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What role for offsetting aviation greenhouse gas emissions in a deep-cut carbon world?

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The long-term goal of containing average warming below the 2 °C limit requires deep cuts in emissions from all sectors. The fast growing global aviation industry has committed to reduce carbon emissions. Carbon offsetting is an integral element of the sector's strategy. Already, airlines offer voluntary carbon offsetting to those customers who wish to mitigate the impact of their travel. To ensure carbon offsetting can make a meaningful and credible contribution, this paper first discusses the science behind ‘carbon offsetting’, followed by the associated policy perspective. Then, against the context of different aviation emissions pathways, the paper provides empirical evidence of current airline practices in relation to offsetting mechanisms and communication. Building on these insights, the challenges of reducing aviation emissions and using carbon credits to compensate for ongoing growth are discussed. The paper concludes by proposing five principles of best practice for carbon offsetting that airlines can use as a basis to develop credible emissions strategies, and that could inform the sectoral framework currently being developed by leading aviation organisations.

1. Introduction

The “Paris Agreement”, the key outcome of the 21st meeting of the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC), sets out an ambitious emissions reduction path. The long-term goal of containing average warming well below the 2°C limit demands substantial reductions in anthropogenic greenhouse gases (GHG) by mid-Century. The IPCC (2013) estimated a range of global carbon budgets (i.e., the maximum permissible total GHG emissions) for the period 2011–2100 consistent with this global warming goal. Including estimates of 2012–2016 emissions (Global Carbon Project, 2015), the global budget to have greater than 66% probability of limiting warming to below 2° as of 2016 is around 840 Gt carbon dioxide (CO_2). Current annual global emissions are more than 36 Gt CO_2, which leaves only 24 years of emissions, assuming emissions do not increase post-2016. Given these tight scientific estimates, state Parties agreed to aim to reach global peaking of GHG emissions as soon as possible, and to undertake rapid reductions thereafter, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of GHG in the second half of this century (UNFCCC, 2015).

Sixty-two percent of aviation emissions are in international air space, and as a result they are currently not attributable to the national GHG accounts of any given state (Cames et al., 2015). Thus, international aviation is not covered under the Paris Agreement. Since the industry's emissions are significant in the order of at least 2–3% of global emissions (Global Carbon Project, 2015), a global aviation mitigation scheme is essential. A suite of measures are being explored to reduce emissions (Cames et al., 2015; Peeters et al., 2016; Schäfer et al., 2015), and considerable progress has been made in increasing fuel efficiency of aircraft. The improvement rate in fuel burn had been estimated to be around 55% between 1960 and 1979 (Peeters et al., 2005). Slightly more conservatively, and based on data from 26,331 aircraft, Rutherford and Zeinali (2009) estimated that efficiency increases in fuel burn were about 51% between 1960 and 2008.

The key challenge of aviation is less the exact levels of efficiency gains, but the continuous growth in demand. Over the last 20 years, aircraft capacity measured in available seat-kilometres has grown by more than 25%, and demand is forecast to continue to grow at around 5% per annum (Cames et al., 2015). The global fleet is

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expected to grow by 20,930 airplanes to reach about 40,000 in 2032 (Peeters et al., 2016). Considering both growth and efficiency gains, it has been estimated that fuel demand from aviation will increase by between 1.9% (Chèze et al., 2011) and 2.6% (IEA, 2012) per annum until 2025. Projected growth in the aviation industry, in the absence of additional, significant mitigation action, could see its share of global CO_2 emissions increase to 22% by 2050 (Cames et al., 2015). Whilst the most effective measure of reducing aviation emissions is to decrease growth, this does not feature in the 'basket of measures' (ICAO, 2017, p. 1) promoted by the industry. Reducing travel also seems unlikely from a consumer perspective (Becken and Bobes, 2016).

The global travel and tourism sector is pursuing substantial global growth, and at the same time has to respond to the ambitious global emission contraction pathway outlined in the Paris Agreement. Several sector agreements are noteworthy (even though they still fall short of the Paris Agreement targets). IEA, 2016, the World Travel and Tourism Council reiterated its 2009 target of halving sector emissions by 2035, relative to 2005, and flagged that these will have to be revised following the Paris Climate Summit (WTTC, 2016). Similarly, the 2007 four-pillar strategy by the International Air Transport Association (IATA, 2009) adopted a set of steps and targets. A constraint on aviation CO_2 emissions from 2020 ("carbon-neutral growth") was to be followed by a reduction in emissions of 50% by 2050, relative to 2005 levels. This was going to be achieved by, among others, an average improvement in fuel efficiency of 1.5% per year, the use of market-based instruments and biofuels.

Most recently in September 2016, in its 38th Assembly the International Civil Aviation Organisation (ICAO) agreed on the principles of a Market-Based-Mechanism (MBM); the Carbon Offset and Reduction Scheme for International Aviation (CORSIA). The idea of CORSIA is to complement measures of efficiency and biofuels, essentially by purchasing carbon credits to achieve the agreed goal of "carbon-neutral growth" from 2020 onwards (ICAO, 2017). Details on emission measurement, the types of carbon credits that are eligible, and how the aviation scheme is linked into national Governments and global frameworks are currently being worked on.

The aviation industry is cognizant that given limits to improving fuel efficiency (Peeters et al., 2016) and the social licence evident in support of international travel particularly for tourism and trade, their mitigation targets can only be achieved through schemes that provide for the purchase of carbon credits such that GHG emissions are reduced elsewhere but the benefits accredited to aviation. Already, some airlines are participating in carbon markets, for example in the European Union and New Zealand where Emissions Trading Schemes are in place. In addition, airlines engage in voluntary carbon offsetting, either at the corporate level or by offering offsetting opportunities to their customers. However, substantial progress has been hampered by different national-level policy environments, inconsistent approaches to measuring and reporting emissions, lack of commitment and uncertainty around consumer demand for more sustainable aviation.

Regardless, amongst existing initiatives, carbon offsetting plays a major role, with IATA (2016b) suggesting that "*carbon offsetting is simply a way for individuals or organizations, in this case airline passengers and corporate customers, to 'neutralize' their proportion of an aircraft's carbon emissions on a particular journey by investing in carbon reduction projects*." Definitions for carbon offsetting differ, and may use the terms 'compensating' or 'neutralising' emissions, referring to "*an activity that prevents, reduces or removes greenhouse gas emissions from being released into the atmosphere to compensate for emissions occurring elsewhere*" (Carbon Neutral, 2016). Whilst credible programs discuss the need for permanent and additional reductions, the language around whether emissions are avoided, reduced or removed is loose (Ecobusiness, 2016).

The scientific basis to carbon offsetting is often misunderstood, leading to the potential for perverse outcomes, including a failure of projects to reduce atmospheric concentrations of GHG, the primary purpose of mitigation activities (Mackey et al., 2013). Given the projected increase in air travel, we can anticipate a likely increase in uptake of offsetting for air travel. It is important, therefore, to clarify the issues surrounding offsets so that the sector, their customers, and the international community, can all be confident in what is or is not being achieved in terms of addressing the deep emission cuts needed to meet the Paris Agreement targets. This paper has three objectives: First, to discuss the science behind 'carbon offsetting'. Second, to assess future aviation emission pathways in order to clarify the depth of the aviation emission challenge. Third, to provide empirical evidence of how offsetting is currently offered by airlines, including ways it is communicated, level of detail provided, and offset projects supported. We conclude by discussing points of contention, and provide good practice principles that can assist in making appropriate use of carbon offsetting schemes in ways that are consistent with the best available science.

2. Carbon offsetting perspectives

The key to assessing the aviation sector's carbon offsetting schemes is to appreciate the difference between scientific and policy perspectives. The former is based on the accumulated knowledge from research published in peer reviewed journal articles. The state of knowledge is evaluated and synthesised every seven years by the Intergovernmental Panel on Climate Change (IPCC), which is the primary source of scientific information used to inform state parties under the UNFCCC. The policy perspective, on the other hand, reflects the norms of international negotiations under the United Nations treaty system, the inevitable tensions that arise among the state parties between national self-interest and international cooperation, and their resolution through bargaining and deal-making (Depledge, 2013), together with how these in turn influence national policies and private sector responses.

2.1. The scientific perspective

The benefits and limitations of carbon offsetting schemes can only be understood in the context of the global carbon cycle and the major stocks, flows, and natural processes which regulate, among other things, the atmospheric concentration of CO_2. Carbon is stored in four major stocks: the atmosphere (as a gas); the ocean (mainly dissolved carbonate ions); terrestrial ecosystems (especially forest biomass carbon and soil carbon); and fossil fuel in the geosphere (oil, coal and gas). Carbon naturally flows between the land and the atmosphere, and the ocean and the atmosphere. However, fossil fuel stocks do not naturally de-gas into the atmosphere in the absence of humans burning them for energy. Furthermore, the natural exchange of carbon between the land and the atmosphere is being greatly accelerated by the release of CO_2 from deforestation and degradation. We therefore have two sources of anthropogenic CO_2 emissions: (1) burning fossil fuel stocks and (2) depleting biomass carbon stocks.

Of the 36 Gt CO_2 emitted into the atmosphere globally from human sources in 2015, around 90%[1] were from fossil fuel and cement production, while 10% came from the land sector (Global Carbon Budget, see Le Quéré et al., 2016). Land carbon emissions, however, account for about 36% of the anthropogenic CO_2 emitted

[1] Coal burning was responsible for 41% of total emissions, oil 34%, gas 19%, cement 6%, and gas flaring 1%.

into the atmosphere from 1850 to 2000 (Haughton, 2015). The current known fossil fuel stocks are around 1940 Gt Carbon (IPCC, 2013), which if mined and combusted is equivalent to about 911 ppm[2] of atmospheric CO_2. The estimated stock of ecosystem carbon globally is between 450 and 650 Gt Carbon (IPCC, 2013). Complete deforestation this century would lead to an increase of 130–290 ppm (House et al., 2002). To have a greater than 66% probability of limiting global warming to less than 2°, atmospheric GHG concentrations should be no more than 450–480 ppm (IPCC, 2014), yet the current concentration is already at 400 ppm – leaving little headroom for ongoing emissions.

Atmospheric concentrations of CO_2 could be reduced by restoring all previously released land carbon. This would reduce concentrations by no more than 40–70 ppm by the end of the century (House et al., 2002), as the land's "sink" function is limited to the amount of carbon that was naturally stored in the forest before human impacts; plus an additional amount (in the order of 25%) due to the "CO_2 fertilization" effect. This effect relates to an increase in the productivity of terrestrial plants with elevated atmospheric CO_2 concentration because a physiological response of the plant stomata leads to higher water-use efficiency and a consequent increase in plant biomass (Denman et al., 2007). However, this effect varies geographically, is constrained by nitrogen availability, and depends on CO_2 continuing to increase (Mackey et al., 2013). If CO_2 concentrations were stabilized, this effect would disappear probably after a few decades.

There is ongoing confusion about the lifetime of fossil fuel CO_2 in the atmosphere with many people thinking it is around 100 years; whereas the science is clear that a more accurate answer is many thousands of years (Mackey et al., 2013). This confusion is partly due to the two-way natural flows of CO_2 between the atmosphere, ocean and land. On an annual basis, through natural processes, about 26% of CO_2 emissions are absorbed by the oceans, 30% by the land, and 44% remains in the atmosphere (Global Carbon Project, 2015). The atmospheric stock of carbon is growing because anthropogenic emissions from burning fossil fuel and deforestation and degradation are outstripping the capacity of the natural sinks (oceans and land) to absorb them.

The confusion also can be attributed to thinking that the lifetime of atmospheric CO_2 is equivalent to the average amount of time that individual carbon atoms spend in the atmosphere before they are removed by uptake into the ocean or the terrestrial biosphere. However, the short-term uptake and release, or exchange of one carbon atom for another, has no impact on the climate because the exchange does not result in net CO_2 drawdown from the atmosphere. Rather, the relevant consideration is the time it takes for the CO_2 concentration in the atmosphere to recover significantly toward its original, pre-disturbed concentration.

The atmospheric life time of a pulse of CO_2 can be estimated using models of the global carbon cycle that account for the key biophysical processes that effect net CO_2 drawdown from the atmosphere. A series of papers (e.g. Archer et al., 1997; Archer and Brovkin, 2008) have used these models to explain the processes and time scales involved, as follows. The primary process is absorption of CO_2 by the ocean. However, the solubility of CO_2 gas in seawater decreases with warming and there may be changes in ocean circulation or ventilation patterns and rates that impact CO_2 invasion. Two key sediment processes serve to draw down carbon: a fast pH-neutralizing reaction of CO_2 with $CaCO_3$ (calcium carbonate) on the sea floor, followed by a longer timescale weathering reaction of CO_2 with carbonates on land. These processes operate at a range of timescales from thousands to hundreds of thousands of years. Equilibration with the ocean will absorb most of it on a timescale of 2–20 centuries. Even if this equilibration were allowed to run to completion, a substantial fraction of between 20 and 40% of the CO_2 would remain in the atmosphere awaiting even slower chemical reactions with $CaCO_3$ and igneous rocks. The remaining CO_2 is abundant enough to continue to have a substantial impact on climate for thousands of years. Given these facts as they are known to science, a number of key conclusions can be drawn to inform our discussion of aviation offsets.

Forest protection and restoration do not offset fossil fuel emissions in the physical scientific understanding of the word. The influence on the global climate system of additional atmospheric CO_2 from the combustion of fossil fuels is not neutralised by offsets in the land sector. Fossil fuel carbon emissions are best understood as a separate and additional source of atmospheric CO_2 emissions to those from deforestation and degradation. Protecting forests avoids biomass-based emissions and represents an important mitigation action given the significant stock of carbon stored in the world's forests. Forest ecological restoration is also an important mitigation action as it serves to replenish the ecosystem carbon stocks that were depleted by prior land use. Both forest protection and restoration therefore are important components of a comprehensive approach to GHG mitigation along with the deep cuts needed in fossil fuel emissions. Indeed, emissions from both sources must reduce to zero by the end of this century to meet the Paris Agreement global warming target.

Additional drawdown of carbon from the atmosphere above and beyond the rate provided by the natural processes that comprise the global carbon cycle (ocean invasion, sedimentation, weathering, ecosystem uptake) will require that new technologies for carbon capture and storage are developed. While such 'negative emissions technologies' might play a role, they are unlikely to deliver the carbon reductions required (Smith et al., 2015), and any artificial absorption of atmospheric carbon would need to be sequestered permanently.

2.2. The policy perspective

As noted, climate change policy reflects negotiated outcomes between national governments that are parties to the UNFCCC. Consequently, the idea of "carbon offsets" has developed a meaning and usage that is not necessarily consistent with the scientific understanding of the word as explained above. There are two key international frameworks in use that employ different accounting conventions (e.g. see Australian Government, 2015). The UNFCCC classification system provides consistent estimates of the changes in the release of net anthropogenic emissions to the atmosphere by a country over time and is used by all state parties in their annual national inventory report. The Kyoto Protocol classification system remains relevant for so-called Annex 1 (developed) countries until the end of the second commitment period 2013–2020. The Protocol differs from the UNFCCC system as it emphasises the role of direct human activities and of changes in management practices in generating net emission outcomes on the land.

Carbon accounting rules in the land sector under the Kyoto Protocol are complex and are referred to as Land Use, Land Use Change and Forestry (LULUCF) (UNFCCC, 2014). Kyoto Protocol rules cap credits from forest management at 3.5% of base-year emissions. For developing countries, the Kyoto Protocol LULUCF rules do not apply and instead there is the voluntary incentives-based mechanism known as REDD + - Reducing Emissions from Deforestation and Degradation including the role of the role of conservation, sustainable management of forests and enhancement of forest carbon stock; see UN REDD Programme, (2017).

Implementation of the Paris Agreement, however, will have

[2] 1 ppm CO_2 in the atmosphere is equivalent to 2.13 Gt C (CDIAC, 2017).

profound implications for (1) the operation of the voluntary carbon market under which the aviation sector funds project-based offset activities and (2) how aviation offsets are related to national mitigation commitments and associated national greenhouse gas accounts. Article 6 of the Paris Agreement authorises the use of internationally transferred mitigation outcomes towards nationally determined contributions, specifies that these are to be authorised by State parties, and requires them to be regulated through a new mechanism. Importantly, they must not lead to double counting.

As the rules needed to implement the Paris Agreement are, as of writing, under negotiation, many issues relevant to aviation offsets remain unresolved including (1) if there will be any limits on the use of carbon offsets generated in the land sector domestically or purchased internationally to offset fossil fuel emissions in national accounts; and (2) whether the voluntary market will be able to continue to operate on a project basis independently from governments. Once the implementation rules are finalised, national policies will then have to be modified to reflect these international policy determinations, the specifics of which as they related to private sector offsets will no doubt vary with national circumstances. It is also worth noting that there is a growing understanding that the Paris Agreement will necessitate a change to the approach taken under the Kyoto Protocol to the land and forest sector. Attention should now be paid to the quality of carbon stocks in this sector as the Agreement notes the importance of ensuring the integrity of all ecosystems and the protection of biodiversity, both of which are closely linked to the resilience, and therefore risk profile, of carbon stocks.

A carbon offset is defined as occurring when an individual, company, NGO, or state invests in a project elsewhere that results in a reduction of GHG emissions that would not have occurred in the absence of the project (WBCSD & WRI, 2005). Fundamental to the concept of a carbon offset therefore is the notion of "additionality," which differentiates the emissions reductions produced by an offset project from the "business-as-usual" (BAU) scenario of baseline emissions without the project. For every tonne of emissions that is reduced, a carbon credit worth a tonne of reduced CO_2 can be claimed and, through a market-based scheme, the resulting carbon reductions can be sold as carbon credits. Carbon offsets are created under either formal schemes, established and regulated by governments and international bodies, or through voluntary offset markets. The Paris Agreement has further recognized and validated the role of offsets through, among other things, establishing guidance for international trading between domestic carbon markets, as well as a new offsetting mechanism. Carbon offset projects can be broadly classified into the following types (Polonsky et al., 2011).

2.2.1. Energy-related

Reducing or avoiding CO_2 emissions from fossil fuel energy use can be achieved by (a) investing in energy efficiency projects or (b) replacing fossil-fuel based energy sources with renewable ones. Energy efficiency projects can focus on buildings (e.g., insulation), replacement of inefficient technology (e.g., light bulbs), or transportation (e.g., wing tips on aircraft). Renewable energy projects that generate carbon offsets include, amongst others, solar technology, windfarms and hydroelectricity.

2.2.2. Forest management

Significant CO_2 emissions result from deforestation and degradation. Changing forest management can therefore deliver mitigation benefits compared to a BAU scenario by protecting forests from destructive land activities (Houghton et al., 2015). There are also some minor mitigation benefits to be gained from modifying forest management practices to reduce the level or rate of emissions, for example, by reducing the collateral damage from logging operations. Another type of forest management is called "afforestation and reforestation" referring to the establishment of trees on non-treed land; usually land that once supported natural forest cover but has been cleared for other land uses, typically agriculture, either a long time ago (hence, afforestation) or more recently (reforestation) (IPCC, 2000). Forests can be regrown as a natural ecosystem or, alternatively, as a plantation, with the dual intention of harvesting the trees on a regular basis. These two forms of forest regrowth will result in very different sequestration rates and in the size and longevity of their biomass carbon stocks. In both cases, additional forest management is needed to help protect trees from fire, pest invasion, and illegal logging, among other things.

2.2.3. Reductions of other GHGs

Waste is a small contributor to global GHG emissions (~5%), with the largest source being landfill methane (CH_4), followed by wastewater CH_4 and nitrous oxide (N_2O), plus minor emissions of CO_2 from incineration of waste (Bogner et al., 2007). Important options for mitigation in waste management are waste reduction, followed by re-use, recycling and energy recovery. Waste treatment technologies and recovering energy to reduce demand for fossil fuels can result in significant direct emission reductions from waste disposal (IPCC, 2014).

To illustrate the mitigation benefits of carbon offsetting, we can compare the use of three kinds of projects to purchase a carbon credit to offset one tonne of CO_2 from a flight: an energy-related project, a forest protection project, and a reforestation project (Table 1):

1. *Purchasing offsets generated from an energy project* – purchasing the offset results in the avoidance of an additional one tonne of fossil fuel CO_2 that would otherwise have occurred. This achieves a relative reduction of one tonne of CO_2 compared with the alternative of not buying the offset. Thus, if the flight produced one tonne of CO_2, the offset results in one instead of two tonnes of fossil fuel emissions. Offsetting therefore leads to a relative reduction of the carbon flow into the atmosphere, compared with the status quo scenario of two parties emitting one tonne each.
2. *Purchasing offsets generated from a forest protection project* – here the credit is generated through changes in forest management that prevent deforestation and degradation and thereby avoid future biomass carbon emissions. As with the energy-related example, the forest protection carbon credit results in one not two additional tonnes of CO_2 flow into the

Table 1
Comparison of three types of carbon offset options and their net effect on the CO_2 emissions into the atmosphere.

Type	Fossil fuel CO_2 from flight	Fossil fuel CO_2 elsewhere	Biomass CO_2	Total CO_2 flow into atmosphere <u>without</u> offset	Total CO_2 flow into atmosphere <u>with</u> offset
Energy	1 tonne	1 tonne avoided	–	2 additional tonnes	1 additional tonne
Forest protection	1 tonne	–	1 tonne avoided	2 additional tonnes	1 additional tonne
Re-forestation	1 tonne	–	1 tonne sequestered	2 *additional* tonnes compared with pre-deforestation balance	1 *additional* tonne compared with pre-deforestation balance

atmosphere. However, in this case the avoided emission of one tonne is biomass CO_2 rather than fossil fuel CO_2. Again, in absolute terms and from a perspective of atmospheric carbon stock, emissions in the atmosphere have increased by one tonne of fossil fuel CO_2.

3. *Purchasing credits generated from a reforestation project* – this credit has been generated by making use of previously deforested land that can serve as a sink to regrow a biomass carbon stock. Given that the reforestation project has resulted in one tonne of CO_2 being sequestered from the atmosphere, does this mean that the flight emissions have been 'neutralized' and in absolute terms there has been no increase in atmospheric CO_2? We argue this is not the case because the reforestation project has actually served to repay the carbon debt from when the land was previously cleared and is therefore restoring a depleted biomass carbon stock. If this logic is accepted, then the end result is the same as in the other two project types, namely, in absolute terms, emissions in the atmosphere relative to pre-industrial levels have still increased by one tonne of fossil fuel CO_2. If we accept a concentration of around 400 ppm as the new normal, then carbon sequestration through biomass means that the emissions from the flight have not added to the ("new normal") stock of carbon in the atmosphere. As noted above, the amount of biomass carbon that can be removed from the atmosphere is limited.

The above examples show that the science of what carbon offsetting means for atmospheric concentrations of CO_2 is not straightforward and different to the commonly held view that it neutralizes aviation emissions. The good news is that in all three cases the offsets result in there being one less tonne of CO_2 in the atmosphere compared to the counterfactual of not purchasing a carbon credit. Thus, a relative reduction of CO_2 *flow* has been achieved, but not an absolute one in terms of atmospheric *stock*. Further, there is a qualitative difference between the types of offset: the renewable energy project prevents one tonne of fossil fuel emissions occurring elsewhere, the forest protection project avoids one tonne of biomass carbon emissions that would otherwise occur, while the reforestation project reduces by one tonne the atmospheric stock of CO_2. As such, offsetting aviation sector emissions through purchasing carbon credits, while not neutralizing them in terms of the concentrations in the atmosphere, can make a significant contribution to mitigation efforts by slowing the rate at which anthropogenic CO_2 is emitted into the atmosphere and helping 'repay' the carbon debt from previous land use change.

It is also important to note that the discussion on carbon offsetting of airplane emissions focuses on the CO_2 contribution to radiative forcing and neglects other effects that lead to climate impacts in the order of 2–4 times the carbon effect alone (Lee et al., 2009). Since the scientific base of the exact coefficient for aviation emissions remains slightly uncertain, most aviation schemes only consider carbon. The following sections prodetails background on future aviation emission pathways.

3. Future aviation emissions

3.1. Emission pathways

Owing to growing demand, absolute aviation emissions are increasing. International aviation emissions alone have grown by over 30% between 2000 and 2010, and are estimated to increase by about 64% between 2010 and 2020 (Cames et al., 2015). In the long-term and considering ongoing moderate improvements in efficiency, emissions are expected to grow by a factor of between 7 and 10 by 2050 compared with 1990 (Cames et al., 2015; Lee et al., 2013). Several emission pathways have been explored in the literature (these typically take into consideration relevant socio economic trends, including estimates of oil prices). Fig. 1 shows the steep increase in BAU emissions, assuming moderate efficiency improvements, by 2030 and 2050. If more ambitious technological and operational improvements are achieved, emissions grow slightly slower, but still result in more than a doubling of emissions compared to present levels.

Alternative scenarios have been developed, with differing assumptions on activity level, relative carbon intensity and the specific target for 2050 (CDP et al., 2015). Targets are called "science-based" if they are in line with the cuts required for the 1.5–2° limit. Three of the scenarios shown in Fig. 1 have been developed on this basis: the IEA's 2°C pathway (IEA W2W 2DS), the constant share of the IPCC's 2 °C pathway (referred to as RCP2.6), and the 'budget approach' (see earlier about the remaining carbon budget) (Cames et al., 2015). In addition, Fig. 1 plots emissions for the IEA 4 °C

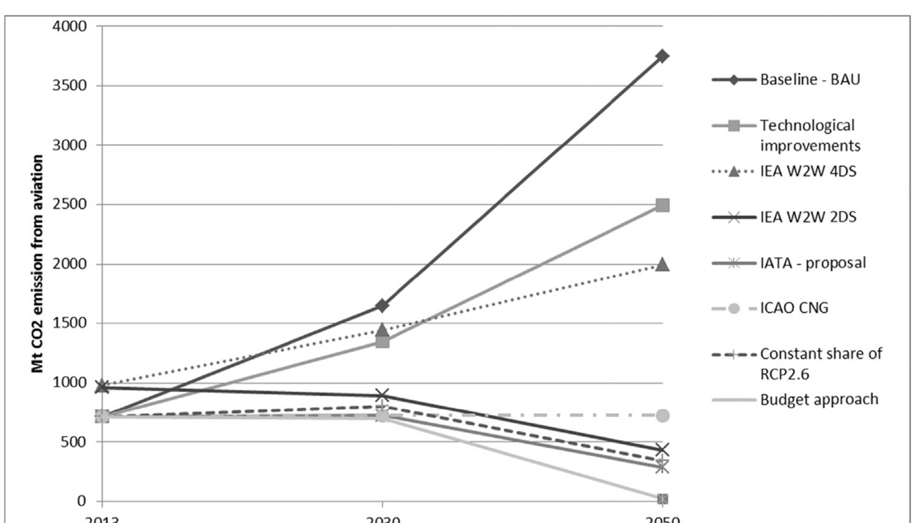

Fig. 1. Three-point emission pathways for aviation. Emissions have been extrapolated to 'total aviation emissions' when the original source referred to international emissions (assuming a 38% share of domestic emissions, Lee et al., 2013). Further, the IEA scenarios reflect well-to-wheel emissions and are therefore slightly higher than emissions from other scenarios. Sources: IEA (2016); IATA (2009, 2013); Cames et al. (2015).

scenario, the IATA proposal of halving 2005 (net) emissions by 2050, and IACO's aim of carbon-neutral growth from 2020. The IEA 2DS scenario is the least stringent of the 2 °C scenarios, but still requires improvements in energy intensity of the global fleet of 2.6% per annum between until 2050, combined with reductions in travel activity by 39% compared with BAU. Considering past trends these assumptions are highly optimistic, and raise questions about the feasibility of the RCP2.6 and carbon budget scenarios, which require even deeper cuts. The 'budget approach' would require that 2050 emissions are 96% lower than in 2005.

3.2. Role of carbon offsets

Even under the assumption of the most favourable combination of measures, namely the 'maximum feasible technical and operational reductions', plus usage of 'likely' and 'speculative'[3] biofuel, and an extension of existing market-based mechanisms to 2050, Lee et al. (2013) concluded that the level of emissions in 2050 would be 1330 Mt CO_2 for all aviation and 774 Mt for international aviation. It is clear that to achieve any of the pathways of negative emissions growth in Fig. 1, it is necessary to purchase carbon credits.

In the meantime, and in the absence of a globally agreed offsetting mechanism for aviation, research and practice have focused on voluntary carbon offsetting. In particular, discourse has centred on the environmental awareness of travellers regarding climate change and carbon offsetting, and on specific knowledge about the emissions caused by travel (e.g. Babakani et al., 2016; Choi, 2015; Eijgelaar et al., 2016; Higham et al., 2016). Broadly speaking, tourists, especially those originating from Western countries, are quite aware of the climate impact of their travel (Becken, 2007). Specific knowledge, however, is often lacking, and research found that travellers need and want more information on their travel-related emissions, in particular with regards to greater transparency of carbon emissions of airlines (Higham et al., 2016). Notwithstanding incomplete understanding, travellers were found to be willing to support offsetting for a number of reasons, including environmental attitudes (Mair, 2011), belief in climate change (Choi and Ritchie, 2014), wanting to 'make a difference' (Birgelen et al., 2011), and self-worth and/or social norms around offsetting (Blasch and Ohndorf, 2015). Uptake of carbon offsetting can be enhanced by using tailored communication messages (Babakani et al., 2016).

As a result, the practice of 'compensating' carbon emissions has become more common, but is still at a very low level, possibly in the order of several percent of travellers (McLennan et al., 2014). Choi and Ritchie (2014) found that 30% of travellers interviewed as part of a study in Australia had bought offsets before. The study also established that renewable energy projects in developing countries were most popular amongst travellers. Hagmann et al. (2015) reported that 31.9% of travellers surveyed in Germany had heard about offsetting, and 7.6% had bought offsets in the past. Higham et al. (2016) found widespread scepticism and uncertainty about carbon offset schemes amongst travellers from four Western Countries. Given the complexity around carbon offsetting, it is perhaps not surprising that that a substantial proportion of consumers are unsure about their role in carbon offsetting (Polonsky et al., 2011), despite a wide range of tools to engage (Becken and Bobes, 2016). The airlines play a key role in communicating and facilitating voluntary carbon offsetting, and understanding current practices may provide insights into the future more central role that offsetting will play within the aviation emission regime.

4. Empirical part: carbon offsetting offered by airlines

This part of the paper investigates to what extent airlines communicate carbon offsetting and whether they provide options to their customers to purchase offsets. The method used to extract data from airlines is discussed first, followed by an analysis of extent and nature of offsetting offered.

4.1. Creating a database

The first step was to create a database of airlines and their relevant carbon offsetting activities. Two inventories were used to obtain a list of airlines. One was a list of 'major airlines' to capture the largest companies in the industry (Nations Online, 2009). This source generated a list of 78 airlines. In addition, and to account for smaller and more recent airlines, the airline information site 'seat guru', a subsidiary of TripAdvisor, was consulted (Seat guru, 2016). Additional airlines were added to the database, resulting in a total of 139 airlines.

The second step involved finding out what information airlines provided on their role in carbon offsetting and whether the airline offered any form of carbon offsetting to their customers. This was elicited by first searching the airline's website using the search terms 'carbon', 'carbon offset', or 'offset'. The information found was extracted into a spreadsheet. If no information was provided on the airline's website, then other material was searched using the same terms. Additional sources included the company's annual report and the broader Internet using the search engine google. If more details were found the spreadsheet was enhanced, and the airline was identified as one being involved in carbon offsetting. Some airlines clearly stated that they did not support carbon offsetting, in which case they were labelled as 'no' in terms of carbon offsetting. All other airlines, where the above search process did not reveal any information, were classified as 'no data' for their offsetting engagement.

For those airlines that were identified as being involved in offsetting and offering options to their customer, further information was compiled in a spreadsheet. This included whether offsetting was provided on the airline's website, before purchase of ticket or afterwards, how much had been offset in the past or per annum, and whether the carbon offsets were certified. Also, information was collected on whether the method of calculating emissions was explained or disclosed, and what types of projects the airline invested in. The above information was analysed to understand the level of engagement, clarity and transparency of communication, and offsetting projects supported. The findings are presented in the following section.

4.2. Offsetting options and information provided by airlines

A total of 44 airlines (or 31.7%) were found to be actively involved in carbon offsetting activities (see Appendix A for a list). Thirty-four airlines provide an offsetting option to their customers on their website, but only four airlines feature a link to carbon offsetting on their home page (Iberia, KLM, Scandinavian Airlines and Thai Airways). Nine out of 34 airlines offer the offsetting option before the actual ticket purchase. This means that for the other 25 airlines it is not possible to determine the amount of emissions and cost of offset before making the purchase. Five airlines explicitly note that they did not support offsetting. Emirates, for example, state: "*We understand that some customers still want to off-set their travel-related emissions. In this case we refer our passengers to one of*

[3] Lee et al. (2013) used a 10% contribution of biofuel as a likely case and a 30% contribution as speculative; in both cases life-cycle savings are only 50% due to emissions generated in the production of the biofuels.

the world's leading carbon off-set organisations." No information could be found for the remaining 90 airlines, which suggests that they are unlikely to be involved in carbon offsetting.

Additional information was relatively limited, with eighteen airlines giving detail on the certification of their carbon offsets. Certifying bodies included, for example, Zero-footprint (Air Canada), J-Credit Scheme (All Nippon Airways), Lloyd's Register Quality Assurance Limited (Austrian Airlines), Australia Government's National Carbon Offset Standard (Jetstar, Qantas and Virgin Australia), KPMG Sustainability (KLM), Deloitte and Touche (SAS), MyClimate (Swiss), and Quality Assurance Standard (Kenyan Airlines, SriLankan Airlines, South African Airways). Similarly, airlines' reporting of methods used to calculate emissions was found to be neither comprehensive nor consistent (Table 2), with 11 airlines not disclosing any information on their methods. Except for the 'fixed price' approach used by two airlines, airlines broadly state that the amount of CO_2 generated depends on travel distance and airline specific factors. Several airlines refer to a third party (typically a carbon calculator on a different website), or an established external method to estimate emissions (e.g., ICAO factors). Kenya Airways applies a mixed approach by using ICAO emission factors and enhancing them with data from their own operations. A small number of airlines disclose that the price of carbon varies and that carbon offset would adjust accordingly.

4.3. What offset projects do airlines invest in?

Ten airlines reveal how much carbon has been offset through their various schemes. Often, the information is dated, however; for example "*the offset program, kicked off in 2008, has enabled Asiana Airlines to offset about 8500 tons of GHG by 2011*" (Asiana Airlines). Since the uptake by travellers is comparatively small, total purchase of carbon credits is limited. In the case of Qantas, which seems to have greater success in engaging its customers, the voluntary offsets bought by customers equate to about 1.6% of the airline's direct fuel-related emissions. Very few airlines demonstrate adequate disclosure (see examples below) on the total amounts of carbon offsets in a given timeframe, but the amounts of offset are very low.

- Qantas Group: "In National Carbon Offset standard annual report 2013–2014 prepared by Qantas Group, a total of 187,024 tonnes of CO_2-e were purchased."
- JetBlue: "Since partnering with Carbonfund.org in 2008, JetBlue has offset more than 220 million pounds (103,000 metric tons) of CO_2e. In 2013 alone, we offset more than 36 million pounds (16,329 metric tons) of CO_2 emissions."
- Virgin Australia Annual Report 2013: emission offsets purchased by tourists (tonnes CO_2-e) were 54,462 (in 2013); 65, 971 (in 2012); 65,491 (in 2011).

Most of the 44 airlines that engage in carbon offsetting offer some information on the projects which they support financially through offsetting purchases by customers, although the extent of detail and transparency varies (Table 3). Several airlines report multiple projects, resulting in a database of 89 projects. Note that in some cases it was difficult to discern which project was supported, as airlines listed a variety of ongoing projects that were typically managed by a third company. Some project descriptions are very generic (e.g. "*sustainable energy projects*", KLM) and it was not possible to extract more insight from publicly available information. Most projects were identified as aiming to avoid fossil fuel CO_2 emissions, with the most commonly supported initiative relating to cooking stoves (12 projects) that either entail fuel switching (e.g. from coal to biomass) or a more efficient combustion process. Nineteen projects relate to forest protection; most of which appear to be verified by an external standard (e.g. Verified Carbon Standard). Most airlines emphasis co-benefits of biodiversity protection and sustainable development for local communities. Several prominent projects are (independently) supported by multiple airlines, for example the Kasigau Corridor REDD + Forestry project in Kenya. Table 3 shows that most projects are in Asia and Africa, concentrated in a small number of countries.

The language used to communicate the carbon offsetting activities often lacks clarity or scientific accuracy. For example, Air Canada's statement that offsets constitute "*meaningful steps to decrease the carbon dioxide (CO_2) in our atmosphere*" implies that purchasing offsets results in reduced CO_2 concentrations in the atmosphere, which as shown earlier is not the case. Cathay Pacific's explanation concerning their program is more refined and emphasises the reduction of emissions elsewhere but does not relate to absolute amounts of CO_2 in the atmosphere ("*The logic behind FLY greener is simple: it helps make sure the CO_2 generated from air travel is reduced elsewhere. This is called "carbon offsetting"*"). A similar argument is presented by Volaris stating: "*Our 2015 goal is to neutralize the emissions generated by 100 flights in the MEX-GDL route through the procurement of carbon credits, thus, reaffirming our commitment to the Environment*". No further information is provided on the materiality of this initiative relative to all flights by the airline. Very few airlines use precise terminology (e.g. Austrian Airlines report that "*over the lifetime of the plant, 2100 tonnes of CO_2 will be avoided*" and Qantas state that their forest protection project helps "*avoid the emission of 4.3 million tonnes of carbon per year*"). It is important to note that many airlines provide detail on their website on internal carbon reduction projects beyond carbon offsetting (e.g. improvements in aircraft fuel efficiency), but these are not the focus of this present analysis.

Table 2
Approaches and methods used to estimate CO_2 emissions by airlines.

Approach	Description	Examples
Fixed price	The airline offered to add a fixed price to offset a flight, or suggested a specified contribution towards offset. These were in the order of $US 5 –10 dollars.	EasyJet and Volaris
Third-party	The airline provided a link to an existing carbon calculator and/or organisation that offers carbon offsets.	Delta – Nature Conservancy; Swiss Air – MyClimate; Monarch – Climate Care
External method	An externally developed and accepted methodology is used to estimate emissions.	Brussels Airlines: Bilan Carbone Method (ADEME); Thai Airways – IATA calculator; Japan Airlines – ICAO emission factors
Internal method	Airline specific data on fuel consumption, fleet composition, and load factors are used to determine with relatively great level of detail emissions either per passenger-kilometre or specific flight sectors.	Air New Zealand, Air France, Cathay Pacific, Qantas, Jetstar, Virgin Australia, KLM, Scandinavian Airlines

Table 3
Carbon offset projects supported by airlines.

	N	%	Example quotes
Project type			
Energy-related	46	48.9%	"Photovoltaic cells on rooftops give families electricity and light. For people living in rural Ethiopia this constitutes a substantial improvement in living conditions." (Lufthansa) "Located in the rural areas of Shanxi Province, China, this fuel-switching project reduces greenhouse gases by replacing coal with renewable biomass on a household level. More than 7000 inefficient coal burning stoves are replaced with highly efficient ones that use agricultural residue, which are currently burned in the fields as waste." (Cathay Pacific)
Forest protection	19	20.2%	"The Conservation Fund is working to rebuild the area's commercial timber inventories to support the local economy and restore habitat for local rare and threatened species while protecting the forest from conversion to vineyards or home developments." (United Airlines) "Protect 177,000 hectares of virgin rainforest in Papua New Guinea, and give 60% revenue from sale of carbon credits to local communities to invest in health, education, communication, and accessibility program for local communities." (Jet Star)
Reforestation	8	8.5%	"[…] a forest restoration project that aims to create a forest that will continue to be healthy beyond the lifespan of the current generation of trees, maximize the amount of CO2 that can be sequestered (or absorbed), and emulate natural forest growth." (Air Canada) "Carbon offsets purchased from the fund go towards tree planting and forest cultivation in Iceland." (Iceland Air)
Waste management	9	9.6%	"The Project utilizes state-of-the-art technology to capture harmful methane greenhouse gas from the landfill and convert it into electricity that can be used towards powering homes." (JetBlue Airways)
Unidentified	12	12.8%	"Your contribution will flow into myclimate climate protection projects in developing and emerging economies." (Swiss Air)
Location			
Asia	18	19.1%	China (5), India (5), Taiwan (3), Lao (2),
Africa	15	16.0%	Kenya (7), Uganda (4)
North America	12	12.8%	Canada (8), USA (5)
South America	10	10.6%	Brazil (4), Peru (3)
Pacific	9	9.6%	Australia (4), New Zealand (1), Papua New Guinea (2)
Latin America	7	7.4%	Mexico (5)
Europe	5	5.3%	UK (3)
Unidentified	18	19.1%	

5. Discussion: contentions and recommendations

5.1. Voluntary carbon offsetting

Carbon offsetting for aviation has been promoted for a long time, with multiple providers of carbon credits offering travel-specific calculators (Becken and Bobes, 2016; Mair, 2011). About one third of airlines are actively engaged in carbon offsetting, although the information provided on the types of credits used, certification or standards, and projects is minimal. The analysis of 139 airlines and their offsetting communication and initiatives highlighted that activities in this space are rudimentary and inconsistent. Furthermore, the way carbon offsetting is framed is often incorrect from a scientific point of view, as argued in the earlier part of this paper. Airlines, wittingly or unwittingly, promote the notion that carbon offsets neutralise flights – in the sense that the emissions 'do not exist' because they have been reduced elsewhere. Very few airlines correctly stated that the offset results in avoided emissions elsewhere, and still have a climate impact in that fossil fuel carbon is released into the atmosphere (just less of it).

According to information provided by some airlines the uptake by travellers has been small, and quantities of CO_2 avoided or sequestered have been insignificant. This is consistent with the literature that indicates that voluntary carbon offsetting for air travel is pursued by a minority of travellers (Davison et al., 2014: McLennan et al., 2014). Once aviation emissions are included in broader policy frameworks (e.g. a price of carbon or an ETS) the uptake of voluntary offsetting could be even smaller (Choi, 2016). The aviation industry has now formalised carbon offsetting as a cornerstone of its global policy framework, the CORSIA (ATAG, 2013; ICAO, 2017). One question is how such a framework sits alongside engaging customers in climate change mitigation through purchasing carbon credits or by flying less. Another questions concerns whether a scheme that is built on carbon offsets meets the need for deep cuts across all sectors, as stipulated in the Paris Agreement.

5.2. Airlines rely on carbon offsets

The emission pathways shown in Fig. 1 highlight clearly that technological improvements and efficiency gains (e.g. through air traffic management) are insufficient. Already, some claim that the industry as a whole has failed to achieve its fuel efficiency goals of 1.5% per annum (Kharina and Rutherford, 2015; Lee et al., 2013). Based on analysis of fuel burn between 1968 and 2014, the aviation industry is lagging behind its stated goals by about 12 years. As the growth projections highlight, even a 1.5% improvement rate would not be enough to counteract emission growth due to increases in demand. Apart from radical technical advances (Bows-Larkin, 2015; Peeters et al., 2016) and new generation aircraft (Schäfer et al., 2015), which are critical to achieving a substantial reduction, carbon offsetting remain an essential pathway to contribute to global climate mitigation.

How big then is the carbon gap for the aviation industry? In other words, what is the total amount of offsets needed over time? Cames et al. (2013) estimated that the cumulative gap for international aviation (from 2020 to 2050) between the industry-defined carbon neutral growth goal and BAU is 25 Gt of CO_2. To comply with the RCP 2.6 pathway, the gap would be 33 Gt, and the carbon budget approach would require purchase of credits to the amount of 37 Gt of CO_2. Questions have been raised whether there are sufficient credits to meet this demand. Recent analysis claims that existing Clean Development Mechanism projects would generate enough credits to 2035, although the number of a total of 5.67 Gt of CO_2-e until 2030 that was reported by Hermwille (2016) seems insufficient compared with the figures provided above. Also, there is uncertainty around the future of CDM beyond 2020, and once 'double counting' is resolved, it is unlikely that countries will have much spare capacity of reductions that have not already counted towards their own Nationally Determined Contributions. The global carbon market is likely to get squeezed by 2030 at the latest.

5.3. Policy implications

The majority of policy discussions on airline carbon offsetting refer to international aviation. The reason for this focus is that in principle emissions from domestic aviation will fall under national jurisdictions and climate policies. As a result, the CORSIA specifically addresses emissions from international aviation. The analyses and estimates of emission gaps, as shown above, then seem to ignore the fact that the significant emissions of domestic aviation are shaped by the same factors, namely, increasing activity, limited pace of technology improvements, demand for biofuel, and competition over airspace. Ultimately domestic aviation will compete for increasingly scarce, yet much needed carbon credits to comply with reduction targets. This is already evidenced in countries, where airline emissions are subject to a an Emission Trading Scheme, and where targets can only be met through the purchase of carbon offsets (e.g. European Union, New Zealand) (Carbon News, 2016).

To address international aviation emissions, ICAO has now decided to implement a global mandatory offsetting scheme that "*should not be focused on suppressing demand for air travel*" (ATAG, 2013, p. 1). Without an absolute cap this will not result in absolute reductions as airlines are legitimised to continue to purchase credits to compensate for growth in emissions. In the absence of any other legislation, absolute reductions in emissions will therefore depend on deep cuts in other sectors (Bows-Larkin, 2015). In the growing discussion around science-based targets, this basic problem is recognized and the use of carbon offsets is therefore explicitly not recommended. Instead, targets should be designed to achieve real reductions (CDP et al., 2015). In its technical notes, the CDP (2016, p.8) states "*Offsets do not count toward science-based targets. Offsets can be applied additionally, beyond reductions needed for science-based targets e.g. toward carbon or climate neutrality targets. When submitting targets to be assessed for science-based ambition do not include reductions that are planned to be made with offsets.*" Apart from the scientific basis of what offsets do and what they do not do, one key factor of success is the generation of carbon credits with high integrity. This is something that ICAO and airlines are working on.Where to from here?

There is no doubt that the deep cuts required are a major challenge for the aviation industry. If any of the reduction pathways discussed earlier are to be achieved, the most favourable technological assumptions plus reductions in demand are necessary. Legislation may be necessary to implement some of these. The strategy to rely on carbon offsetting is unlikely to work in the long-term, as pressure mounts from governments, communities, and business, for all sectors to contribute their fair share of the mitigation burden. Notwithstanding, offsetting projects present an important opportunity for airlines to contribute to helping others reduce GHG emissions that would otherwise occur, along with the co-benefits of biodiversity protection and sustainable development. Depending on the type of project, funds raised by airlines, either through voluntary offsetting or as part of a sector agreement, could be an important component of a comprehensive cross-sectorial approach to avoiding future fossil fuel and biomass emissions. Investing in carbon sinks, for example through forest restoration, is critical for achieving climate targets (Houghton et al., 2015) and the aviation industry could play a significant role here. Considering the low price-elasticities of aviation (Schiff and Becken, 2011; Smyth and Pearce, 2008), air travel seems perfectly placed to generate additional revenue for 'environmental donations' that can support climate mitigation projects.

As noted, airlines already have built partnerships with carbon offsetting companies and particular projects, for example on forest protection. While these can be fruitfully continued and expanded, it is critical for their long term credibility that airlines ensure the climate change benefits of these schemes are correctly communicated to their customers. The analysis presented here provides insights that can help the aviation sector improve the reporting of their carbon offset schemes. The following five principles are proposed as best practice:

1. The terminology and wording used by the aviation sector and airline businesses to describe their carbon offset schemes accurately portray the scientific realities and the mitigation benefits being achieved.
2. Customers have the information needed to understand that the carbon offsets they purchase do not neutralise fossil fuel emissions from flights in the sense that the flight 'does not matter'. The flight still increases atmospheric concentrations of CO_2 and therefore contributes to global warming. Offsetting a flight, however, slows down the fossil fuel flow of CO_2 and as a result leads to relatively lower concentrations compared with the status quo of not offsetting.
3. The most credible aviation carbon offsets programs are those designed to genuinely help avoid emissions through funding renewable energy projects and forest protection and restoration activities. When these activities occur in developing countries, social co-benefits can be important. Co-benefits are also important in developed countries.
4. The projects supported through the offsetting money are selected carefully and reported on regularly, including the total volume of GHG avoidance or reduction, and the methodology for estimating emissions is communicated transparently.
5. Carbon credits are third-party audited and information on the quality of the credit (including assurance that double accounting does not occur) is disclosed.

6. Conclusion

As the world community turns its attention to implementing the Paris Agreement, governments and civil society will be paying careful attention to how all sectors can better share the mitigation burden of limiting global warming to the 2° target and the global carbon cap this implies. While the social licence under which the aviation sector clearly operates is unlikely to be revoked, its emissions, especially the international component, will come under increasing scrutiny. In addition to technological change, and possible reductions in demand, carbon offsetting is currently pursued as a key pillar of aviation's mitigation response. Scientifically, carbon offsetting does not reduce atmospheric concentrations of CO_2 in the atmosphere, and must remain a second or third choice option. However, when pursued, the principles suggested here should be adhered to so to provide a credible basis on which each airlines can develop their brand-specific approach to carbon offsets. In addition, adoption of these principles as part of a sector-wide framework will facilitate the aviation industry's reporting of credible aggregate mitigation statistics, enhancing its role as a Non-State Actor.

Appendix A. List of airlines in this study and summary of their offsetting activity

Airline	Offsetting identified (no = 0, yes = 1, unknown = 2)	Offsets certified (yes = 1)	Certified by whom?	Projects mentioned (N)
Aer Lingus	2			
Aeroflot Russian Airlines	2			
Aerolineas Argentinas	2			
Air Canada	1	1	ZeroFootprint	7
Air China	2			
Air Europa	2			
Air India Express	2			
Air New Zealand	1			1
Air Tahiti Nui	2			
Air Transat	2			
Air Vanuatu	2			
Air VIA	2			
AirAsiaX	2			
AirAsia	2			
Air Berlin	2			
Air France	1			
AirTran Airways	2			
Alaska Airlines	0			
Alitalia	2			
Allegiant Air	2			
American Airlines	2			
All Nippon Airways	1	1	J-Credit Scheme	1
Asiana Airlines	1			1
Atlas Global	2			
Austrian Airlines	1	1	Lloyd's Register Quality Assurance Ltd	15
Avianca Airlines	2			
Bangkok Airways	2			
Belair Airways	2			
Brussels Airlines	1	1	Not specified	1
Cathay Pacific	1			2
China Airlines	2			
China Eastern Airlines	2			
China Southern Airlines	2			
Clickair	2			
Condor	2			
CopaAirlines	1			3
Corendon Airlines	2			
Czech Airlines	2			
Delta Air Lines	1			3
Dragon Air	1	1		2
EasyJet	1	1	EU ETS	
El Al Israel Airlines	2			
Emirates	0			
Etihad	1			
Ethiopian Airlines	2			
Eurowings	2			
EVA Air	2			
ExpressJet Airlines	2			
Fiji Airways	2			
Finnair	2			
Flybe	0			
Frontier Airlines	1			
Garuda Indonesia	1			
Germania	2			
Gol Linhas Aéreas	2			
Gulf Air	2			
Hainan Airlines	2			
Hamburg Airways	2			
Hawaiian Airlines	2			
Horizon Air	2			
Iberia	1			1
Icelandair	1			1
IndiGo Airlines	2			
InterSky	2			
Japan Airlines	1			
Jet Airways	2			
Jet Solidaire	2			
Jetblue Airways	1			1
Jetstar	1	1	Australia Govt National Carbon Offset Standard	4
Kingfisher Airlines	2			
KLM	1	1	KPMG Sustainability	not disclosed

(*continued*)

Airline	Offsetting identified (no = 0, yes = 1, unknown = 2)	Offsets certified (yes = 1)	Certified by whom?	Projects mentioned (N)
Korean Air	2			
LAN Airlines	2			
Lion Air	2			
LOT Polish Airlines	2			
Malaysian Airlines	1			not disclosed
Middle East Airlines	2			
Mesa Airlines	2			
Monarch	1			3
NIKI	2			
Lufthansa	1	1	MyClimate	2
Nok Air	2			
Norwegian Air Shuttle	2			
Olympic air	2			
Oman Air	2			
Openskies	2			
Peach airline	2			
Pegasus	2			
Philippine Airlines	2			
Pinnacle or Endeavor Air	2			
Porter	2			
Qantas	1	1	Australia Govt National Carbon Offset Standard	4
Qatar Airways	1			
Regional Express	2			
Royal Brunei	2			
Royal Jordanian	2			
Ryanair	2			
S7 Airlines	2			
Scandinavian Airlines	1	1	Deloitte and Touche	2
Saudi Arabian Airlines	0			
Scoot Airlines	2			
Singapore Airlines	2			
Skylane	2			
Southwest Airlines	2			
SpiceJet	2			
Spirit	2			
Spring Airline	2			
Sun Country	2			
SunExpress	2			
Swiss Air	1	1	MyClimate	4
Taca airlines	2			
TAM	2			
TAROM	2			
Thai Airways	1			
Thomas Cook Airlines	2			
Thomson Air	1			1
Tigerair	2			
Transavia	2			
TUIfly	1			1
Turkish Airlines	2			
United Airlines	1			3
Vanilla Air	2			
Vietnam Airlines	2			
Virgin America	1			3
Virgin Atlantic	1	1		9
Virgin Australia	1	1	Australia Gov National Carbon Offset Standard	1
Vueling Airlines	2			
WestJet	1			2
Wizzair	2			
WOW air	2			
Aeroméxico	1			3
British Airways	1			3
Cebu Pacific Air	1			1
Habour Air	1			4
Kenya Airways	1	1	Quality Assurance Standard	1
South African Airways	1	1	Quality Assurance Standard	2
Sri Lankan Airlines	1	1	Quality Assurance Standard	1
TAP Portugal	1			3
Volaris	1	1	Not specified	2

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