Calculating The Carbon Dioxide Emissions Of Flights

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INTRODUCTION

As climate change has risen up the agenda, it has become increasingly important to monitor and record carbon dioxide emissions to the atmosphere. Governments, institutions, businesses and individuals have all become engaged in monitoring the size of their carbon footprints, as the first crucial stage towards developing strategies to reduce emissions. Where direct measurement of emissions is not possible, carbon calculators are used to provide an estimate instead.

Carbon calculators are used by Governments for international emissions reporting, for businesses' declarations of corporate social responsibility, and also by individuals wishing to reduce their own environmental impact. In the latter case, they may choose to use a carbon offset company, and pay them to reduce an equivalent amount of emissions via a carbon reduction project.

This widespread usage is reflected in the proliferation of carbon calculators. A host of different calculators have been developed by government departments and environmental agencies, environmental NGOs, international trade bodies and carbon offset companies. Unfortunately this leads to inconsistency between calculators as no two methodologies are identical. The calculator methodology necessarily involves some degree of approximation and assumptions to be made, as well as subjective decisions about boundaries of responsibility for emissions and the actors they should be attributed to. Calculators also vary in sophistication with regards the level of data input required and range of data sources they draw upon. The 'best' calculators should be simple to use, but be based around high quality input data and sound modelling. Furthermore, they should be sophisticated enough that any change in behaviour on behalf of a user should be reflected in an observed reduction in the calculated carbon footprint. For example, a simple calculator based upon an 'average car' would not reflect someone purchasing a newer more efficient model, whereas a more sophisticated model would capture such a change. Ideally, there should be a standard method for calculating components of travel, such as air, in order to ensure that reporting and claims for reductions or offsets becomes standardised, and so that industry progress in reduction is measured, thereby guaranteeing transparency and integrity in ongoing reporting.

This work assesses carbon calculators for aviation emissions – an area which is particularly sensitive to assumptions made - and introduces a new carbon calculator methodology developed by Sabre Holdings.[1] It argues that this new methodology represents a step change in sophistication and accuracy for the calculation of aviation emissions, and that it possesses the characteristics to make it an international standard for use by offset companies and business CSR reporting.

CALCULATING EMISSIONS

When seeking to determine the extent of emissions from an activity, it is impractical to measure the mass of emissions directly. Emissions are thus calculated from a known quantity such as fuel burned, or units of electricity consumed. Combustion of fuel is a stoichiometric chemical reaction, so the mass of CO_2 emissions can be directly related to fuel burn. Thus for example, for every kWh of energy supplied by gas or fuel oil, the CO_2 emissions are 0.206 or 0.281 $kgCO_2$, respectively.[2]

Emissions resulting from the use of electricity are more complex to calculate as they depend on the mix of generating plant in the host country. However, the total emissions from all plant can be calculated from the known fossil fuel burn, and compared to the total end consumption to give a national emissions factor for electricity use.

Transport represents a different challenge. For personal transport, fuel consumption can be monitored and converted into a corresponding mass of emissions by multiplying by the appropriate emissions factor (*e.g.* for petrol 2.317 $kgCO_2$/litre).[2] However, where fuel consumption is not monitored, some degree of estimation is necessary. The distance travelled, as logged by an odometer, can be converted into fuel burn (and therefore into a mass of emissions) by making assumptions about the fuel efficiency of the vehicle. The fuel efficiency of different vehicles varies markedly, so any single emissions factor is a considerable source of potential error. If the model of vehicle is known then the manufacturers measured fuel efficiency can be used, but if not, a crude assumption must be made as to what is an 'average' or 'typical vehicle. Furthermore, even if the vehicle model and its fuel efficiency are known, real fuel burn can vary from this value measured under standard test conditions, due to environmental factors such as headwinds, urban *vs.* motorway driving, hilly *vs.* level terrain. A further source of inaccuracy comes when attributing emissions from a journey to individuals – per person emissions are naturally highly dependent on vehicle occupancy.

Such arguments regarding the calculation of emissions from transport are particularly pertinent to the aviation sector. Different greenhouse gas emissions calculators give widely varying results for the same flight due to variations in the underlying assumptions made in the calculator methodology. For example, two different emissions calculators estimate emissions for a return flight from London to New York to be 1.53[a] or 3.48[b] tCO_{2e}, a variation of more than a factor of 2. This highlights the huge uncertainty in calculating aviation emissions, and its critical dependence on the methodology adopted. Whilst, calculator developers are increasingly transparent about the assumptions they make, and the reasoning behind them, there is as yet no internationally agreed and adopted methodology for the calculation of aviation emissions. As will be discussed below, this work aims to remove some the uncertainty around the underlying assumptions by using higher quality input data, and contribute towards the development of an international standard.

Much of the uncertainty about calculating the environmental impact of aviation emissions derives from the fact that emissions at altitude can instigate a host of chemical reactions in the atmosphere, which each have global warming and cooling effects over a variety of timescales, varying from less than 1 day to several hundred years.[3] The overall effect is certainly one of an increased warming effect compared to emissions at ground level, but the extent of this remains open to debate, both in terms of how to calculate the magnitude of this effect, and what the value should be.

Historically the Intergovernmental Panel on Climate Change (IPCC) quoted a value of 2.7 for this multiplier, with a range of 2-4.[4] Climate scientists have been able to update this study more accurately and have published a value of 1.9.[5] More recent studies have questioned the validity of this approach and estimated a value of 1.2 for this effect.[6,7] Detail on the assumptions underlying these figures is beyond the scope of this paper, but can be found in the literature.[3] For the purposes of this work, it is only necessary to note that some calculators may use a multiplier as high as 4, whilst others may regard the issue of a multiplier too contentious, and deal only with the warming effect of carbon dioxide (*i.e.* a multiplier of 1[2]).

Irrespective of the use of a multiplier for aviation emissions, there is still a large uncertainty in calculating the CO_2 emissions. For a passenger, the fuel burn will be unknown, so CO_2 emissions must be calculated based solely on the point of origin and destination, and a series of assumptions about the plane itself.

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[a] Climate Care, http://www.climatecare.org/

[b] Atmosfair, http://www.atmosfair.de/index.php?L=3

There will always be a variation between the emissions from any single flight and that of a calculated flight. This is because:

- Climatic conditions may vary, such as headwinds or tailwinds
- Flight distance may vary, due to detours to avoid inclement weather
- Aircraft may be kept in holding patterns
- The mass of aircraft load may vary between flights

For any given aircraft flying the same route emissions will vary because of such factors. However, these effects will average themselves out over multiple flights so that the calculated value will still represent a good estimate of an 'average' flight.

However, there are a series of factors that influence per passenger emissions that the passengers themselves will be unaware of. These include:

- The plane type
- The engine type on the plane
- The seating configuration
- The freight load

Aviation emissions calculators therefore have to make assumptions about each of the above factors, which introduce considerable errors and variations between methodologies. A standard methodology might make assumptions about which type of planes fly short-haul and long-haul routes, and how many seats would be on board a 'typical' plane. Freight load data, by weight, is also extremely rare in the public domain, so allocating a proportion of emissions to freight is also a loose approximation.

The following section introduces how a conventional aviation emissions calculator is constructed, and the sensitivities to the input parameters. The report then goes on to outline how the Sabre Holdings model can remove some of these assumptions and improve the accuracy of the overall model.

CALCULATING CO_2 EMISSIONS

All emissions calculators utilise broadly the same methodology, illustrated schematically in Figure 1.

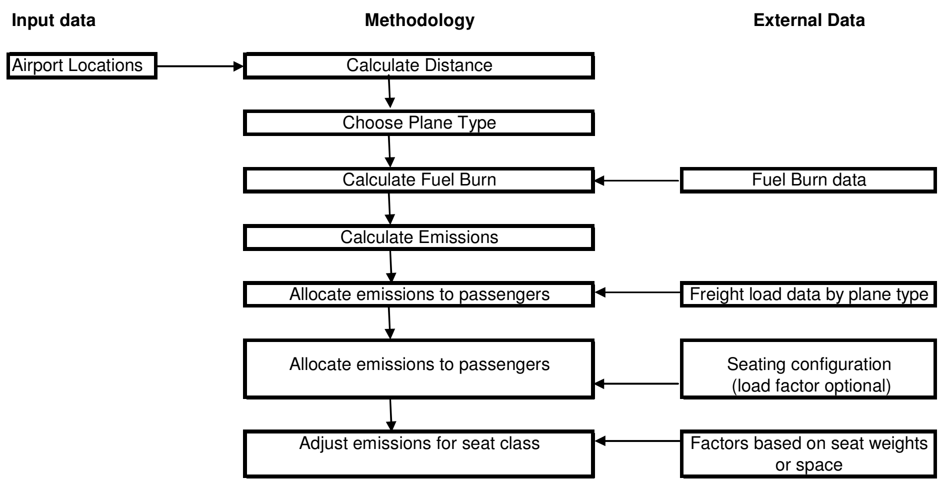


Figure 1 Emission calculator methodology

The distance between point of origin and destination can be calculated using a Great Circle calculation from a database of airport longitude and latitudes to a high degree of accuracy. Some methodologies adjust this distance by a factor to account for deviations from a perfect route (*e.g.* to avoid inclement weather conditions) and stacking around the destination airport.

This is then converted into a fuel burn for the flight. This usually necessitates an assumption about what type of plane would typically undertake a flight of such distance. Emissions are highly sensitive to the chosen plane model - Figure 2 shows there can be a factor of 2 between the most and least efficient plane models flying the same distance. Fuel burn data are publicly available for many models,[8] but these datasets are now becoming dated and do not include more modern plane models such as the Boeing 737-800 or Airbus A380. This is likely to lead to an overestimate in emissions as newer, more efficient planes are not represented.

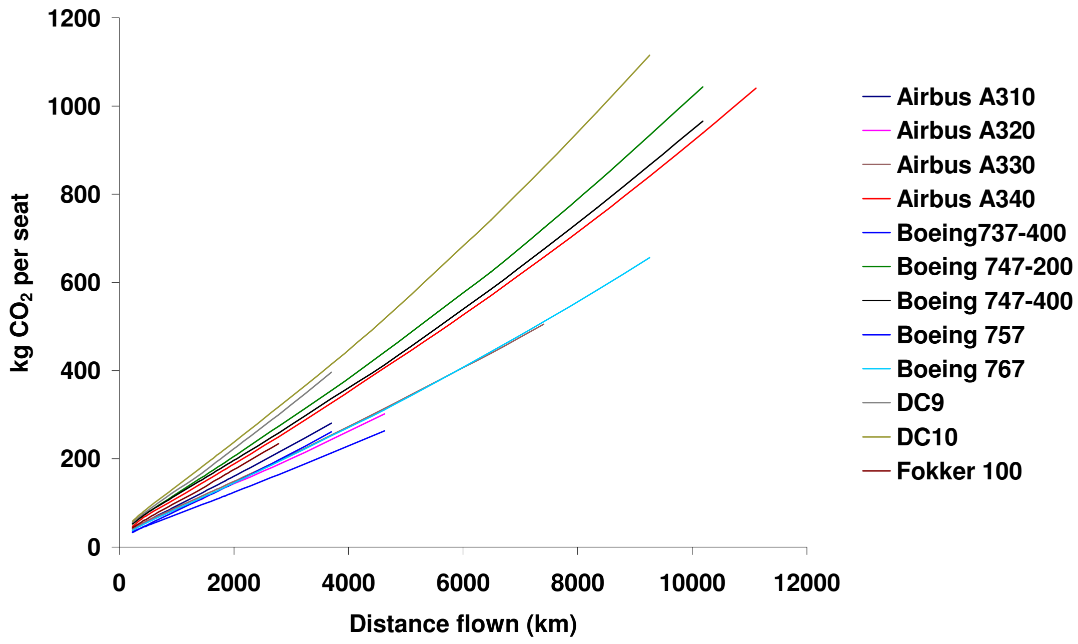


Figure 2 Emissions per seat as a function of distance for different plane models[c]

The calculated fuel burn can be converted into emissions of CO_2 by multiplication by an emissions factor of 3.157 $kgCO_2$/kgfuel. This factor is a chemical constant relating the mass of CO_2 produced by stoichiometric combustion of a known amount of fuel.

Sensitivity to distance flown

There is a variation in sophistication between emission calculator methodologies in the way emissions are calculated as a function of distance. As can be seen from Figure 2 above, the relationship between emissions and distance travelled for a given plane type is not linear. This is because there are emissions associated with the take off part of the flight, irrespective of distance flown. In reality short flights have a much higher emissions per km flown as a greater proportion of the emissions arise from the take off section of flight (See Figure 3, below).

[c] Seating configurations taken from Atmosfair, no multiplier used.

Second, flights become marginally less efficient as the distance flown increases, because a greater mass of fuel is required to be carried to travel longer distances. Thus the lines in Figure 2 curve upwards slightly, as efficiency decreases above a distance of *ca.* 5000 km (Figure 3).

Mathematically, emissions can be represented as a function of distance in one of 3 ways. The simplest methodologies use solely an emissions factor per km (*i.e.* formula of the form $y=ax$, where y is fuel burn and x distance flown). Whist this is consistent with the methodology for calculating emissions from other transport modes such as rail or road, it neglects the impact of the take off section of flight and doesn't represent increased fuel load on long flights. Even splitting into bands for short, medium and long haul flights does not capture the form of Figure 3, especially for short haul flights.

A more sophisticated methodology incorporates a constant term (*i.e.* formula of the form $y=ax+b$), which provides a much more accurate estimation of emissions as a function of distance flown, especially for short flights. In simple terms, the constant can be attributed to the LTO cycle, with the remainder attributed to the CDD phase of flight. Furthermore, utilising a formula of this form also allows a multiplier to just those emissions at altitude (*i.e.* the CCD portion). A more accurate representation still would be a polynomial formula such as $y=ax^2+bx+c$.

Freight load

When calculating per passenger emissions for flights it is necessary to first remove the emissions that are associated with the transport of freight. Most passenger flights, except short-haul budget carriers also transport freight in the hold of the plane. Freight factors for wide bodied aircraft are typically 15-30%, whilst narrow bodied planes are typically 0-10%.[1,9,10]

Publicly available industry data on freight load are rare, so most calculators make assumptions as to the proportion of total weight that is due to freight, especially those developed by offset companies.[3] More comprehensive data are available from industry sources such as the Civil Aviation Authority,[9] ICAO[10] or US DOT 41 Form data.[1]

Sensitivity to seating configuration

Once the freight load has been removed, emissions can be allocated to the seats on the plane. Once again the model is highly sensitive to the assumptions made. Figure 3 shows the impact of choosing the highest, lowest and median seating configurations on emissions. There is approximately a factor 2 difference in emissions between planes with high and low seating numbers.[11]

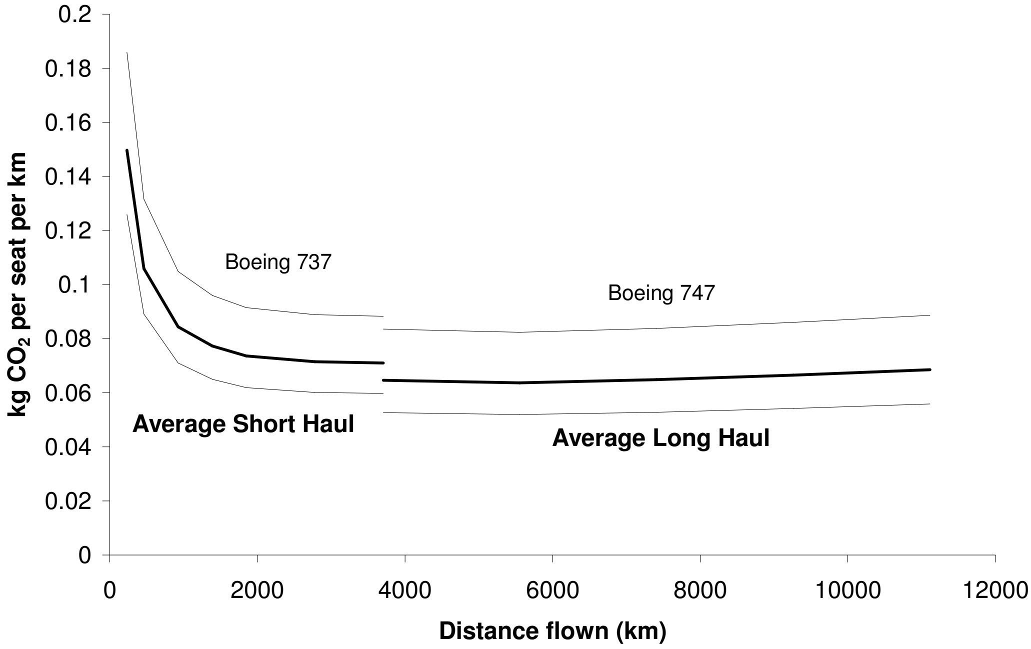


Figure 3 Sensitivity of emissions to seating configuration – high, low and median case.[3]

A further distinction exists as to whether emissions are allocated per passenger or per seat. Emissions allocated per passenger will account for all emissions from the plane and allocate them to a sold ticket, but requires an assumption to be made about the likely percentage plane occupancy. Emissions allocated per seat make no assumptions about flight occupancy and allocate a proportion of emissions to those filled seats but emissions allocated to unfilled seats are not accounted for. For offsetting and reporting purposes, allocating emissions to seats is preferable because the customer is not responsible for how the airline is in filling the other seats on the aircraft. The traveller is responsible solely for the carbon emissions for the seat they occupy.

Some models also make a distinction between economy and premium seats – where there are more premium seats, the fewer overall seats on the plane and the higher the emissions per seat. It therefore seems equitable to allocate a greater share of emissions to premium seats. This is done in one of two ways – simplistically passenger emissions are allocated proportionally to the space taken up by the respective seat types. However, the limiting factor for flights is weight, and emissions are split between freight and passengers on the basis of weight. Therefore it is more reasonable to allocate emissions between standard and premium seats based on the relative weights of total passenger, luggage and seat weight.

EXISTING EMISSIONS CALCULATOR PROTOCOLS

There are already many independently developed aviation emissions calculators in existence, developed by offsetting companies, and government and international bodies. In recent years there has been a desire for greater consistency between calculators, as the plethora of calculations makes reporting inconsistent and is confusing for clients wishing to offset.

However, discrepancies remain between calculators both arising from the quality of the data sources and any assumptions made, to more subjective issues of allocating emissions and the use of multipliers. This section reviews the approach of some of the more commonly used emissions calculators.

DEFRA

The Department for Environment, Food and Rural Affairs (DEFRA) is the United Kingdom government department responsible for environmental protection, food production and standards, agriculture, fisheries and rural communities in the United Kingdom. The department's priorities include protecting the natural environment, food security and a thriving farming sector, and promoting a sustainable, resource efficient and low carbon economy. The department has been responsible for CO_2 emissions reporting in the UK, and developed its own calculator methodologies which have subsequently been adopted by other international organisations.

DEFRA developed their own emissions calculator methodology[9] to promote consistency by using data and factors consistently across Government departments. DEFRA also made the calculator open source such that third parties could adopt the same approach and ensure even wider consistency in emissions reporting.

The DEFRA methodology publishes a series of emissions factors for short, medium and long haul flights, of 0.1580, 0.1304 and 0.1056 $kgCO_2/km$, respectively. These figures are derived from a more complex emissions calculation of standard form (see Figure 1) of which the key underlying assumptions are:

- Fuel burn data are calculated for 'typical' aircraft over illustrative trip distances, and the 2008 revision includes a 'significantly wider variety of representative aircraft for domestic, short and long haul flights'.
- Freight load may be treated in one of 2 ways under the DEFRA methodology. First, emissions are allocated in the proportions of the respective weights of passengers and freight, giving a freight load of 28.8% for long-haul, less than 1% for short haul. A second variant takes into account the additional weight necessary for passenger services (seats, galley etc.) and allocates a lower percentage to freight (11.9% for long haul).
- Under the DEFRA methodology emissions are allocated per passenger, based on load factors of 66.3, 81.2 and 78.1% for domestic, short-haul and long-haul respectively.
- Seating configurations are based on CAA statistics, supplemented by information from non-UK carriers. These are averaged over the different plane types to give the 3 emissions factors for domestic, short-haul and long-haul.
- Emissions are allocated between economy and premium class on the basis of space allocation.
- A multiplier is not recommended for use in the DEFRA methodology, although the department does apply a multiplier of 2 for its own internal reporting.

International Civil Aviation Authority

The International Civil Aviation Organization (ICAO) is an agency of the United Nations, which adopts standards and recommended practices concerning all aspects of international civil aviation including air navigation, prevention of unlawful interference, facilitation of border-crossing procedures, air accident investigation and transport safety.

The ICAO also has a dedicated environmental unit – the council's Committee on Aviation Environmental Protection (CAEP), which focuses on problems that benefit most from a common co-ordinated worldwide approach, such as aircraft noise and the impact of aircraft engine emissions. The ICAO has investigated the potential of market-based measures such as trading and charging as a means of reducing emissions. It has endorsed the development of an open emissions trading system for international civil aviation, and is developing guidance for states who wish to include aviation in an emissions trading scheme

The ICAO has also developed its own emissions calculator for use in carbon offsetting schemes, again with the aim of achieving an internationally agreed methodology for calculating an individual passenger's share of aviation emissions.

The ICAO methodology adopts a generic emissions calculation methodology as shown in Figure 1, above.

Key features of the ICAO methodology are:

- The exact plane type can be mapped to 50 equivalent aircraft types for which fuel burn data exist in the Corinair database (although this means more modern plane models will be absent). In practice the ICAO emissions calculator uses aggregated data to estimate the typical emissions associated with a given route between any airport pair.
- Freight load data is comprehensive and an appropriate freight load factor is chosen depending on whether the plane is wide or narrow bodied, for 17 different route groups.
- Emissions are allocated per passenger, based on a passenger load factor. This factor also varies by route group and whether the plane is wide or narrow body.
- Seating configurations are calculated from the number of economy seats that can be fitted inside the aircraft based on a standard cabin layout (in terms of galleys toilets and exits and using a 31/32 inch row separation)
- Emissions are calculated as CO_2 only and a multiplier is not used. The ICAO believes that a multiplier should not be used to take account of the non-CO_2 effects of aviation until a scientific consensus has been reached on the subject.

THE SABRE HOLDINGS MODEL

Sabre® is a computer reservations system (GDS) used by airlines, railways, hotels, travel agents and other travel companies. The Sabre database contains information about all flights including the date of travel, airline, departure point and destination, as well as technical details about the plane used for the flight (model and seating configuration). It can immediately be seen that many of the unknown parameters from the passenger viewpoint are known in the Sabre database, and that more detailed and accurate estimations of emissions can be achieved. This is possible because of the availability of two high quality and detailed data sources: the SAGE model and the Passenger Name Record.

SAGE

The accuracy of any aviation emissions calculator is strongly dependent on the quality of the fuel burn data used as an input to the model. Such fuel burn data is rare in the public domain, and often incomprehensive. The datasets are also prone to being out of date as new plane models and engine types are developed. This scarcity of accurate input data therefore necessitates the adoption of a 'typical plane' within emissions calculator methodologies, with the subsequent inaccuracies this approach brings. The SAGE model, however, gives modelled fuel burn for a large number of aircraft types (>200), thereby circumventing this issue. Although modelled, the SAGE model presents numerous advantages for emissions calculators, so long as the accuracy of the model is thoroughly validated.

The System for assessing Aviation's Global Emissions (SAGE) was developed by the US Federal Aviation Administration's Office of Environment and Energy. The model was developed as a tool to examine annual global emissions, but because global emissions are calculated as the sum of many individual flights, it allows scenarios to be disaggregated to regional, national, airport and individual flight levels. Scenarios may, for example, examine the influence of policy measures, technological development, changes in the fleet stock, and operational practice. The model is available to the international aviation community, although not the general public at present.

This high fidelity of the model is also ideally suited for emissions calculators. Fuel burn data at the individual flight level, based on aircraft type, represents a quantum leap in sophistication for emissions calculators, hitherto based on crude averages and assumptions.

Passenger Name Record

The passenger name record (PNR) contains information about the individual flights and is utilised for booking flights for passengers. The PNR contains information about the point of origin, destination, airline, plane type used and can access seating configuration. The latter two parameters, used in conjunction with the SAGE model provide accurate CO_2 emissions calculations on a flight by flight basis

Sabre Holdings Methodology

Figure 4 illustrates the methodology of the Sabre Holdings model, and can be described in four steps.

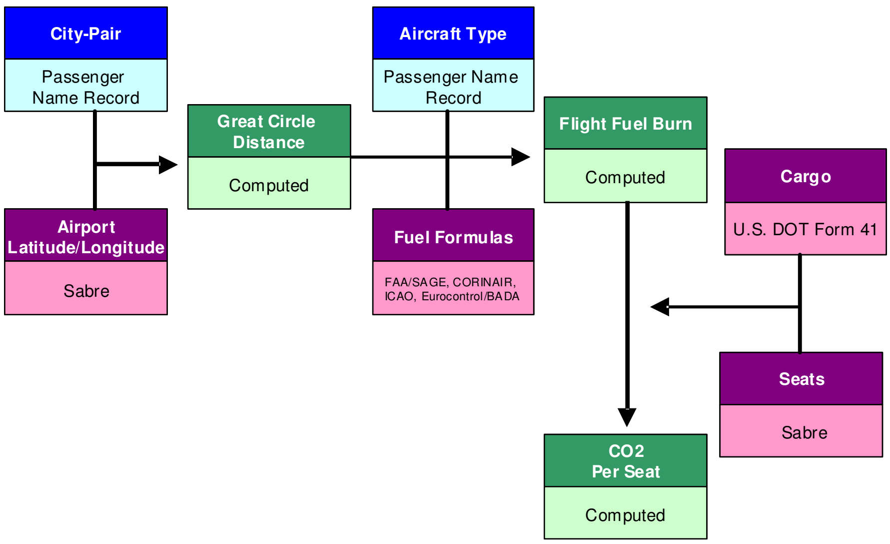


Figure 4 Schematic methodology utilised in the Sabre Holdings model

- The passenger name record provides the departure point and destination, and the distance between them can be calculated by a simple great circle calculation from known attitude and longitude coordinates. The extra fuel burn for stacking and deviations from great circle route is accounted for in SAGE, so no factor is applied here to model for this.

- The PNR also details the plane type used for the flight. The Sabre Holdings model has developed fuel burn formulas as a function of distance for each plane type. Therefore, using the appropriate formula, and inputting the flight distance calculated in Step 1, gives a fuel burn for the flight.
- The fuel burn per seat is then calculated. First emissions related to cargo are removed, based on data from US Form 41 traffic data. Second, fuel burn is allocated per seat. The Sabre Holdings model contains seating configuration data disaggregated by airline and plane model, based on data held in the Sabre Holdings reservation system.
- CO_2 emissions per seat can be calculated by multiplying by an emissions factor of 3.157 $kgCO_2$/kgFuel. It should be noted that this is CO_2 only, and does not include a multiplier for the additional climate impacts of emissions at altitude.

Advantages

There are many advantages of the Sabre Holdings model over conventional aviation CO_2 emissions calculators.

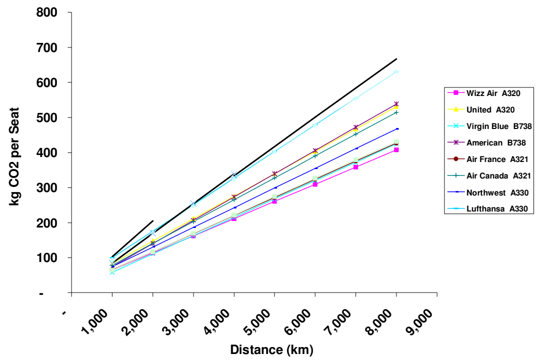
- Because the SAGE sub-model has fuel burn data for vast range of airplane types, it is not necessary to assume a ‘typical’ plane for the flight. Instead the characteristics of the actual plane can be modelled.
- Since the model uses the typical seating configuration by airline and by plane type, the calculated carbon emissions represent the efficiency of a particular airline more accurately. Thus, a two-class Boeing 777 operated by Continental Airlines has a different emissions profile per seat than a 4-class Boeing 777 operated on the same route by British Airways.
- Because the information is known months in advance when the flights are scheduled, CO_2 emissions can be calculated and displayed to the customer in advance. This will allow customers to incorporate the environmental impact of the flight into their purchasing decision. Furthermore, the extra detail in the Sabre Holdings model alters the decision making process around the environmental impact of a flight from one of ‘fly vs. don’t fly’ to one that is more sophisticated.
- Allowing customers to choose lower carbon flights should create a market pull towards more environmentally benign flights. This will encourage airlines to invest in capital equipment which promotes low carbon dioxide emissions per seat (e.g. efficient planes, high number of seats)
- Provides a tool for accurate pre- and post-trip corporate reporting of CO_2 emissions, whilst simultaneously providing the information required for the choice of low carbon flights.
- Allows comparison with the CO_2 emissions of other transport modes, such as rail.
- Provides a tool that could be used by offsetting companies, and removes the inaccuracies arising from methodological assumptions in current models. Because the Sabre Holdings model is more sophisticated than other aviation CO_2 emissions calculators, this could provide a potential unifying approach to calculator methodologies and remove the misleading variation between calculators that is observed today.

SUMMARY OF DIFFERENT EMISSIONS CALCULATORS

Table 1 Key features of different emissions calculators

Parameter	DEFRA	ICAO	ClimateCare[d]	Sabre Holdings
GCD correction	10%	Up to 11%	10%	Accounted for in FAA/SAGE
Plane type	Indicative short, medium, long haul calculated from range of typical aircraft	Uses aggregated data from model. Based on scheduled aircraft mapped onto 50 equivalent aircraft types	Indicative hybrid short and long haul (5 planes)	Scheduled aircraft mapped onto >200 equivalent aircraft types. Exact match 95% of time.
Fuel burn data	Corinair	Corinair	Corinair	FAA/SAGE
Form of emissions algorithm	$y=ax$, for domestic, short-haul and long-haul (0.180, 0.126 and 0.11 $kgCO_2/km$)	$y=ax+b$	$y=ax^2+bx+c$	$y=ax+b$
Freight factor	<1% domestic and short-haul 28.8% long-haul	47-88% depending on route and wide/narrow body. 34 classes	20% long-haul 0% short-haul	20% widebody 10% narrow body 1% regional jets
Per seat/passenger	Passenger	Passenger	Seat	Seat
Load Factor	65.3% domestic 81.2% short-haul 78.1% long-haul	67-100% depending on	n/a	n/a
Seating configuration	Representative from CAA data	Number of economy seats that can be fitted in cabin	Median	Specific to airline and aircraft model
Cabin class adjustment (economy:premium)	Range of ratios for different seat classes in domestic, short-haul and long-haul	1:2 based on space allocation	1:1.1 short-haul 1:1.5 long-haul	1:1.1 narrow body 1:1.5 wide body Based upon relative weight
Multiplier	No	No	Yes, 2, applied to ax^2 and bx terms only.	No, but may be applied to ax term.

[d] Aviation carbon calculator also developed in conjunction with ECI, University of Oxford



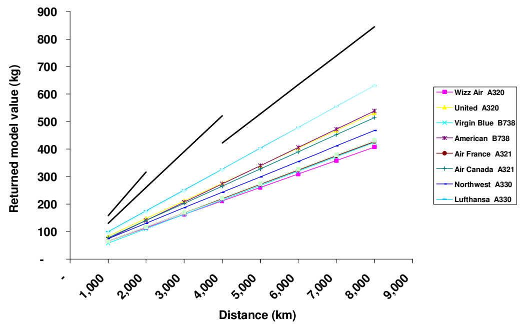


Figure 5 Comparison of results from SABRE Holdings methodology and DEFRA a) per seat and b) as reported b each model.

Figure 5 shows typical outputs from the Sabre Holding methodology for a range of planes, carriers clearly showing the range of emissions per seat that are possible due to different plane model and seating configuration.

Also shown on the same axes are the outputs from the DEFRA methodology. When converted to emissions per seat (Figure 5a) it can be seen that the outputs are consistent, although the DEFRA model gives values at the high end of the Sabre Holdings model range as it uses older aircraft types. It should be remembered that DEFRA report emissions per passenger (Figure 5b) so values returned by the DEFRA model will be higher than that seen in the Sabre Holdings model.

CORPORATE EMISSIONS REPORTING FORMATS

One of the most common uses of aviation emissions calculators is for corporate reporting purposes, as part of overall corporate social responsibility. This section details the most widely used reporting protocols and their approach to accounting for aviation emissions.

The Greenhouse Gas Protocol Initiative

The Greenhouse Gas Protocol (GHG Protocol) is the most widely used international accounting tool for government and business leaders to understand, quantify, and manage greenhouse gas emissions. The GHG Protocol, a decade-long partnership between the World Resources Institute and the World Business Council for Sustainable Development, is working with businesses, governments, and environmental groups around the world to build a new generation of credible and effective programs for tackling climate change.

It provides the accounting framework for nearly every GHG standard and program in the world - from the International Standards Organization to The Climate Registry - as well as hundreds of GHG inventories prepared by individual companies.

For transport emissions the GHG Protocol allows emissions to be calculated from either distance travelled or from the fuel burn and provides emissions factors accordingly. In the case of aviation, it is unlikely that fuel burn will be known by the passenger or reporting organisation, so a distance based methodology will be used in virtually all cases.

The GHG protocol uses emissions factors based on DEFRA's methodology, with emissions factors of 0.180, 0.126 and 0.11 kgCO_2/km travelled for short, medium and long haul flights respectively.[12] As noted above these simple emissions factors are a crude simplification (see Figure 2). The Excel spreadsheet does provide a series of more accurate emissions factors for flights of varying distance at a resolution of

300km which may be used instead. It should also be noted that DEFRA have since revised their emissions factors (see above).[9]

By contrast, the Sabre Holdings methodology would provide a more accurate measure of emissions, on a flight by flight basis, as a function of distance travelled. It would also allow the difference in emissions between different carriers and planes to be recognised, such that best practice can be rewarded. The GHG protocol has different emissions factors for different forms of road transport (e.g. hybrid, small car, medium car etc.) so environmentally conscious decision making is reflected here. In the aviation sector, all flights are calculated the same way irrespective of the efficiency of the plane and adopted seating configuration.

Being based on DEFRA's methodology, the GHG protocol is consistent with the Sabre Holdings model when reported on a per seat basis (See Figure 5a). However, the extra detail in the Sabre Holdings model exceeds the requirements established by the GHG Protocol allowing more sophisticated reporting. However, the GHG emissions factors are quoted on a per passenger basis (based on DEFRA), and it is recommended that these emissions factors are adjusted accordingly. The GHG Protocol recommends setting boundary conditions for reporting institutions where they have "financial or institutional control" over emissions. Reporting emissions on a per passenger basis allocates emissions from unfilled seats to passengers. However, the customer has no control on passenger load factor, so the GHG Protocol adoption of a 'per passenger' based methodology actually breaks its own reporting guidelines.

WRI

The World Resources Institute (WRI) is an environmental think tank aiming to motivate human society to live in ways that protect Earth's environment and its capacity to provide for the needs and aspirations of current and future generations. The WRI provides objective information and practical proposals for policy and institutional change that will foster environmentally sound, socially equitable development, and aids other institutions in delivering this agenda. Climate Protection is one of the key goals of the WRI and it has developed a calculator tool called 'SafeClimate' to enable individuals and institutions to calculate their carbon footprint.

The WRI uses a simple emissions calculator methodology using a flat emissions factor of 0.18 $kgCO_2$/km. This is applied to flights of all length and is based on the emissions factor for short haul flights used by the GHG Protocol Initiative, in turn derived from the DEFRA calculator methodology. Therefore, as stated above, the Sabre Holdings methodology meets and exceeds both the standard protocol required by the GHG protocol, when based on per seat emissions.

Global Reporting Initiative

The Global Reporting Initiative (GRI) is an organisation that has pioneered the development of the world standard in sustainability reporting guidelines. The GRI Guidelines are the most common framework used in the world for reporting, being used by more than 1000 organisations from 60 countries. Such organisations include corporate businesses, public agencies, smaller enterprises, NGOs, and industry groups.

THE GRI publishes a framework for reporting, based primarily around the Sustainability Reporting Guidelines, which detail both principles and indicators that organisations can use for reporting their economic, environmental, and social performance. The guidelines are constantly reviewed through a consensus-seeking process with participants drawn globally from business, civil society, labour, and professional institutions. The first version was released in 2000 and the guidelines are currently in their third version, known as the G3 guidelines.

The benefits of a single consistent reporting framework for sustainability are clear – it allows organisational performance to be compared with respect to each other, and against national and international laws, performance standards and voluntary initiatives. Reporting also demonstrates organisational commitment to sustainable development; and allows a monitoring of performance against these indicators over time

The GRI-3 guidelines[13] contain a series of protocols for reporting performance under 6 categories – economic, environmental, human rights, labour, product responsibility, and society. The reporting of CO_2 emissions lies within the environmental section, as does the reporting of material use, energy, water, effluents and waste. There are a total of 30 environmental protocols of which 17 are core (must be reported) and 13 additional (voluntary). The most pertinent for passenger aviation emissions is protocol EN17, covering indirect greenhouse gas emissions – that is greenhouse gas emissions that arise from business practice but where the business does not own the source of those emissions (*i.e.* business flights cause emissions, but the airline owns the plane).

Under EN17, reporting organisations are required to:

- Identify the greenhouse gas emissions resulting from indirect energy use.
- Additionally, identify which of the reporting organisation's activities cause indirect emissions and assess their amounts (e.g., employee commuting, business travel, etc). When deciding on the relevance of these activities, consider whether emissions of the activity:
- Are large compared to other activities generating direct emissions or energy related indirect emissions (as reported in EN16);
- Are judged to be critical by stakeholders;
- Could be substantially reduced through actions taken by the reporting organisation.
- Report the sum of indirect GHG emissions identified in tonnes of CO_2 equivalent.

However, EN17 does not provide a methodology for calculating these emissions, noting only that "Information can be obtained from external suppliers of products and services. For certain types of indirect emissions such as business travel, the organisation may need to combine its own records with data from external sources to arrive at an estimate". Therefore no coherent methodology exists for use by all reporting organisations. They are however referred to the Greenhouse Gas Protocol (see above)

The advantages of Sabre Holdings over the GHG protocol have already been noted, and therefore similarly apply here. Again, the Sabre Holdings model could provide a coherent reporting framework for organisations, allowing comparison between them, and rewarding a shift to fewer or lower carbon flights. Application of the Sabre methodology would be considered suitable for GRI-3 reporting purposes, which makes no definitive recommendation on adopted methodology.

Carbon Disclosure Project

The Carbon Disclosure Project is an organisation which works with shareholders and corporations to disclose the Greenhouse Gas Emissions of major corporations. The CDP works with 3,000 of the largest corporations in the world, including large emitters such as electricity generators and blue chip financial investment companies. The CDP therefore covers institutions responsible for 26% of global anthropogenic emissions and with $57 trillion under management. The influence wielded by the participating institutions is seen as vital in encouraging organisations to measure, manage and reduce emissions and climate change impacts.

The CDP has started towards establishing a globally used standard for emissions and energy reporting, though this is based on the Greenhouse Gas Protocol, rather than being developed in house. As with other reporting initiatives it allows benchmarking of emissions, comparison with other organisations, and progress over time to be tracked under a consistent calculation methodology. It also provides a visible demonstration of their commitment to carbon disclosure and emissions management to a wide range of stakeholders

Under the CDP, all companies are encouraged to report their emissions data using the Greenhouse Gas (GHG) Protocol (see above): the most widely used international accounting tool in respect of emissions and one which global governments and industrialists are familiar with.[14]

As noted above the GHG protocol is somewhat limited in terms of the sophistication with which it reports aviation emissions, and that the Sabre Holdings methodology could offer significant advantages in the accuracy with which emissions are reported, and more accurately reflect institutional practice by opening up the choice of low carbon versus high carbon flights.

POTENTIAL FOR ADOPTION OF SABRE HOLDINGS' CALCULATION METHODOLOGY

Potential for Adoption by Offset companies

Carbon calculators form an essential part of the business of offset companies, in order to determine the amount of carbon to be offset and the amount of revenue raised for projects. Many different carbon calculators have been developed by individual offset companies for their own needs but companies make a different set of assumptions in their methodology and use different data sources. The methodological approach is broadly identical across different calculators (See Figure 1), but varies in the following ways:

- Quality and breadth of input data. A series of key assumptions are made within calculator methodologies due to the simplicity of the input data. For most calculators this is simply the departure point and destination, which can be converted into a distance. Assumptions must then be made about the type of plane that is likely to undertake a flight of that length, the seating configuration on board and proportion of emissions allocated to freight. Even using a hybrid of many plane types still leaves assumptions and averaging issues, and even the best models are not capable of capturing the difference between an 'efficient' and 'inefficient' flight over the same route.
- Subjective approaches. Some differences in calculator CO_2 methodologies may be viewed as subjective differences in approach. This is most notable when considering whether to allocate emissions on a per seat or per passenger basis. It is also an issue when allocating emissions between premium and economy seats on either a weight or space basis. In a wider climate change context, the use of multiplier to account for non-CO_2 effect remains highly contentious and as yet there is neither an agreed value for which metric to use nor what its value should be.

The inconsistency between emissions calculators has been recognised, as has the impact of this inconsistency on consumer confidence in the offsetting industry. Wide variations in CO_2 emissions for the same flight between offset providers is confusing for clients, despite being entirely valid if one were to dissect the nuances of the methodology. The carbon offset industry trade body ICROA recognises the need for more consistency. It declares *"that there are currently different approaches to calculating air travel emissions …. ICROA commits to developing a consensus … through an international, collaborative and transparent process".*

Similarly the International Civil Aviation Authority recognises the need for consistency and has attempted to create this by developing its own calculator. However, whilst the calculator has many strong features, especially in terms of breadth of input data, it does not definitively solve the underlying causes of inconsistency outlined above. As such ICAO's calculator could be viewed as just another calculator on the market unless widely adopted by the offset industry. Similarly DEFRA's attempt to achieve consistency by developing its own methodology has arguably resulted in a calculator that is less sophisticated than many used by offset companies, by reducing emissions down to simple emissions factors for domestic short and long haul flights.

The Sabre Holdings methodology does have the potential to solve the issues of inconsistency by providing emissions calculated from exact plane types and seating configurations. The quality and breadth of data issue could be resolved by adoption of Sabre Holdings technology.

However, subjective differences between methodologies would remain, and further industry consultation would be needed to address the issue of seat/passenger emissions allocations and the use of a multiplier. The involvement of both ICAO and ICROA in promoting this are key to the adoption of the sophisticated methodology that Sabre Holdings provides.

Potential for Adoption for Reporting Purposes

Corporate reporting strategies such as the Carbon Disclosure Project or GRI each recommend the use of the Greenhouse Gas Protocol for reporting of emissions. For aviation, the GHG Protocol uses emissions factors based on DEFRA's emissions factors of 0.180, 0.126 and 0.11 $kgCO_2$/km travelled for short, medium and long haul flights respectively.

This paper has criticised the DEFRA methodology for its approach of reducing CO_2 emissions calculator to a series of 3 emissions factors which is an oversimplification when compared to other calculator methodologies. However, the major criticism of using a simplified calculator for emissions reporting purposes is that it does not capture the behavioural change that could be achieved by institutional change. At present, a flight between 2 locations would be identical irrespective of plane used, seating configuration, carrier etc. An institution looking to reduce its emissions and see this reflected in its company reporting has only one choice – to fly or not to fly. An institution can therefore only change its level of service, but not the efficiency of its transport choices. In a wider context, encouraging the adoption of more efficient means of transport by travellers is vital, as is the market and technological pull towards lower carbon aircraft and seating configurations it creates.

The Sabre Holdings methodology is sufficiently detailed that it can provide this information. Should Sabre Holdings be adopted for reporting, an institution would then face two decisions – is this flight necessary and if it is, what is the lowest carbon carrier to use for the flight. This greater level of detail would allow an institution to reduce emissions for the same level of transport service – an important factor when many institutions still have no operational choice (*e.g.* teleconferencing) other than to fly.

However, widespread adoption of the Sabre Holdings methodology is likely to require a change in the way companies undertake their emissions reporting – which is a potential barrier to adoption. It is envisaged that the CO_2 footprint of a flight will be made available at the point of purchase, so the reporting institution ideally needs to capture this information at this point. At present, using calculators that are not flight specific, emissions can easily be calculated retrospectively. It is possible that Sabre Holdings could make historic flight emissions data available, so that emissions could be calculated retrospectively. Logging and reporting companies could also find a niche to undertake this service for reporting institutions.

In order for the advantages of the Sabre Holdings methodology for reporting purposes to be realised, there are two critical factors. First, the reporting initiatives would need to accept and recognise that the Sabre Holdings calculation methodology meets and exceeds their standard requirements – and the GHG protocol which is the recommended reporting format by other initiatives has a critical role to play here. Second, a cultural change would be required within reporting institutions with regards the sophistication of their own internal emissions recording, as well as an institutional change towards the use of lower carbon carriers and flights.

CONCLUSIONS

The Sabre Holdings model is based on a wide range of high accuracy input data, allowing the calculation of emissions from a single flight, depending on carrier, plane type and seating configuration. As such this is the most detailed aviation carbon calculator in existence capable of providing emissions information to clients at a higher level of accuracy than before.

This higher level of accuracy also allows new decision making processes to be adopted by individuals and institutions. Existing aviation carbon calculators which give information about a 'typical' flight over a given route will give the same CO_2 emissions irrespective of the efficiency of the plane or number of seats on board. Clients wishing to see a reduction in their calculated CO_2 are reduced to a choice of 'fly' *vs.* 'don't fly'. Provision of more accurate emissions data allows clients to choose the lowest carbon flight, should they decide that the flight is necessary. This in turn should create a market pull for low-carbon flights, with airlines adopting more efficient planes with denser seating configurations.

The Sabre Holdings model has the potential to be adopted by both aviation offsetting companies and for corporate social responsibility reporting. At a point when there is a demand for greater consistency between carbon calculators, so as not to confuse the market, the development of a detailed, high accuracy carbon calculator is exceedingly timely.

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