels, 27 September 2005. http://europa.eu.int/eur-lex/lex/LexUriServ/site/en/com/2005/com2005_0459en01.pdf. Accessed 30.10.06.

DEFRA (2004) Scientific and technical aspects of climate change, including impacts and adaptation and associated costs. London: Department for Food, Environment and Rural Affairs. http://www.defra.gov.uk/environment/climatechange/pubs/pdf/cc-science-0904.pdf. Accessed 30.10.06.

EURACTIV (2007) Commission goes ahead with plans to cut aviation pollution. http://www.euractiv.com/en/transport/commission-goes-ahead-plans-cut-aviation-pollution/article-160634. Accessed 07.01.07.

European Commission (2005) Reducing the climate change impact of aviation report on the public consultation March–May 2005. http://ec.europa.eu/environment/climat/pdf/report_publ_cons_aviation_07_05.pdf.

European Commission (2006) EU emissions trading scheme delivers first verified emissions data for installations. Press Release, 15 May 2006. Brussels: EC. http://ec.europa.eu/environment/climat/emission/pdf/citl_pr.pdf. Accessed 30.10.06.

EEA (European Environment Agency) (2005) Climate change and a European low-carbon energy system. http://reports.eea.europa.eu/eea_report_2005_1/en/Climate_change-FINAL-web.pdf. Accessed 07.01.07.

EEA (European Environment Agency) (2006) The European Community's initial report under the Kyoto Protocol. Report to facilitate the calculation of the assigned amount of the European Community Pursuant to Article 3, Paragraphs 7 and 8 of the Kyoto Protocol Submission to the UNFCCC Secretariat. EEA technical report no. 10/2006. Copenhagen: European Environment Agency.

Forster, P.M.d.F., Shine, K.P. and Stuber, N. (2006) It is premature to include non-Co_2 effects of aviation in emission trading schemes. *Atmospheric Environment* 40 (6), 1117–1121.

Fulton, L. and Eads, G. (2004) IEA/SMP model documentation and reference case projection, 35 IEA. http://www.wbcsd.org/web/publications/mobility/smp-model-document.pdf. Accessed 30.10.06.

Godard, O. (2006) A quelles conditions les transports peuvent-ils être rendus compatibles avec le développment durable? 8eme journée. Transports, Energie, Environnement, Ecole Nationale des Ponts et Chaussées, Paris.

Gössling, S. (2000) Sustainable tourism development in developing countries: Some aspects of energy-use. *Journal of Sustainable Tourism* 8 (5), 410–425.

Gössling, S. (2006) Analysis of tourist flows, greenhouse gas emissions, and options for carbon offsetting schemes in the context of Linnéjubileet 2007. Prepared for Linnédelegationen, Stockholm, Sweden.

Gössling, S. and Peeters, P. (2007, in press) 'It does not harm the environment!' – An analysis of discourses on tourism, air travel and the environment. *Journal of Sustainable Tourism* 15 (4).

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

Gössling, S., Bredberg, M., Randow, A., Svensson, P. and Swedlin, E. (2006) Tourist perceptions of climate change. *Current Issues in Tourism* 9 (4&5), 419–435.

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

Holden, E. and Høyer, K.G. (2005) The ecological footprints of fuels. *Transportation Research, Part D* 10 (5), 395–403.

IETA (International Emissions Trading Association) (2006) The Voluntary Carbon Standard. Verification Protocol and Criteria, Geneva, Switzerland.

IPCC (International Panel on Climate Change) (1999) Aviation and the global atmosphere. In J.E. Penner, D.H. Lister, D.J. Griggs, D.J. Dokken and M. McFarland (eds) *A Special Report of IPCC Working Groups I and III.* Cambridge: Cambridge University Press.

IPSOS Mori (2006) Climate change and taxing air travel. http://www.aef.org.uk/publications/detail.php?art_id=230. Accessed 23.07.06.

Jackson, R.B., Jobbágy, E.G., Avissar, R., Roy, S.B., Barrett, D.J., Cook, C.W., Farley, K.A., le Maitre, D.C., McCarl, B.A. and Murray, B.C. (2005) Trading water for carbon with biological carbon sequestration. *Science* 310, 1944–1947.

Lecocq, F. and Capoor, K. (2005) *State and Trends of the Carbon Market 2005*. Washington, DC: The World Bank Carbon Fund and the International Emissions Trading Association. http://www-wds.worldbank.org/. Accessed 30.10.06.

Lee, D.S. and Sausen, R. (2000) New directions: Assessing the real impact of CO_2 emissions trading by the aviation industry. *Atmospheric Environment* 34, 5337–5338.

Lynes, J.K. and Dredge, D. (2006) Going green: Motivations for environmental commitment in the airline industry. A case study of Scandinavian Airlines. *Journal of Sustainable Tourism* 14 (2), 116–138.

Marrakesh Accords (2001) Marrakesh Accords and Marrakesh Declaration. http://unfccc.int/cop7/accords_draft.pdf. Accessed 20.10.06.

Meinshausen, M. (2005) On the risk of overshooting 2°C. Avoiding dangerous climate change. In *Proceedings of the International Symposium on the Stabilisation of Greenhouse Gas Concentrations.* Hadley Centre, UK Meteorological Office, Exeter, 1–3 February 2005. http://www.stabilisation2005.com/14_Malte_Meinshausen.pdf.

Meinshausen, M. (2006) What does a 2°C target mean for greenhouse gas concentrations? A brief analysis based on multi-gas emission pathways and several climate sensitivity uncertainty estimates. In J. Schellnhuber, W. Cramer, N. Nakicenovic, T. Wigley and G. Yohe (eds) *Avoiding Dangerous Climate Change* (pp. 265–280). Cambridge: Cambridge University Press.

Öko-Institut (2006) Green goal. http://www.oeko.de/aktuelles/schwerpunkte_2006/green_goal_tm/dok/110.php. Accessed 26.10.06.

Peeters, P.M. and Middel, J. (2006) Historical and future development of air transport fuel efficiency. In *Proceedings of the International Conference on Transport and Climate Change (TAC)*, 25–29 June 2006, Oxford.

Peeters, P. and Schouten, F. (2006) Reducing the ecological footprint of inbound tourism and transport to Amsterdam. *Journal of Sustainable Tourism* 14 (2), 157–171.

Peeters, P. M., van Egmond, T. and Visser, N. (2004) European Tourism, Transport and Environment. Final Version. Breda: NHTV CSTT.

Peeters, P., Gössling, S. and Williams, V. (2006) Air transport greenhouse gas emission factors. In *Proceedings of the Tourism and Climate Change Mitigation Conference*, 11–14 June 2006, Westelbeers, The Netherlands.

Peeters, P.M., Szimba, E. and Duijnisveld, M. (2007a, in press) European tourism transport and the main environmental impacts. Journal of Transport Geography.

Peeters, P., Gössling, S. and Becken, S. (2007b) Innovation towards tourism sustainability: Climate change and aviation. *International Journal of Innovation and Sustainable Development* 1 (3), 184–200.

Read, P. and Lermitt, J. (2005) Bio-energy with carbon storage (BECS): A sequential decision approach to the threat of abrupt climate change. *Energy* 30 (14), 2654–2671.

Reich, P.B., Hobbie, S.E., Lee, T., Ellsworth, D.S., West, J.B., Tilman, D., Knops, J.M.H., Naeem, S. and Trost, J. (2006) Nitrogen limitation constrains sustainability of ecosystem response to CO_2. *Nature* 440 (7086), 922–925.

Sausen, R., Isaksen, I., Grewe, V., Hauglustaine, D., Lee, D.S., Myhre, G., Köhler, M.O., Pitari, G., Schumann, U., Stordal, F. and 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. and Yohe, G. (eds) (2006) *Avoiding Dangerous Climate Change*. Cambridge: Cambridge University Press.

Shine, K.P., Berntsen, T.K., Fuglestvedt, J.S. and Sausen, R. (2005) Scientific issues in the design of metrics for inclusion of oxides of nitrogen in global climate agreements. *PNAS* 102, 15768–15773 (published online before as 10.1073/pnas.0506865102).

Sterk, W. and Bunse, M. (2004) Voluntary compensation of greenhouse gas emissions. Policy paper no. 3/2004. Wuppertal Institute for Climate, Environment, and Energy Website, October 2004. www.wupperinst.org/download/1078-compensation.pdf. Accessed 30.10.06.

Strasdas, W. (2006) Standards for voluntary carbon-offset schemes. Enhancing their effectiveness to reduce GHG emissions from individual air travel. In *Proceedings of the Tourism and Climate Change Mitigation Conference*, 11–14 June 2006, Westelbeers, The Netherlands.

Taiyab, N. (2006) Exploring the market for voluntary carbon offsets. International Institute for Environment and Development (IIED). http://www.iied.org/SM/eep/documents/MES8.pdf#search=%22exploring%20the%20market%20for%20development%20carbon%22. Accessed 22.09.06.

T&E (European Federation for Transport and Environment) (2006) *Clearing the Air. The Myth and Reality of Aviation and Climate Change*. Brussels, Belgium: T&E. http://www.transportenvironment.org/Article201.html. Accessed 26.10.06.

The Climate Group (2006) The Voluntary Carbon Standard v1 for consultation. http://www.theclimategroup.org/index.php?pid=778. Accessed 05.10.06.

The Gold Standard (2006) Various documents. www.cdmgoldstandard.org. Accessed 25.09.06.

TRADEOFF (2006) Aircraft emissions: Contribution of different climate components to changes in radiative forcing – TRADEOFF to reduce atmospheric impact. http://www.iac.ethz.ch/tradeoff. Accessed 30.10.06.

UNFCC CDM Registration Website (2007) http://cdm.unfccc.int/Statistics/Registration/NumOfRegisteredProjByHostPartiesPieChart.html. Accessed 10.01.07.

WBCSD (World Business Council for Sustainable Development) (2004) Mobility 2030: Meeting the challenges to sustainability. http://www.wbcsd.ch/. Accessed 30.10.06.

Wit, R.C.N., Boon, B.H., van Velzen, A., Cames, M., Deuber, O. and Lee, D.S. (2005) Giving wings to emission trading. Inclusion of aviation under the European Emission Trading System (ETS): Design and impacts. CE Delft report no. 05.7789.20, Delft, The Netherlands.

WTO (2005) *Tourism Market Trends. World Overview and Tourism Topics* (2004 edn). Madrid: World Tourism Organisation.

Appendix: Glossary

Afforestation: Planting of new forests on lands that historically have not contained forests.

Additionality: Reduction in emissions by sources, or enhancement of removals by sinks, that is additional to any of these activities that would occur in the absence of a Joint Implementation or a Clean Development Mechanism project activity, as defined in the Kyoto Protocol Articles on Joint Implementation and the Clean Development Mechanism.

Annex I countries: Group of countries included in Annex I (as amended in 1998) to the United Nations Framework Convention on Climate Change, including all the developed countries in the Organisation for Economic Cooperation and Development, and economies in transition.

Certified Emission Reduction (CER) Unit: Equal to one tonne (metric ton) of CO_2-equivalent emissions reduced or sequestered through a Clean Development Mechanism project, calculated using Global Warming Potentials.

Clean Development Mechanism: Defined in Article 12 of the Kyoto Protocol, the Clean Development Mechanism is intended to meet two objectives: (1) to assist Parties not included in Annex I in achieving sustainable development and in contributing to the ultimate objective of the convention, and (2) to assist Parties included in Annex I in achieving compliance with their quantified emission limitation and reduction commitments.

Emissions Trading: A market-based approach to achieving environmental objectives that allows those reducing greenhouse gas emissions below what is required to use or trade the excess reductions, to offset emissions at another source inside or outside the country. In general, trading can occur at the intra-company, domestic and international levels. The IPCC Second Assessment Report adopted the convention of using 'permits' for domestic trading systems and 'quotas' for international trading systems. Emissions trading under Article 17 of the Kyoto Protocol is a tradable quota system based on the assigned amounts calculated from the emission reduction and limitation commitments listed in Annex B of the Protocol.

European Allowance Unit: Permission to emit one ton of carbon dioxide equivalent in a specified period of time assigned to a country.

Global Warming Potential (GWP): An index, describing the radiative characteristics of well-mixed GHGs, that represents the combined effect of the differing times these gases remain in the atmosphere and their relative effectiveness in absorbing outgoing infrared radiation. This index approximates the time-integrated warming effect of a unit mass of a given GHG in today's atmosphere, relative to that of carbon dioxide.

CO_2-e or CO_2equivalent: The concentration of carbon dioxide that would cause the same amount of radiative forcing as a given mixture of carbon dioxide and other GHGs.

Joint Implementation: A market-based implementation mechanism defined in Article 6 of the Kyoto Protocol, allowing Annex I countries or companies from these countries to jointly implement projects that limit or reduce emissions, or enhance sinks, and to share the Emissions Reduction Units. JI activity is also permitted in Article 4.2(a) of the United Nations Framework Convention on Climate Change.

Radiative forcing: Radiative forcing is the change in the net vertical irradiance (expressed in watts per metre square) at the tropopause due to an internal change or a change in the external forcing of the climate system, such as a change in the concentration of carbon dioxide or the output of the sun. Usually, radiative forcing is computed after allowing for stratospheric temperatures to readjust to radiative equilibrium, but with all tropospheric properties held fixed at their unperturbed values.

Radiative Forcing Index (RFI): The ratio of total radiative forcing to that from CO_2 emissions alone is a measure of the importance of aircraft-induced climate change other than that from the release of fossil carbon alone.

Reforestation: Planting of forests on lands that have previously contained forests but that have been converted to some other use.

Sequestration: The process of increasing the carbon content of a carbon reservoir other than the atmosphere. Biological approaches to sequestration include direct removal of carbon dioxide from the atmosphere through land-use change, afforestation, reforestation and practices that enhance soil carbon in agriculture. Physical approaches include separation and disposal of carbon dioxide from flue gases or from processing fossil fuels to produce hydrogen- and carbon-dioxide-rich fractions and long-term storage in underground in depleted oil and gas reservoirs, coal seams and saline aquifers.

United Nations Framework Convention on Climate Change (UNFCCC): The Convention was adopted on 9 May 1992 in New York and signed at the 1992 Earth Summit in Rio de Janeiro by more than 150 countries and the European Community. Its ultimate objective is the 'stabilisation of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system'. It contains commitments for all Parties. Under the Convention, Parties included in Annex I aim to return GHG emissions not controlled by the Montreal Protocol to 1990 levels by the year 2000. The Convention entered into force in March 1994.

Source: http://www.ipcc.ch/pub/syrgloss.pdf.