Train or plane, ethical and policy choices

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The Issues

- Aviation currently represents around 2% of total CO_2 emissions[1]. Emissions from aviation are growing faster than any other source[2]. There is currently a contradiction between the EU and its Member States' rhetoric towards tackling climate change and its policies facilitating the aviation industry.

- In an age of man-made climate change we need to consider feasible alternatives to air travel as well as the amount we travel. Here we shall examine the environmental impact, in terms of CO_2 emissions, of train travel and compare it to medium and short-haul flights.

- Counting aviation emissions is notoriously complex; often slightly changing the unit of measurement can significantly affect the message figures present. Understanding the complex and often contradictory information available is essential to tackle the growing threat of climate change. For clarity, the unit of CO_2 g (or kg) per passenger kilometre (pkm) will be used throughout this paper.

[1] Committee on Climate Change (CCC) http://www.theccc.org.uk/topics/global-targets/international-aviation
[2] European Commission as quoted by the BBC http://news.bbc.co.uk/2/hi/science/nature/6955009.stm

1. How bad is flying compared to train travel?

Flying is considerably worse for the environment not only in terms of CO_2 emissions but also because of the effects they have due to the altitude they are released at. This is combined with the other greenhouse gases (GHG) that aviation release.

Train travel is normally a greener option than flying. This is different however from saying it is green. For as long as train travel is dependent upon fossil fuels it will continue to contribute to climate change.

There are a number of issues which will not be addressed in this paper such as travel to airports/train stations and other operational emissions such as building infrastructure and maintenance.

A direct comparison between flying and train travel is complicated by the number of variables which have to be taken into consideration. These include:

Flying:
- Non- CO_2 emissions
- Aircraft model
- Occupancy rate
- Seat class
- Fuel used for cargo or freight
- Fuel used as a result of detours and delays

Rail:
- Diesel or electric powered engine
- Energy mix fuelling the trains' network

Each will be addressed in turn.

2. Counting CO_2 in air travel

Estimates of CO_2 emissions from aviation vary from 98.3g[3] through to 175.3g[4] pkm within just one methodology. For a wide range of reasons a number of organisations[5] have tried to calculate aviation CO_2 emissions using a number of different methodologies. To illustrate why they come to such varying conclusions this paper will aim to explore the different methodologies they use to deal with the above variables.

2.1 Accounting for non-CO_2 emissions (such as nitrogen oxide, carbon monoxide and water vapour)

Laurie Michaelis from the Living Witness Project[6] comments:

Aircrafts also emit nitrogen oxides and water vapour …which at high altitude has a large contribution to global warming. The impact is very uncertain. In the Intergovernmental Panel on Climate Change [IPCC] report on Aviation and the Global Atmosphere, NOx [Nitrogen Oxide] *and linear contrails were each estimated to have an impact of a similar order of magnitude to that of the* CO_2.

There is no consensus on how to account for other GHG emissions emitted by aviation. There is consistency within mainstream science that the effects of contrails specifically are uncertain. This is how a few organisations have chosen to interpret the science around non-CO_2 emissions:

Organisation	**Response to how to calculate non-CO_2 emissions**
Department for Environment Food and Rural Affairs (DEFRA),UK	Acknowledges that other gases affect climate warming but suggests that it is impossible at the moment to calculate an exact multiplier
Virgin Atlantic (US)	Does not account for non-Co2 emissions[7]
IPCC	Suggest a multiplier of 2.7 with a range of 2-4
Atmosfair,German carbon offset company	Applies a multiplier of 3 for any emissions above 9,000 metres and a multiplier of 1 for emissions below 9,000 metres
TRX travel analytics, on-line carbon calculator	Uses a multiplier between 1 and 2.7

2.2 Accounting for the aircraft model

The aircraft model directly affects the fuel efficiency, the number of seats and the amount of cargo it holds and therefore its CO_2 emissions.

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[3] DEFRA (2008) *Guidelines to Defra's GHG Conversion Factors: Methodology Paper for Transport Emission Factors,* DEFRA, London

[4] DEFRA (2008) *Guidelines to Defra's GHG Conversion Factors: Methodology Paper for Transport Emission Factors,* DEFRA, London

[5] This will be roughly based on the paper; Kollmuss, A and Lane, J (2008) *SEI working paper, Carbon offsetting and air travel, part 1: Co2- Emissions Calculating,* Stockholm Institute, Stockholm

[6] The Living Witness Project is an organisation set up to help Quakers incorporate sustainable living into their and their communities' lives, see http://www.livingwitness.org.uk/aboutus.html for more information

[7] According to SEI report

Organisation	How they account for different aircraft models
DEFRA	Uses an average from a number of aircrafts
Virgin Atlantic	Uses its own data from its own aircraft
Atmosfair	Optional, uses fuel burn rates from 47 different aircrafts
Jardine (2009) academic paper	Estimates that there could be as much as a factor of 2 in different fuel rates between models
TRX travel analytics	Uses a burn rate from over 180 different aircraft models

2.3 Accounting for the occupancy rate of the aircraft

The more people an aircraft carries (assuming you are looking at emissions per person) the more efficient it becomes. Therefore occupancy affects the CO_2 pkm.

Organisation	How they account for occupancy rate of the aircraft
DEFRA	They take a rate of 66.3, 81.2 and 78.1 % for domestic, short-haul and long-haul respectively[8]
Virgin Atlantic	Does not account for occupancy rate
Atmosfair	Averages are used; within Germany 60%, within the EU 62% and international flights 75% (charter flights at 80%)
AEA (Association of European Airlines)	Reported an average passenger load rate (PLR) of 82.2%, PLR rates tend to be about 12% lower on short-haul flights[9]
TRX travel analytics	Airline specific data used where available.

2.4 Accounting for the seat class

If you want more leg room and a bigger seat you limit the capacity of the plane and thus increase the CO_2 pkm[10]. Thus, seat class affects emissions.

Organisation	How they account for seat class
DEFRA	Emissions are allocated between economy and premium class
Virgin Atlantic	Emissions are divided between four different seat classes
Atmosfair	Uses a multiplier of 0.8 for economy class, 1.5 for business, 2.0 for first class
TRX travel analytics	Uses a multiplier of 1 for economy, 1.13 for premium economy, 2.04 for business and 2.69 for first class

2.5 Accounting for fuel used for cargo or freight

Additional cargo adds significantly to the amount of CO_2 produced per flight. It follows however that this should not be distributed amongst passengers if we are working out an equitable system. There are a number of ways that have been produced to subtract or account for these extra emissions.

Organisation	How they account for extra cargo or freight
DEFRA	Uses a system that uses the CAA (Civil Aviation Authority) data and works out that each passenger accounts for approximately three times their actual luggage and body weight. They call it the Equivalent Freight Weighting Option.

[8] There were a number of contradictory sources available for DEFRA and so I have used the most recent (Feb. 2009) from Jardin 2009 *Calculating the Carbon Dioxide emissions of flights*

[9] European Environment Agency 2008 *Climate for transport change*

[10] Although extra passengers would add to the total CO_2 emissions due to extra weight, it is far more efficient to move a set number of people on one flight than it is for multiple flights. When working out Co2 pkm, the more people there are equals the more you divide the CO_2 by.

Virgin Atlantic	Emissions are assigned to weight, the exact methodology is unknown
Atmosfair	Assumes an average cargo load of 8%, and a passenger luggage body weight of 220 lbs; this results in an extra 2% marginal fuel increase due to cargo which is then subtracted from the total.
TRX travel analytics	Flight specific data when available; if not, averages are used

The weight of the cargo, however, is significant as the fuel used is directly correlated to the weight of the cargo.

2.6 Accounting for additional fuel used as a result of delays or detours

During takeoff more fuel is used than when cruising[11]; changing altitude because of bad weather, circling before landing, or any other detour for whatever reason affects the overall emissions. This is complicated however by the emissions being released at altitude being more damaging. Although planes are at their most efficient when cruising at altitude the emissions released are more damaging than when released at lower altitudes.

Organisation	Their response
DEFRA	Adds 9% for uplift. They take into account indirect flight paths and delays.
Virgin Atlantic	This is not applicable as they use direct fuel consumption from their planes.
Atmosfair	Adds 1kg of fuel per passenger for holding delay and 2.5kg for taxiing. Also adds 50km to each trip for re-routing.
TRX travel analytics	Adds multipliers per 1000 miles of: US domestic flights: 1.07 Intra-European flights: 1.10 Other short-haul: 1.085 Long-haul flights: 0.01

[11] This is a reason why short-haul flights are so bad for the environment

3. Counting CO_2 in train travel:

CO_2 emissions for trains are slightly easier to calculate, but still hold significant variations. Estimates of emissions for train travel vary from 6g pkm (electric trains that are run on predominantly nuclear energy in France[12]) to 100g pkm for the UK underground[13] [14]. The main reason for variation in CO_2 output is whether it is run from electricity or diesel.
Data around occupancy rate is a lot harder to access than it is for air travel. This is partly explained due to the poor recording system of passenger numbers and information on trains, especially compared to air travel.

3.1 Diesel or electric engine

From an academic perspective it has proved much harder to find data on carbon counting for trains than it is for air travel. DEFRA however provides a reasonable section in their methodology paper. They conclude:

- International Rail (based on the Eurostar) uses 17.7g pkm
- National Rail (based on Dept. for Transport Network Modelling Framework) 60.2g pkm.

Their estimate on international travel is not applicable to all of Europe as it depends on the electricity mix that fuels the electric high speed train network. It also depends on another number of variables such as the ticketing system, for example Eurostar ensures a high occupancy rate by using a reservation only system.

We can broadly conclude that electric trains will be more efficient than diesel trains; this is dependent however upon the energy mix used to produce electricity. This conclusion can not be applied universally; for example, areas of Eastern Europe that are reliant on predominantly fossil fuels by encouraging electric trains could add demand to polluting electricity production.

3.2 Energy mix fuelling the train network:

If the train is powered by an electric engine then the emissions are dependent on the mix of fuel used to produce the electricity.

Examples of different countries' electricity mix:

Country	**Nuclear**	**Renewables**	**Solid Fuels**	**Gas**	**Oil**	**Other**
Austria	0%	62%	11%	19%	3%	5%
Belgium	46.5%	4%	6.85%	25.39%	1.38%	1.55%
Cyprus	0%	0.02%	0%	0%	99.98%	0%
Czech Republic	26.05%	3.53%	49.65%	4.17%	0.26%	0.71%
Denmark	0%	10.06%	24.65%	9.43	1.61%	0%
France	79%	11%	4%	4%	1%	1%
Germany	26%	12%	42%	12%	2%	6%

[12] SCNF web-site
[13] Estimate from Laurie Michaelis from the Living Witness Project
[14] The London underground is exceptionally inefficient due to the air pressure in the very tight tunnels

Ireland	0%	9%	29%	51%	10%	1%
Latvia	0%	57%	0%	42.9%	0.1%	0%
Netherlands	4%	10%	24%	59.43%	2%	0%
Poland	0%	3%	91%	3%	2%	1%
Spain	20%	17%	22%	30%	8%	3%
Sweden	46.7%	50.2%	0%	0.9%	1.2%	0.4%
UK	19%	5%	38%	36%	1%	1%

Source:
ec.*europa.eu/energy/strategies/2008/doc/2008_11_ser2/strategic_energy_review_wd_future_position1.pdf*

The SCNF web-site claims that French electric trains operate on just 6g of CO_2 pkm. Although this figure is an industry figure so can be assumed to be optimistic, we can see that the French electric rail system would be a lot more efficient than if Poland electrified its rail infrastructure. These considerations must be taken when considering the development of clean travel alternatives. There is a need for cleaner electricity mix alongside a reduction in demand.

There are other contentious arguments around the expansion of electric high speed trains. There is an issue of high speed trains being more energy intensive the faster they get. It is apparent however that perhaps the more pressing concern may be that they will encourage the regular travelling of medium distances. It is apparent that a lot of the current thinking is based around how to best meet demand for travel rather than trying to reduce the demand. We should approach high speed trains with a degree of caution for they are not low carbon per se but they could provide an alternative to some short haul flying.

4. Examples comparing flying to train travel:

These examples do not include additional emissions such as the travel to the airport. Nor do they include other emissions such as the construction and maintenance of infrastructure, the manufacturing of planes/trains or the staff costs etc.

Example 1 - From Paris to Madrid return:

Flying:

Estimates vary from 177kg through to 936kg.

Organisation	CO_2 estimates for a return flight from Paris to Madrid
Atmosfair	620kg of CO_2
Virgin Atlantic	N/A
TRX Travel Analytics	Business Class: • 347kg with Air France (936kg with RFI multipliers) Economy Class: • 177kg with Air France (477kg with RFI multipliers)

Time taken to fly: Around 2 hours (plus travel to the airport and 2 hours check in time)

Train:

Based on a personal calculation using approximately a 2,600km round-trip multiplied by the SNCF 6g of CO_2 pkm, equates to approximately 15.6kg. If you take a similar distance journey in a country with a more carbon-intensive electricity mix such as the UK it becomes considerably more. An electric train in the UK uses approximately 50g of CO_2 pkm. In the UK a 2,600 km trip on an electric train would emit close to 130kg of CO_2.

Time taken to travel by train: The most relaxing option is to get the overnight sleeper train.

Example 2: London (Gatwick) to Marrakech return:

Flying:

Estimates vary from 280 kg through to 1,543kg per passenger trip

Organisation	CO_2 estimates for a return flight from London to Marrakech
Atmosfair	1,220kg
Virgin Atlantic	Economy Class: 484kg Business Class: 1,489kg
TRX Travel Analytics	Business Class: • 572kg with Air Maroc (1,543kg with RFI multipliers) Economy Class: • 280kg with Air Maroc (756kg with RFI multipliers) • 510kg with Air Artic (1,377kg with RFI multipliers)

Time taken to travel by air: Around 4 hours (plus 2 hours check-in time and travel to the airport)

Train:

This route is based on the recommended route from www.seat61.com and uses an adaptation of the DEFRA methodology.

The Route:	**CO_2Emissions**
London to Paris Eurostar	10.9 kg
Paris to Madrid by trainhotel	15.6 Kg[15]
Madrid to Algeciras	76.6 kg[16]
Algeciras to Tangier by ferry	1.8 kg[17]
Tangier to Marrakech by train	70 kg[18]
Total	**177.9 kg**

Time taken to travel by train: Obviously this option would take considerably longer than the flying alternative, at an estimate it would take around 3 or 4 days.

What issues do these examples raise?

We can see from these examples that:

1) As the distance gets further it is much harder to calculate accurate emissions as the variables are multiplied and accurate figures become harder to come by. The multiple changes due to a fractured rail service make calculations difficult. There is an argument to take an EU average energy mix but this would not reflect individual policy development at Member State level. Calculations vary significantly across Member States.
2) Even if you do not add non-CO_2 emissions into your figures, it is essential to be aware of them, as if you ignore them, it can make flying look a lot more appealing for your environmental credentials that it might actually be.
3) On a number of short-haul flights it is quicker to take the train. With the expansion of the high speed rail network across Europe this is likely to become the case in even more scenarios. It is clear however, that across distances of more than three or four hundred kilometres, flying is normally faster.

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[15] A journey length of 2,600 km, multiplied by the SNCF web-site figure which claims to transport customers for just 6g pkm would result in **15.6kg** of CO_2 pkm

[16] Figures became increasingly hard to come by: We assume you can travel 400 kilometres to Cordoba on a high speed electric train and then a further 290 km to Algeciras on a diesel train. We will work out the high speed train to Cordoba on roughly 45g pkm (as Spain is a lot more reliant upon oil and gas than France) and for the normal train, assuming it has a normal diesel engine, we will use the average of 70g pkm. This means it is (45g pkm x 400 km) =18000g + (70g pkm x 290 km) 20300g = 38300g (38.3kg of CO_2 pkm), double it to make it a return = **76.6Kg** CO_2 pkm.

[17] This section is on ferry (I take the industry figure of 12g of CO_2 pkm which I acknowledge is optimistic). For an approximately 80 km crossing, that would be 960g or 0.9kg of CO_2 which doubled is **1.8kg**

[18] 500 kilometres with a 70 g pkm average

5. Travel and personal travel allowances?

If we look at how these figures fit into a wider sustainable lifestyle we can see the true cost of aviation and also travel on our personal CO_2 emissions. Few would suggest that the developed world has the right to travel or pollute more than anyone else, thus a series of equitable carbon allocation systems have been produced. These estimate what a sustainable CO_2 allowance per person would be. A few organisations' suggested personal carbon allowances are listed below.

Organization	Suggested annual CO_2 per person
Council of the European Union	2 tons by 2050
Fair shares, Fair Choices	3.92 tons for 2009 down to 2.87 by 2017
The Campaign Against Climate Change	3.28 tons in 2009 with a 10% decrease year on year

We can see by comparing current averages that we are far from a sustainable situation. These are the current CO_2 equivalent emission averages:

Country	Current average annual CO_2 equivalents emissions per person
UK	11.5 tons
USA	21 tons
India	1.3 tons
Global	5.8 tons[19]

Source: Living Witness Project http://www.livingwitness.org.uk/

If we take a conservative allowance for 2009 of around 4 tons to be reduced to 2 tons by 2050 we can see that any medium to long-haul flight instantly takes up a significant section of this personal carbon allowance. When combined with the other major contributions to our CO_2 footprints such as other transport (commuting), energy in your home, food, materials and waste we can see that there is little chance of flying annually in a sustainable world if these calculations turn out to be true. For more information on sustainable living and personal carbon calculations see the Living Witness Project (http://www.livingwitness.org.uk/).

[19] Although a recent study has put this figure closer to 9.9 tons, see http://www.uea.ac.uk/env/research/reshigh/unexpected accessed 19/05/2009

6. Policy Recommendations:

Understanding the complexity of carbon counting needs to be conceptualised at both a personal and policy level; often claims for environmental credentials are based on misleading carbon calculations. It is essential for policy makers to be able to distinguish between what is greenwash and what is progressive environmental policy. From a personal perspective it essential to have a knowledge around carbon counting to be able to be able to understand carbon offsetting schemes and to make educated travel choices. From this brief paper we can draw a few policy recommendations that should be adopted with a sense of urgency to help consumers and policy makers move Europe into a positive position for tackling climate change.

1) More information should be made available in a comprehensible medium on the environmental impact of all modes of travel including train and aviation to ensure easy comparison for concerned consumers.
2) There needs to be greater cooperation between Member States and train operators to ensure easier travel through the EU.
3) This network needs to incorporate major air hubs to try and discourage link flights for relatively small distances. The use of coaches and other low carbon alternatives should be examined further.
4) Aviation fuel should be taxed substantially to discourage the use of short haul flights from an economic point of view. This should be undertaken alongside the scaling down of need for short-haul aviation.
5) The use of personal carbon allowances should be explored further to help individuals and policy makers facilitate the reduction of travelling in a fair and equitable way. This may be a more just way of enabling individuals to travel in a scenario where there will be an inevitable dwindling of flights and travel opportunities.

Essential Reading:

Jardine, C.N. (2009) *Calculating the carbon dioxide emissions of flights.* Environmental Change Institute, University of Oxford, Oxford

Givoni, M and Banister, D (2008) *Reinventing the wheel- planning the rail network to meet mobility needs of 21st century,* University of Oxford, Oxford

Kollmuss, A and Lane J. (2008) *SEI working paper, Carbon Offsetting and air-travel. Part 1: CO2-Emissions Calculations. Up-dated version.* Stockholm Environment Institute, Stockholm

Some useful web-sites:

http://www.atmosfair.de/index.php?L=3
http://carbon.trx.com/
www.carbonneutral.com
www.eurostar.com
http://www.virgin-atlantic.com/en/gb/bookflightsandmore/carbonoffset/index.jsp
http://www.sncf.com/en_EN/flash/#/CH0006/BR0521/
www.seat61.com/Europe.htm