United in the Interests of British Air Line Pilots

BALPA

Aviation and the Environment

The Pilots' Perspective

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Foreward by the Chairman of the British Airline Pilots' Association

I have been flying for over 30 years, and each flight reminds me of the beauty of our planet. I recognise that I am privileged to see it from a special vantage point and most of us who operate aircraft never lose this sense of awe. Many of us have children and care deeply that they, and their children, can grow up to see our planet similarly in all its glory and confident that climate change is not out of control.

But as a pilot I also deal in facts and complexity. It is what pilots do. And it both saddens and infuriates me that aviation has become the "bête noire" for environmental damage when it so clearly is only a part – and a small part at that. Singling out aviation as a key contributor to climate change does not really take the discussion very far.

The contributors to greenhouse gases and climate change are many and varied and by focusing on aviation and dealing in misinformation we are ducking the painful reality that there are much more fundamental issues that need to be addressed, such as how we each act as citizens.

BALPA has produced this booklet for 3 main reasons.

Firstly, to put the debate into context; to give some facts about aviation and to look at how we have always played our part environmentally. For instance in my early days on the flightdeck I used to taxi to the runway behind aircraft spewing out filthy exhaust; I now see it much less, clean engine technology has reduced it by 90% in 40 years and will in due course eradicate it all together.

Secondly, to look at some of the policy and operational options that will help control our contribution to environmental damage. The holding patterns and congestion we all experience mean that we are prolonging fuel burn and emissions. We need to improve our co-ordination and expand our infrastructure sustainably. As a pilot I also watch the snake like snarl of cars trying to access airports through want of decent public transport access and am acutely aware that they are causing far more damage than the aircraft I am operating.

And thirdly, to engage people on the issue. We hope to stimulate debate amongst our own members, their colleagues operating in other countries, the industry at large – especially those in air traffic control, engineering and operations – policy makers and politicians. We know we have a part to play but we want practical and "joined up" solutions that enable aviation to continue to be a source of social and economic advancement, equality and great pleasure for the many, many people who I and my colleagues transport to the corners of this beautiful planet.

We welcome feedback to beautifulplanet@balpa.org. Drawing on this feedback we will later this year produce a further booklet on an agenda for change in aviation.

Captain Mervyn Granshaw

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Executive summary: Aviation and The Environment: The Pilots' Perspective

Since the mid–1990s, the air transport industry has been under attack, mainly by environmentalists. The reason? Because, it is claimed that aircraft are a major, if not the major, cause of greenhouse gases in the atmosphere. Behind this assault on the industry lie many misconceptions about the nature of air transport, the financial, social and economic contexts in which it operates and its impact on local and national territories. This attack has made it relatively easy for the UK Government to double airline passenger tax with scarcely a murmur from the public.

There is a view among environmentalists, and even some policymakers it seems, that the answer to the very real problem of aircraft carbon emissions is to 'tax and ground' air travel and air transport. So the argument goes that if there is less air travel, if there are fewer cargo flights, then this would make a massive difference to the growth of greenhouse gases and even forestall global warming. This drastic step would in fact achieve very little, and would be highly damaging to the global economy. Paradoxically, it would also inhibit some of the improvements in environmental care in developing and less developed countries.

The air transport industry is growing around the world, and it is growing because it is needed. It supports tourism and international trade. It also supports the development of many countries in the Third World and those that are industrialising. In the UK it plays a vital part in connecting the UK economy to that of the rest of the world. It plays a significant part in attracting business and investment into the UK, and it also plays a role in maintaining London's position as one of the major financial centres of the world.

Two of the biggest misconceptions about the air transport industry are:

a) That it is a bigger polluter of the environment and the atmosphere than other modes of transport, and
b) That it is highly subsidised.

Both these notions are myths. When we really examine the facts about air pollution it rapidly becomes apparent that air transport is a minor pollutant compared to other forms of transport and other industries. This is not to say that we should disregard the environmental impact of the airlines. Never have we said that, and it is not our contention now. We do take aviation's environmental footprint seriously. But there are other, bigger, footprints out there. These all need to be addressed.

On the question of subsidies it is argued that aviation benefits from having zero tax on fuel and zero Value Added Tax (VAT), unlike other transport sectors which are taxed. Therefore, this logic states, air transport is not constrained and will grow uncontrollably. This is a weak argument which is based on at least one omission. The main omission is the fact that aviation pays its own infrastructure costs entirely. The argument about fuel tax and VAT is designed to give the impression that other transport modes pay high taxes. In reality they pay zero or nominal fuel taxes, which are often rebated through a complex series of grants. In fact, aviation makes a net contribution to the public purse. In the UK, for example, the airline industry made a net contribution to the Exchequer of €659million in 1998. Since

then, with the doubling of air passenger tax, its financial contribution to the public purse has grown enormously.

In addressing the environmental footprint of the airlines, it is essential to consider it in context. Climate change has a number of causes. Many of the other modes of travel that compete with air transport are, according to much scientific research, more polluting than aircraft, both in overall noise and emissions. So encouraging people to switch from air travel to rail, coach or sea transport (even if that were practicable) would be counter-productive in trying to reduce atmospheric emissions. In many of the arguments about the airline industry there is an intellectual laziness. Its critics have not thought their case through. More than that, as our report shows repeatedly, many of its critics have not even looked at all the facts. Many of their arguments do not stand up to the scientific evidence.

Yet, having said that, we recognise that the environmental impact of the aviation industry is an important subject. Indeed it is one that the aviation industry has taken quite seriously. The aviation industry has made great strides in reducing noise and air pollution. It has also become much more fuel efficient, improving fuel consumption by 70%, which in itself has environmental benefits. It has in addition also reduced gaseous emissions such as CO_2 and hydrocarbons by 50% and 90% respectively.

Yet the industry wants to do more to reduce its environmental impacts. It has itself set research goals for improving fuel efficiency as laid out by the Advisory Council for Aeronautical Research in Europe. The targets are challenging:

- To reduce fuel consumption and CO_2 emissions by a further 50%
- To reduce perceived external noise by a further 50%
- To reduce oxides of nitrogen by a further 80%
- To make substantial progress in reducing the environmental impact of the manufacture, maintenance and disposal of aircraft and related products to be done in an environmentally sustainable way.

Also, in our report we consider various operational and technical solutions to reduce emissions. Taking a more integrated approach to air traffic control and dealing with congestion and capacity shortages are key elements in mitigating aviation's environmental footprint. However, as we show the issues here are not simple. We also argue that fuel efficiency and capacity utilisation provide the best operational solution.

A key message of our report is that we need a global solution to deal with the growth in global carbon emissions. One possibility would be ring-fenced taxation, i.e. taxes would be collected from air transport and channelled into directly mitigating its environmental impacts. In the UK, the £2 billion plus now collected in APD could be used more intelligently. For example, it could fund either public transport infrastructure near airports to minimise car use and thus emissions. Alternatively it could fund a massive research programme at key universities to bring forward new technology. Yet on balance we do not believe that such a tax would work.

The real solution lies in incentivising air transport to deliver better operational performance and to develop technical solutions. This means introducing a market mechanism which operates automatically to curb emissions, by encouraging these dynamic processes. What

we are suggesting is that the EU Emissions Trading System (ETS) could be used globally and overseen by ICAO would deal with the air transport industry's environmental impact. There are various ways in which emissions trading could be introduced, and it raises the following questions:

- Should the airline sector be integrated into a generic emissions trading system?
- Should the airline industry have a standalone scheme?
- Should airlines have "grandfathered" permits whereby the allocation of permits is based on past emissions or should there be an auction process?
- Should the industry be granted emission permits or should it pay for rights out of profits?

We also argue that air transport travellers could play their own part in reducing total global emissions, by offsetting the emissions generated by their air travel in a very personal way: they could reduce their own personal carbon emission footprint. Household emissions of CO_2 per person per annum in the UK are around 11 tonnes. Compare that with a flight from London to Barcelona which emits approximately 0.12 tonnes of CO_2 per person (using the IPCC's base factor). If travellers could take some household carbon reduction measures, they would be able to book a responsible trip safe in the knowledge that they would be emitting less carbon than before, and that they would also be supporting local conservation and development – which in turn could help local communities to reduce their own carbon emissions.

Far from disputing the science of global warming as some of our detractors would like to suggest, we actually think the science is conclusive. So we are not climate change sceptics, but we are sceptical about how a bête noire of the environmental movement, such as air transport, has been labelled as the biggest threat to the environment, when clearly other issues are more pressing.

We hope by writing this report to encourage a sense of proportion and an evidence-based approach, which is open and honest about assumptions, as we believe some researchers such as the IPCC and the Royal Commission on Environmental Pollution and Stern have been.

There are climate scientists and specialists, whom we and others have spoken to and quoted in this report, who are also experts on the aviation industry and its effect on the global economy. We may disagree about the forecasts or the implied costs, and we certainly wish to see the benefits taken into account, but we definitely agree that there is a problem. It is getting that problem into perspective and developing genuine solutions to the impact of aviation and the environment which we believe is the key issue.

In conclusion, climate change is a pressing and serious issue for all of us. Indeed according to Sir David King, the UK Government's Chief Scientific Advisor, it is the most important issue that humanity faces. We hope that this report will open up the debate about how we will meet that challenge and the part that the airline industry should play in reaching solutions.

Chapter 1: Aviation under Attack

Introduction: Aviation and the Environment

Since the mid-1990s air transport has been under attack. In the last few years the assault on the industry has been relentless, and it shows no sign of abating. The attacks on the industry have come from many quarters, in particular from environmentalists. They have become a very vocal and powerful lobby in their calls for the growth in air transport to be halted. They argue that the environmental impact of the air transport industry, in particular its contribution to climate change has become unacceptable. The campaigning of the environmentalists has been accompanied by a mass of key reports on the challenge that the world faces from climate change. The environmentalists are using these reports to support their argument that the main cause of man-made upper atmospheric emissions is the air transport industry. But that is not exactly what these reports say. Nevertheless the environmentalists have convinced many people in government and the media that the air transport industry is severely damaging the environment and accelerating climate change.

Behind this concerted attack lie some popular misconceptions about air transport. These are that its noise impact is higher than for other types of transport, that it is heavily subsidised and that in some ways it is still a luxury. In other words, we could comfortably exist without air transport. These misunderstandings of the true impact of air transport and its apparent subsidy have helped to strengthen the environmentalists' case and enabled them to gain acceptability in the media and among the public. Focusing on a single issue has always been popular, and nowhere is this more obvious than in the attack on air transport.

The singling out of aviation as a source of climate change and a contributor to climate change was quite apparent in the attacks on the UK Prime Minister Tony Blair, who was asked to account for his decision to fly to Miami on a winter break. His political rival, David Cameron, leader of the UK Conservative party was also roundly attacked when, as part of an environmental awareness raising campaign, he visited Greenland by air. Even Al Gore the new voice of green politics in the US is castigated on Environment websites for flying as he promoted his "shockumentary" on climate change, "An Inconvenient Truth."

The ordinary citizen who flies regularly on business and leisure is also being made to feel that flying is destructive and selfish, that when they fly over the icy wastes of the Arctic or the rainforest of Brazil, that they and they alone by virtue of their choice of transport are uniquely responsible for the impending destruction below them. The fact that they drove to the airport in a car made from steel generated by coal furnaces, or came by trains which use fossil fuel or electricity generated by power stations, or that they heat their home with oil, or work in an industry like chemicals, is somehow less important and utterly dismissed. Their environmental footprint is reduced to the fact that they have chosen to fly. It is assumed that anything else they do cannot cancel out that impact. That in our view is very much mistaken as we will show later in this report.

We believe this approach is wrongheaded and simplistic. We concede that aviation like all forms of economic activity has an environmental impact, which needs to be managed and mitigated. What we seek to stress is that the impact of aviation can be controlled as it has been in the past through technological advance, through the drive for the efficient use of

fuel and resources in this costly but marginally profitable industry, and by the introduction of a global compact based on emissions trading, which provides the economic incentives to develop aviation sustainably on a global basis.

We are also convinced that governments, in properly rationalising the chaotic and wasteful national patchwork of air traffic control systems, can help to realise real gains in fuel efficiency and thus mitigate the impact on the environment. As the foremost industry professionals, pilots are continuing to adopt measures which reduce the environmental footprint of aviation by:

- flying continuous descent approaches
- minimising fuel consumption
- reducing noise nuisance.

We also think that individuals who wish to fly can partially mitigate their own contribution by both offsetting alternative carbon use and by making a personal contribution to offset directly their own flying, which we outline in the final chapter. We would argue that we can all be more responsible and thoughtful consumers of the world's resources. In our view that means sustainable flying can continue to be a vital part of our economic and social future. Sustainable flying is flying which is made possible by the economic and efficient use of aircraft and adequate infrastructure, better fuel efficiency and improvements in technology. The driver for these improvements will come from the introduction of a robust system of inbuilt market incentives based on emission trading. This will provide the imperative towards efficiency and innovation which will allow air transport to grow sustainably.

Thus we reject the idea that aviation should be drastically curtailed, that short haul flights should stop, that individuals should be taxed further and that massive taxes should be levied on the industry. The industry is becoming a "milch cow" for tax-gathering politicians. We believe that the swathe of regional and national initiatives to target air transport are no more than tax gathering exercises. Typical of these is the UK's Air Passenger Duty (APD). The doubling of APD in the December 2006 Budget for example, was defended on the basis that it was an environmental measure.[1] Yet APD has simply boosted government revenues and has not so far been directed into environmental improvements around airports and towards cleaner fuels and better technology as we believe it should be.[2] The European Parliament's introduction of measures to tax passengers, in isolation from others who use Europe's airspace is also a retrograde step, which cuts across the need to develop a global emissions trading framework overseen by the UN body for promoting and developing Civil Aviation the International Civil Aviation Authority (ICAO).[3]

[1] UK Chancellors Budget statement HM Treasury Dec 2006
[2] British Air Transport Association (BATA), Dec 18th 2006
[3] UK Impact of the Rise in UK Air Passenger Duty 7th December Economics Briefing 2006 IATA

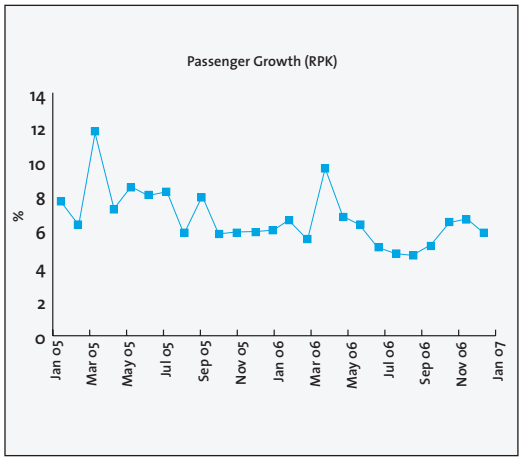
A Thriving Industry

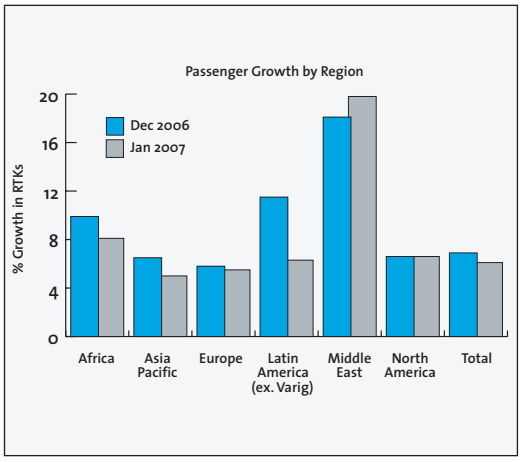
The European and global airline industry is buoyant. Traffic is up; revenue is up, growth is up, profits are up. This is partly a reflection of lower fuel costs and increased yield[4]. However, the fact is that even when fuel prices were near $100 barrel aviation prospered. The reasons are clear: aviation is the transport system of the globalised economy. It transports people and high value products in the quickest possible time and at minimal cost. The world economy is booming on the basis of massive growth in China and India, and amid a global commodities and mergers boom. Airlines are benefiting from the higher business fares in many markets. Consumers with money in their pockets are flying more on leisure. The industry has also grown hugely with the growth and expansion of low cost carriers throughout the world.

We've returned to growth after the terrorist attacks of September 2001, and their aftermath, and we have recovered from wars and epidemics. Even if a pandemic of bird flu takes hold, the industry will probably prove resilient. There could be economic clouds on the horizon, but we have a very robust and growing industry. A lot of that resilience as we all know comes from cost cutting and efficiencies, a lot of it comes out from using labour more productively, but this industry is above all a survivor.

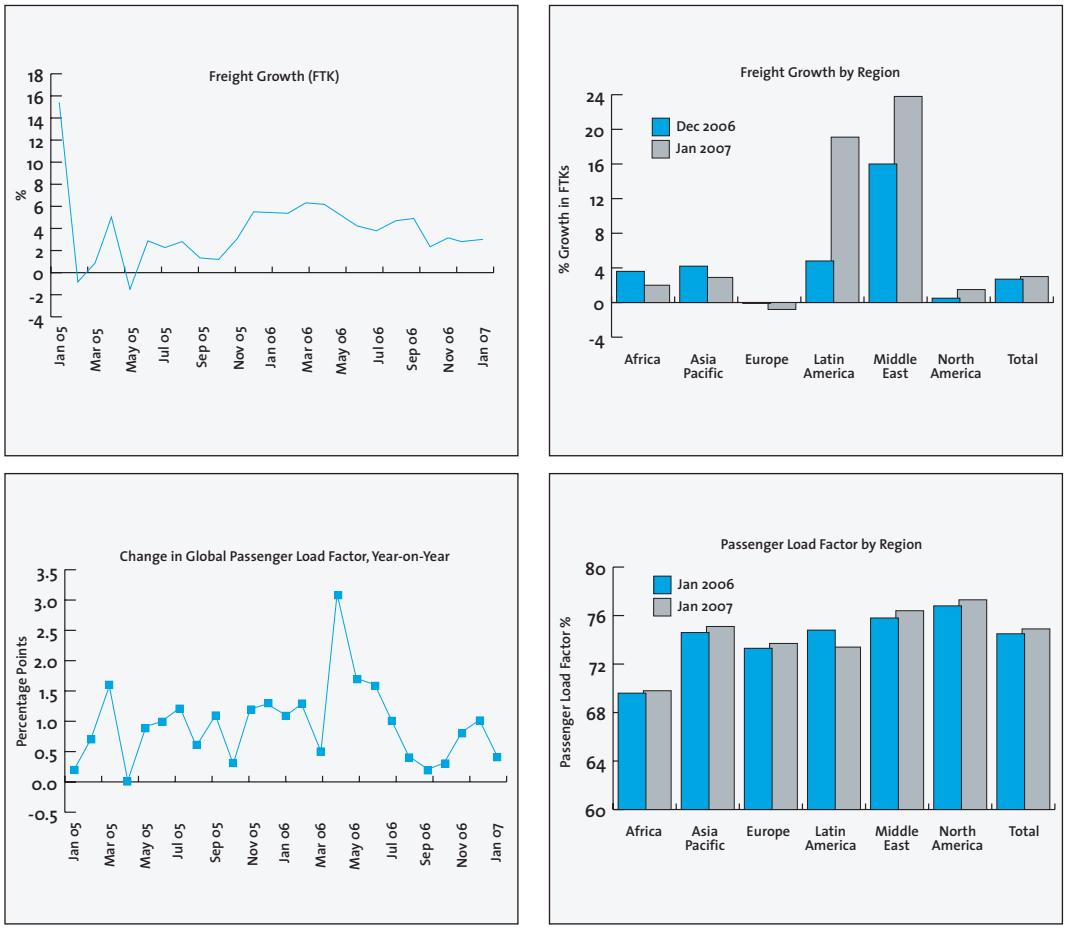
The other reason why our industry is buoyant is because people like to fly. People are flying more domestically and in every corner of the globe because air transport is a triumph of technology over geography. This means that distances are shrunk, and though we have got used to that phenomenon as an everyday feature of our lives, without it the facts of geography would impede connections much more. The industry is growing by roughly 6% per year in terms of passenger growth, and freight is growing around 4.5% per year. (Fig I below). Within specific regions these figures vary with the Middle East achieving levels of 12% and the IATA airlines in the Pacific area achieving 6%

Fig 1.1: Growth By region





4 Morgan Stanley Equity Research Special Report "European Airlines: The View from Heaven" Penny Butcher (author) February 2007.



Source IATA Industry Trends 2006

It can be seen from the regional breakdown of growth in Fig 1 – Passenger Growth by Region that passenger growth in terms of Revenue passenger Kilometres (RPK),is highest in the Middle East with an increase of nearly 20% in volume, a result of the expansion of carriers such as Emirates and Etihad. This increase in year on year growth is contrasted by a near stagnation in passenger numbers in Europe and the US, reflecting their status as mature markets and their stage of the economic cycle. However, the industry is growing more efficiently with an increase in the percentage of occupied capacity, (load factor), evident throughout the world. Freight (Fig 1 – Freight Growth by Region) is also expanding in the developing economies of Latin America and the Middle East, although in Europe it is contracting slightly. Overall there is a picture of industry growth on the basis of more efficient use of resources throughout the world. This means that the industry is on track to record losses of less than half a billion for 2006 and should reach a profit level of $2.5 billion for 2007. This growth and profitability are heard earned, and the constant spectre of fuel prices, global unrest and other shocks means that the industry is always vulnerable.

Can the Environment Sustain this Level of Growth?

Aviation can and will improve its environmental performance as it has always done, however, it should be allowed to develop the successful path of efficiency induced

improvement it has to date. It is clear that industry growth is outpacing gains from the kind of incremental technology improvements we can expect. Progress on fuel consumption for example is coming up against the law of diminishing returns, whereby the gains from such improvements are outweighed by the cost of securing them. If we were to assume the sort of inflated 10 and 15% per annum projections which some environmentalists make, then we will have a major problem.

However, its quite clear that except in some countries like India and China where it is growing from a low base, the aviation industry will not grow on the same basis that it has in past. There is already near saturation of low cost routes in the US and the Europe. The costs of market entry in the form of leasing costs are at an all time high with the result that the entry of new start ups is falling across the world. It is also important to understand the dynamics of competition and market entry within the industry. Where low cost carriers (LCCs) are displacing the charter carriers, substitution rather than direct expansion is taking place. The same applies when LCCs enter markets where scheduled carriers operate; leading to either a withdrawal or a reduction in flights. Infrastructure constraints are another major issue. Reducing available terminals and runway capacity, is often seen as a solution to climate change as it allegedly removes the pressure for the industry to grow. Yet reduced capacity clearly exacerbates the environmental impact as aircraft are flying in more congested airspace burning fuel etc, and achieving lower utilisation. Aviation always grows ahead of GDP, and then often comes into line over the economic cycle. This is happening now. So forecasts based upon crude extrapolation of current trends are way off the mark. If we assume growth will take a more moderate path then it is clear that the benefits of these incremental efficiencies in terms of the environment will be significant.

Air Transport Under Attack

Air Transport as a whole has been coming under siege for many years. A consistent and determined lobby of environmental and community activists has opposed both the growth of air transport in principle, citing its role in climate change, and its role in particular areas citing, noise, construction nuisance and the congestion problems which tend to go with air transport. Possibly the most influential report in recent years has been that of the Tyndall Centre on Climate Change A UK based Academic Scientific Research Establishment. Tyndall published a major report in February 2006 which in effect suggested that if air transport in the UK was not curtailed then all the advances made towards meeting the Kyoto protocols would be cancelled out.[5] The Centre found that based on a "carbon budget" of 450–550 ppmv (parts per million in volume), UK aviation growth would account for between 25 and 50% of all future emissions. Yet the conclusion it came to that the governments should drastically reduce air transport growth in the UK, particularly by halting runway and terminal build and that it should levy massive tax increases, would do nothing for the environment in the UK. The people who wanted to fly would simply fly on other carriers from other nations.

5 Contraction and Convergence: UK Carbon Emissions and the Implications for UK Air Traffic. Bows, Anderson and Upham Tyndall Centre for Climate Change and Research Technical Report no 40. (February 2006).

The UK would lose the huge economic benefits of aviation, and the environmental problems of climate change would continue. The Tyndall report is an impressive piece of multi disciplinary climate research, which unlike other such reports did consider alternatives, but its policy prescriptions are extremist and would do far more harm than good. No one in aviation believes that we should do nothing, but a balance needs to be struck between the economic benefits and the environmental impacts of air transport. We are convinced that the answer lies in a global solution to this global challenge, and we discuss this later on.

Is aviation really the most polluting form of transport?

Opponents of air transport believe first and foremost that aviation is a "dirty" industry, that it is wasteful of resources and that it alone is responsible for the major threat of ozone depletion by the generation of greenhouse gases.

Yet, aviation accounts for only 2% to 3% of global carbon dioxide emissions[6], far less than emissions coming from road transport (10%), power stations (25%) or private households (23%). UK domestic flights account for less than 0.5% of UK emissions, much less than the 24% coming from road transport, 28% from power stations and 28% from private households[7] (see Table 1) below

Table 1.1: UK Emissions by Source

Source	% of UK emissions
Industry	27%
UK domestic flights	0.5%
International Flights	5.0%
Other	17%
Road Transport	24%
Domestic consumers	22.5%

Source: UK DEFRA 2006

In terms of Co2 emissions (which are most understood by scientific research), aviation comes out relatively well in terms of miles flown when compared with other modes. Given that air transport is primarily a means for moving people in excess of 200 miles, its emissions performance is in fact creditable when taken in context.

6 Intergovernmental Panel on Climate Change; Special Report; Aviation and the Global Atmosphere. 1999
7 DEFRA *Digest of Environmental Statistics* October 2006

Figure 1.2: Emissions of transport Modes by Distance

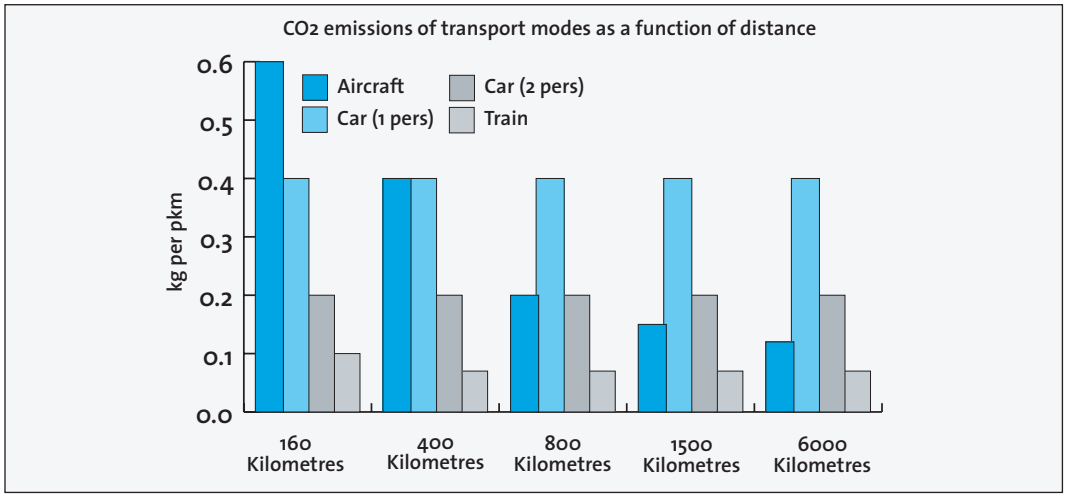


Fig 1.2: which was drawn from the IPCC Report "Aviation and the Global Atmosphere" (1999) indicates that in terms of environmental efficiency air transport can stand comparison with other modes especially over distances in excess of 400 kilometres.[8]

Over the past 30 years, aircraft fuel efficiency per passenger-km has improved by about 50%, lowering emissions of greenhouse gases. However, it has to be acknowledged that demand is rising faster than improvements in technology, and this fact is contributing to that increase in the emissions generated by air transport. The solution from the anti-air transport lobby is that aviation growth is a problem and that it must be "taxed away". This is the thinking behind the EU Parliament decision to introduce a range of punitive taxes to choke off air transport demand, and in the hostility of many opinion formers to the use of flying for the mass of the population.

This perception needs to be challenged. Not only is air transport vital to the global economy and social infrastructure, but its impacts on the environment are manageable. According to the Association of European Airlines (AEA), In 2003 flights departing from the EU accounted for 3.4% of total CO_2 emissions in the EU 25. It is estimated that if the entire European fleet were grounded, we would only decrease global CO_2 emissions by 0.5% annually. If the entire aviation industry was grounded that would only yield about a 3–4% reduction in global CO_2.

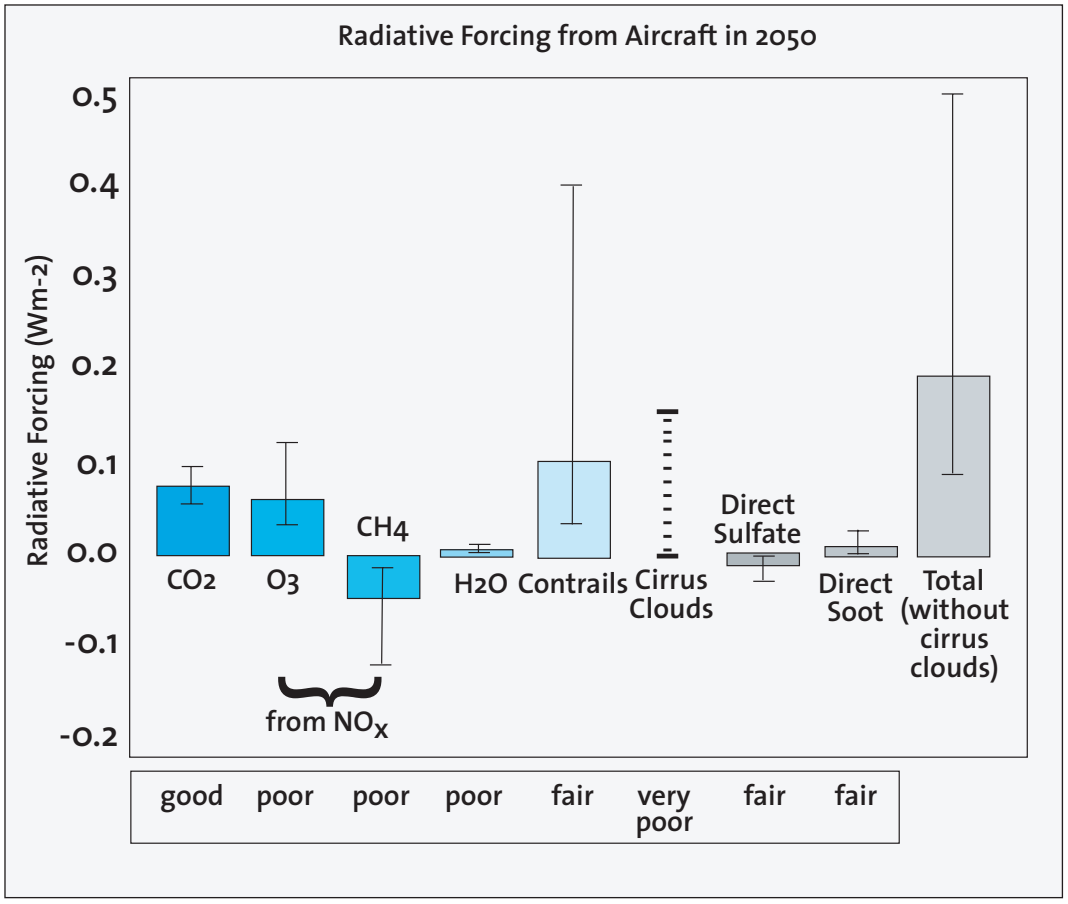
Climate science is a sophisticated multi-disciplinary field of scientific research. Feedback loops whereby one consequence gives rise to another, and unexpected events abound. Instead of a reasoned debate however, we have a shrill argument against aviation which, when, seeks to punish an industry which is not only responsible for a low absolute proportion of damaging emissions, but is actually through its own technology continually working to reduce its environmental impact. Having said that we have to acknowledge that greenhouse gases such as Nitrous Oxide – thought to be responsible for the depletion of the ozone layer – are partly caused by aircraft contrails and their sometimes cirrus forming aftermath. That means that the effect from aircraft contrails could be about 2.5

[8] IPCC 'Aviation and the Global Atmosphere' (1999)

times higher than from Co2 alone. Yet this needs to be to put in perspective. The science on gases other than Co2 and their effects is far less advanced.

It is sometimes claimed that CO2 emissions from air transport may rise and eventually account for up to 15% of world emissions. In fact the Intergovernmental Panel on Climate Change (IPCC), examined a range of projections. Their central projection was that aviation may account for 6% of global emissions by 2050 (IPCC, 1999). This is the last comprehensive study of the issue. Fuel efficiency, direct routings and new technology are all part of efforts that have realised a 70% reduction in aircraft emissions over the last 30 years. Besides technological progress (the industry devotes up to 14% of its turnover to research), straightforward improvements in Air Traffic Management and other simple operational procedures (avoiding flying circuitous routings and stacking in holding patterns) could reduce fuel burn by a further 8 to 18%. The proliferation of national air traffic authorities in Europe leads to a 7% inefficiency when just a 1% saving could save up to 500,000 tonnes of fuel a year, according to the European ATC authority Eurocontrol.[9] These issues are further addressed in chapter 5

Figure 1.3: Aviation Impacts on the Upper Atmosphere



9 UK National Air Traffic Service (NATS) Environmental Report 2005

One of the major planks of argument in the case against aviation is that although CO_2 emissions in themselves can be mitigated, the real effects need to take into account what is called "Radiative Forcing". This is an assumed multiplier for the increased damage which aviation emissions cause at altitude. It's reasonable to assume that damage is more concentrated in the upper atmosphere because some aircraft spend considerable time flying in the troposphere. Yet in reality the science is not that conclusive. The scientific knowledge of the effects of CO_2 is well understood. However, understanding the effects of emissions such as Nitrous Oxides (CH_4) and Cirrus clouds are much less proven. Thus the legend for these effects is labelled in the chart above as "poor" or "very poor". This is an important point because most analyses assumes from these figures that all aviation emissions can be multiplied by a range of estimates with the average factor of 2.7. This multiplier is then applied so that for example aviation's impact in 2050 of 5.5% of global emission in CO_2 becomes 15%. It's also worth bearing in mind that in contrast to CO_2 which is a long-life greenhouse gas with global effects, these impacts can dissipate and even "repair" when action is taken. As the IPCC outline:

- Tropospheric aerosols resulting from combustion of fossil fuels, biomass burning, and other sources have led to a negative radiative forcing, which, while focused in particular regions and subcontinental areas, can have continental to hemispheric effects on climate patterns. In contrast to the long-lived greenhouse gases, anthropogenic aerosols are very short-lived in the atmosphere; hence, their radiative forcing adjusts rapidly to increases or decreases in emissions. (IPCC)

It's also clear that technology which could allow the identification and avoidance of contrails could mitigate these impacts even further. (see chapter 5)

Air Transport is the Noisiest neighbour

Noise is another argument used against aviation growth. The argument is that aircraft are the most invasive transport noise and that as growth increases absolute levels of noise also increases. The noise impact of aircraft is perceived to be getting worse with bigger aircraft and the activity around airports such as APUs (Auxiliary Power Units – the small jet engines which provide ground power for aircraft). contribute to the noise. Thus a major element of any protest against airport expansion is about noise. Furthermore, the necessity of night flights – usually a limited number of arrivals from distant time zones – is seen as another manifestation of the industry's intrusion into the peace and privacy of citizens.

However, this perception of aircraft noise is not borne out by the facts. The number of people disturbed by noise around Heathrow (within the Government's 57 decibel contour) has dropped from 2 million in 1974 to 300,000 today. Often the problem of noise is caused by the concentration of airport and runway development, made necessary by previous environmental campaigns against airport and runway construction. Thus at London Heathrow with only two active runways, those currently exposed to most noise would see a reduction in noise exposure as the additional proposed short runway was brought on stream. The same is true for Stansted, and for the residents around Schipol and Roissy. Again the facts suggest that noise has reduced, but that growth in movements means there are more "episodes" Unfortunately these are concentrated over a few areas because of hostility to airport expansion. Aircraft design has engineered out a lot of the airframe

noise, and of course high bypass turbofans are much quieter. As pilots know, noise abatement procedures are inbuilt to flight plans and steeper approaches are becoming the norm. These very real achievements are dismissed by the anti aviation lobby as mere window dressing. Chapter 2 covers this in detail.

In reality aviation is far from being the noisiest neighbour. According to a European regional Airlines (ERA) study of 2005, high speed and freight rail is the noisiest mode. The study demonstrates that the noise perceived by residents living from 30m to 150m from TGV lines can be as much as twice that of a typical regional jet measured at only 280m from takeoff, i.e. its most noise critical phase. Furthermore, the duration of peak noise recorded for a typical regional aircraft is between 2 and 3 seconds which compares with 8–9 seconds for a standard high-speed train.

As for night flights, as the recent UK Government enquiry into Heathrow night flights indicated, these are tightly controlled and monitored and most arrive in hours between 6 and 7 a.m., rather than the very early hours. Few complain about traffic noise or trains which run throughout the evening. The noise around airports is being controlled and airlines, with an incentive to save fuel are determined to save more, by reducing the "ambient" noise which comes from APUs, ground vehicles and other aspects. Clean technology solutions based upon electrical power are already being introduced too.

Aviation benefits from subsidies

It is often asserted that aviation grows in an unconstrained basis because it is subsidised. It is also alleged that the true costs to passengers are not apparent. According to official UK Government figures, total central and local government public expenditure on transport over the last four years was £36 billion, nearly all of which was spent on roads, rail, bus and tube. Taking account of the tiny fraction spent on air transport, mainly subsidies for socially necessary links to distant islands, aviation still makes a substantial net positive contribution to the Treasury.[10]

The point about taxing aviation should be to meet the mitigation costs of the unwanted effects, such as pollution and noise causes. Everyone in aviation accepts that some mechanism needs to be found to balance growth with a sustainable impact. We address these issues in detail in chapter 6.

We Could Get by without Air Transport

Probably the worst argument against air transport is that not only does it pollute and cause noise, but that it is actually a wasteful and inefficient form of economic activity. The presence of airports is also said to negatively impact the value of property, and in some cases "crowds out" other economic development. Overall air transport is seen as a wasteful extravagance that we could well get along without. The fashion amongst some 'time and cash rich' families to use surface transport to access a two week holiday, are one example.

[10] UK Department for Transport: UK Transport Statistics 2006

The "food miles" movement which seeks to minimise the amount of air freighted produce is another.

The fact is that aviation growth is pivotal to economic development both locally, nationally and internationally. Airports are economic hubs, and they spur growth. Witness the growth of the region round Manchester airport, and at Edinburgh where the Royal Bank of Scotland has built its HQ next to the airport, or at Brentford an unglamorous location near Heathrow where the global pharmaceutical firm GSK is situated. It's no mistake that Disney chose Paris airport region and not say the Port of Tolouse for the location of Euro Disney. In the UK the provision of 530,000 jobs and £10 billion contribution to economic growth as well as a positive impact of the balance of payments are all beneficial economic effects of air transport. The majority of houses around airports command a price premium because of their proximity to the hub of economic development. Then there is the positive economic impact of tourism and the advantages of international exchange and mobility.

Many environmentalists would like to stop cheap access to air transport. There is a deep vein of elitism present here. As those on middle and moderate incomes can afford to fly, the implication is that the activity has become too cheap. This is nonsensical especially when put in global context. Growth in air transport in China, India and other emergent economies is about 25% per year. This is happening because demand for air transport increases as citizens move up the income scale. In fact there is a direct correlation between the absence of air transport and the poverty of a nation. Where air transport is in short supply, so too is economic opportunity. This is especially so when the alternatives are not present. The continent of Africa which has some of the worst natural constraints cannot waste resource on building rail and road networks; aviation is a key solution for transport. The private sector can provide air transport instantly and can upgrade airports and air traffic control services, leaving the State's resources free to concentrate on education and healthcare, to reduce and hopefully eradicate poverty. Air shipment of "cash crops" such as cut flowers and exotic produce such as mange tout and mangoes, opens markets for the developing world. So also does its role in tourism, which is helping to sustain many poor countries. That may annoy some environmentalists as wasteful, but it directly improves the incomes of the world's poorest people. These social and economic benefits are addressed in Chapter 3.

Flying used to be the preserve of the rich, and many environmental organisations would like it to return that way. It is not coincidental that flights are the major method of transport for most tourism, so the alleged despoliation of such as Venice and even the Galapagos islands which can only be directly accessed by sea, is down to aviation. Some go so far as to ascribe the direct climate change effects of hurricanes and the melting of icecaps to air transport. Yet air transport has only grown recently and climate impacts are subtle and nuanced. There is also a fairly compelling but simplistic link between aviation and the generation of "food miles" in foods we eat. The prawns from Madagascar that we eat in Manchester or Madrid came by air. That means a carbon footprint was generated but so also was an income for farmers, who if their fisheries were not demanded by us would have no market. Yes aviation has to pay its verifiable external costs, and emissions trading will make sure it does. Its noise impact is being reduced and unlike other industries it is addressing it environment impacts. However our industry is crucial to the economy, it is here to stay and taxing it out of the skies is neither a feasible nor a desirable option.

The fact that air transport uses fossil fuels which cannot be replaced, and that it flies at altitudes where its emissions have a more significant effect, cannot be induced as a simplistic premise. The message of the environmentalists seems to be don't fly and the earth will survive.

We in the aviation industry will have to meet the external costs of air transport, that is, the verifiable external costs. There is no escaping that and we set out what that means and how it can be done. We will need to minimise the impact as air transport grows in every corner of the world. We'll outline how that can be done. We need to ensure that we push the technology as far as we can.

What Action Should We Take?

The truth is that aviation, like all forms of transport, pollutes but its impact on the environment is exaggerated and the solutions put forward don't address the environmental impact. Thus the attempt to penalise the industry and its flying public is misguided. The most damaging effect of aviation, in terms of its pollution of the upper atmosphere is, in our view, best dealt with by emissions trading. In addition there are major technical advances as outlined in Chapter 5.

It's clear that taxes of the kind proposed by the EU Parliament are not the answer either. Taxation of the type suggested might limit demand but it would do nothing to solve the problem. The "externalities" of noise and pollution can best be remedied by reducing the amount of emissions. To do that you need to incentivise airlines to reduce emissions. That is you must make it worthwhile for airlines to operate the most efficient and environmentally friendly aircraft. Airlines already have a massive incentive given the cost of fuel. Fuel has risen from about 6% of costs to nearly 30%., so the incentive to burn less kerosene and to find new forms of energy is massive. Emissions trading lets airlines which have reduced their emissions "sell" these to airlines who can't do this as fast. But soon all airlines will be incentivised. Already technology is reducing both the emissions and the noise footprint. The idea that punitive taxation would help is plain wrong. These issues are addressed in Chapter 6.

It's also worth pointing out that a great deal of the pollution around air transport comes from the private car used for most journeys to and from the airport. We need real improvements in public transport such as is happening with many new airport developments. In the UK the industry is expected to meet the cost. Clearly, air transport does have impacts but it is also a positive and dynamic industry and is a force for good and for progress. Few suggest stopping cars because of their polluting effects, nor shipping which contributes heavily to marine pollution. Instead they recognise the good of the industry and try to manage and mitigate it's less welcome impacts, and allow technology and the efficiency imperative to work. This sense of perspective is entirely lost from the debate about air transport. Chapter 4 puts the global contribution of air transport to climate change in perspective.

In the continuing debate about the environmental impact of airlines, a lot of issues are misunderstood. Some of the benefits of air transport are misunderstood too. Moreover, many of the statistics and forecasts about the industry are incorrect. It is wrongly assumed

that the environmental impact of air transport will increase in line with the increases in air transport, ignoring the fact that aeroplanes today are more fuel efficient and more environmentally friendly than their predecessors and that the same will be true of the aircraft of the future. There is also the mistaken view that air transport is more polluting than other types of transport and that it is highly subsidised as well. In fact air transport is less polluting than rail, road or sea transport and does not receive subsidies. Finally, there is the completely mistaken belief that the global economy could survive without air transport. Without air transport the global economy would come to a halt.

The biggest flaw with the environmentalists' case against air transport is that they taken one form of transport in isolation from others. and they have not examined air transport in its entire context. This means that inconvenient data is always excluded from their arguments.

Chapter 2: How Aviation has improved its environmental footprint

Aviation has never been a static industry. Its history is one of continuous development in response to the demands that have been placed upon it. Most of the changes in technology and design have been made to meet the ever more demanding requirements of the airlines but some have been at the behest of governments. Arguably the most influential factors have been the need to reduce fuel costs and to lessen the environmental impact of air transport. In particular the noise impact of aeroplanes has been a factor that the industry has taken quite seriously. So it is quite wrong to assume that the industry has made no attempt to reduce its environmental impact. Indeed the opposite is the case.

The facts are that the industry has made up a great deal of progress in reducing emissions and noise over the last few decades. For example, in the US aircraft carry six times more payload than in 1972, whilst improving fuel efficiency by 60% and reducing by 95% the number of people affected by aircraft noise. This is but one example of the progress that has been made. In this chapter we will refer to some major recent research-based reports on these issues from a number of organisations.

These sources are: the previously mentioned IPCC report on Aviation and the Global Atmosphere, the Tyndall report on UK Aviation and the Environment and the UK Parliamentary Office of Science and Technology. The last two reports are highly critical of aviation. It also draws on NASA's 2005 research programme on aviation and the environment as well as IATA's 2004 Environmental Report and the policies arising from the 2006 IATA conference on Aviation and Environment.

Environmentalists and those who are hostile to the air transport industry tend to see it as an unregulated and smokestack industry. But this is far removed from reality. Few sectors are more tightly regulated in terms of environmental impact than air transport. Domestic aviation is included in the Kyoto treaty on carbon emissions, however, some accuse the industry of not addressing international emissions. But because of the complex international treaties, international aviation cannot be included; however, the prospect of global emission trading through ICAO is accepted by the industry. In any case the industry already has tough environmental standards.. The evidence suggests that if the industry tackles this challenge with the same combination of technical ingenuity and expertise and the same level of responsibility, that it has shown in tackling noise and local air quality impact, then the outlook for further environmentally-oriented improvements will be good.

Although air transport has made major strides on noise but paradoxically these have often impeded environmental performance in the process. For example, engines which deliver better performance eon emissions have more parts to filter out the problematic gases. This adds weight and can increase fuel requirements, and it can also make the engine noisier. The engineering task is to achieve a gain on emission without sacrificing other environmental benefits. This is no easy task, yet the industry has achieved it.

On local air quality, on its own land use and construction methods as well as energy use, the industry has taken action. This has often been at considerable expense to the industry developing innovative surface transport solutions. The record is exemplary and stands

comparison with any other industrial sectors, let alone one beset by poor profitability, with more than its share of economic setbacks and which is subject to a great deal of scrutiny. This section of the report reviews that success and points to the emerging improvements on emissions.

Clamour for Noise Reduction Drowns out Real progress

Aircraft noise has been and continues to be a very emotive issue, and it's at the root of most public concern over the growth of air transport. It is much more on the radar of local communities than climate change, although many noise campaigners believe astutely that going along with the tax and ground arguments of the "greens" related to climate change they will get their release from noise nuisance. Virtually all major environmental campaigns against aircraft expansion have been local communities concerned about noise, often encouraged by "green" activists. For example, The Tokyo airport campaign in Japan in the 1970s where masked campaigners fought pitched battles with police to stop a new airport construction. The John Wayne Orange county airport in California was seen as a threat to the tranquillity to the wealthy residents of Burbank. Terminal 5 was built after a 15 year planning hiatus at London's Heathrow; most complaints are based around aircraft noise. And as Heathrow seeks to build a third short domestic and regional runway, the clamour of the campaign from the primarily local pressure group HACAN Clearskies is all about noise. It's also important to note that local people can be rightly concerned about the effect of property blight, where homes are no longer saleable on the basis of their proximity to airports, yet when modelled using the best economic techniques it is often difficult to attribute a reduction in property values to airport construction.[11] Like air quality, airport operators generally provide generous soundproofing and supported purchase programmes.

Noise has to an extent been overshadowed as an environmental issue by the increased focus on climate change. However the industry's progress on noise is a good indicator that with its considerable drivers towards efficiency and its need as a customer service industry to develop its public image, air transport has made considerable progress on noise impacts.

Noise from air transport emanates mainly from aircraft on approach, descent and terminal manoeuvres, and within the "airport complex", from maintenance, motor support vehicles and from APUs. Further noise disturbance comes from related activity such as traffic and construction. Airports, because they are powerhouses of economic activity, become hubs which attract all manner of operations. The fact that airports are built close to major populations or generate major population growth adds to this.[12] Yet it's fair to say that airports expand and so does air traffic however much is being done to rectify the problem.

The real facts about aircraft noise pollution are interesting. According to ICAO, using its own model, approximately 30 million people are exposed to noise based on a day night

[11] See Pennington G, "Modelling Property Values near Airports using Hedonic Price Factors" (1990) *Journal of Transport Economics and Policy*.
[12] York Consulting 2003 Airports and Regional Development:

sound level of DNL55.[13]. Of that total around 10% were exposed to levels of noise nuisance of 65 DNL. Yet put in perspective, only 7% of individuals affected by transport noise live near airports. The majority by far, around four fifths, live near road noise and about 13% near rail noise. Aviation noise is probably more present because it is more identifiable. Paradoxically it is because there is also a well documented, regulated and enforced system for noise complaints around aviation in contrast to other mobile sources of noise nuisance.[14]

The fact is that the majority of noise complaints around airports come, not about the absolute level of noise but, about noise episodes, such as night flights and noise preferential routes. For example at London Heathrow, to spare the residents of Cranford from noise, the airport authority was until recently required to route all flights over the "Westerly flight path thus affecting the residents of Windsor disproportionately. At John Wayne Airport in Orange County California, departures are required to undertake a vertiginous high powered take off in order to spare the ears of the generally wealthy residents of one of the US's richest enclaves. Generally the improvement in noise for one person is a redistribution of the noise problem for another. The imposition of strict noise standards on airlines such as the latest Chapter 4 noise reduction regulations from ICAO requires noise levels to be reduced further on average by about 15–20%. [15]

The ICAO Noise reduction standards which operate globally are the most stringent product regulation standards anywhere in the world. Aircraft are long-lived capital equipment and with constant overhaul and repair their operational lives can be considerably extended. The ICAO standards often curtail the operational life or impose costly modifications such as "hush kitting" in order to comply with noise standards. Hush kitting is probably the crudest noise reduction technology and is only used to "retrospectively" improve noise performance. It essentially involves muffling sound with sound-masking materials. It has been done on many older, previously noisier aircraft.

Manufacturers and airlines have improved the noise performance of aircraft dramatically over 30 years, because all aircraft energy outputs have a cost and the industry is paranoid about reducing costs. The result is that noise exposure has been reduced massively falling by 20 decibels or nearly one third. Noise is not just attributable to aircraft engines but also to their fuselages and, significantly, the undercarriage and control surfaces such as flaps. Manufacturers in the interest of fuel efficiency are always on the lookout for better technology, less moving parts, more composite materials etc as this minimises the fuel burn and thus has a positive feedback for noise reduction. However, airlines have targeted engines as the main source of noise. Ever since Rolls Royce developed for the Tri-Star its "Whisperjet" big fan engine technology and for BAE its 146 in the 1970s, manufacturers have striven to improve noise performance.

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13 "Day/Night Level" This is equivalent to Leq but weights the night noise with a 10db noise penalty to account for the enhanced noise nuisance of night flights.

14 Contrast to the lack of noise enforcement of major mobile urban noise sources such as police sirens, motorcycles (which have a very loud noise footprint) and motor scooters operating without silencers which can be louder than any turbofan jet. It becomes clear that aviation attracts complaints because it has system of redress.

15 International Civil Aviation Organisation (ICAO) Recommended Method for Computing Noise Contours around Airports (Circ 205)

One driver of noise reduction is the high bypass turbofan (HBTF) which is able to run at very low speeds and which provides a considerable noise advantage. HBTFs also economise on thrust, thus reducing fuel burn. Admittedly, because they are bigger they increase weight and drag and thus incur a higher fuel burn. They also require higher engine core temperatures and this could have a negative effect on the emissions of Nitrous Oxides (NO?). The industry has made considerable progress in noise reduction but sometimes this comes at the expense of other environmental impacts as we will see below.

Unquestionably the industry recognises the need to improve noise performance further, especially as traffic and movements grow. In the US for example, according to IATA a major programme known as AST (Advanced Subsonic Transport) will develop new ways to tackle the problem. Europe is also addressing the issue through its FANPAC programme and similar programmes are being undertaken in Japan. However noise is just one of the major environmental issues around air transport. These multi-billion pound programmes show how the industry has the incentive to make more environmental improvements both in order to raise its business performance and to meet its regulatory objectives.

Nevertheless there is a trade-off between noise, fuel burn, and traded emissions and a range of other operational and safety factors. That means that the benefits of noise reduction for a local community need to be balanced with the needs of the rest of the population and of the industry. This was the view of the UK Government in the Night flight debate in respect of London' Heathrow.[16]

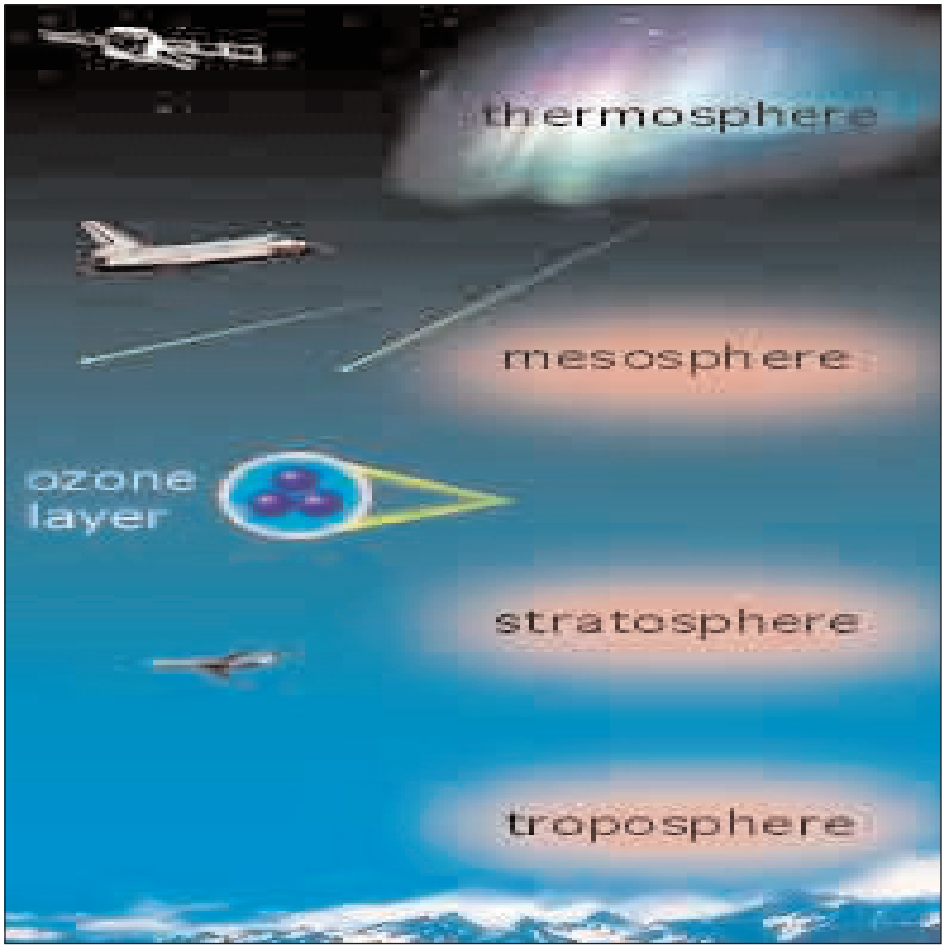
Separating Emissions from Emotions

Aircraft burn large quantities of fossil fuel and they burn it very quickly indeed. Larger aircraft burn more and obviously they tend to burn more fuel on take off and landing. However, proportionately, according to the IPCC report, this still accounts for only 2% of total CO_2 emissions and 13% of those arising from all transport sources.[17] Fuel is the major source of emission producing Carbon Dioxide as well as a cocktail of other chemicals such nitrous oxides and sulphides. Aviation is projected to account for between 4 and 15% of the overall man made emissions of CO_2 by 2050. However the most likely range is 5–6% (IPCC).

Because some aircraft fly in the troposphere (see diagram) those aircraft's engines also expel large amounts of water vapour which, in certain circumstances, can turn into contrails. The mixture of chemicals is also thought to contribute to cirrus clouds, although the science upon this dimension is inconclusive. Aviation also emits nitrous oxides (NOx) which are thought to have increased ozone concentrations at cruise altitude by 6% since 1992 and could reach 13% by 2050. However whilst NOx is a greenhouse gas its presence reduces the effects of methane a more potent and destructive greenhouse gas. These emissions, because they are expelled at high altitude, are thought have an additional multiplier effect on the atmosphere, which could be 2 to 4 times greater than the effect of CO_2 alone. However the science is not as well developed on this aspect, but the airline industry accepts that there is some effect and that it needs to be mitigated.

[16] Night Noise Consultation UK DFT 2004
[17] IPCC Aviation and The Global Atmosphere (1999)

Fig 2.1 : Levels of the Upper Atmosphere



Fuel efficiency and targets

The aviation industry has itself set research goals for improving fuel efficiency as laid out by the Advisory Council for Aeronautical Research in Europe (ACARE).[18] The targets are challenging and are outlined as follows:

- To reduce fuel consumption and CO_2 emissions by a further 50%
- To reduce perceived external noise by a further 50%
- To reduce oxides of nitrogen by a further 80%
- To make substantial progress in reducing the environmental impact of the manufacture, maintenance and disposal of aircraft and related products to be done in an environmentally sustainable way.

There are trade offs as outlined above and there are similar trade-offs to be made to reduce NOx emissions. So both targets are indirectly related to the climate change issue. The industry is also committed to further improve fuel efficiency by 50% per seat kilometre including up to a further 10% from air traffic management system efficiencies and to

[18] ACARE Report 2005

reduce NOx emissions by a further 80%. These are demanding targets on top of that already achieved. A massive programme of investment is taking place to ensure that aviation can meet its targets.

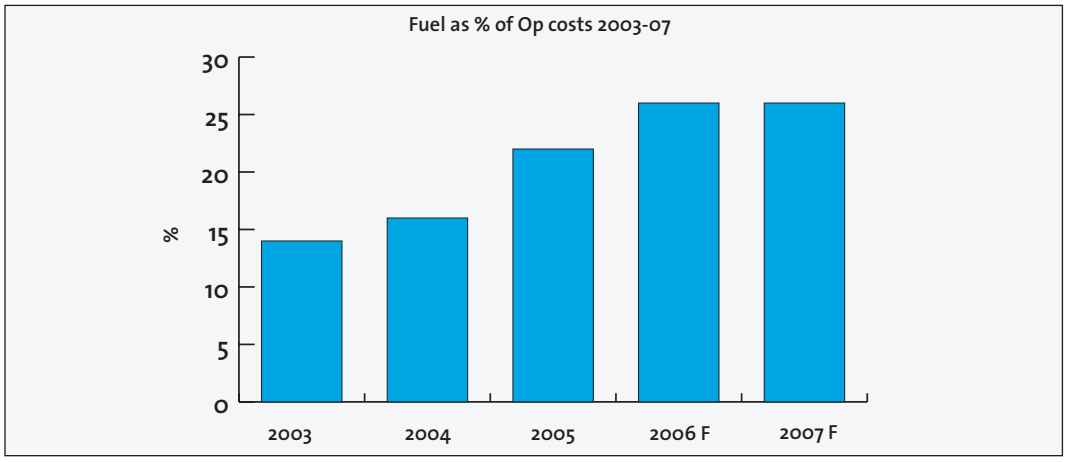
The fact that a new wave of aircraft are about to enter the world's fleets means that a step change can be achieved. It's a common argument of those who are critical of aviation that efficiencies in fuel and design are already "discounted" in models of future growth. However, these are major improvements, which show confidence from policy makers in the industry's ability to mange its environmental performance. The record of previous progress, for example, on noise suggests that the industry can indeed improve its emissions record further.

Fuel Economy: The Driver of Environmental Progress

Kerosene, the fuel used by jet aircraft, accounts for roughly $50–60 billion of expenditure annually in the global airline industry. This makes fuel the second highest cost item, at one point in 2005 fuel costs were $70 billion. This is a crushing burden on the industry and one which the industry has sought to escape. Major trends in airframe and engine design, including the development of twin engined wide-bodied airliners, winglets and carbon composites to reduce weight and drag have all been driven by the need to reduce fuel consumption. These have brought positive feedbacks on reducing the environmental impact.

The IPCC has projected a 20% increase in fuel efficiency between 1997 and 2015; equivalent to a 1% per year improvement in fuel efficiency. IATA as the airline industry global trade federation has been monitoring operator fuel consumption and has adopted fuel efficiency targets. Those set in 2000, for example, sought to achieve fuel efficiency improvements per revenue tonne kilometre of 26% between 1990 and 2012, which is roughly comparable with the IPCC's. In the decade 1993–2004 fuel efficiency improved by 16% or 1.6% per annum. This is a 60% improvement in fuel economy worldwide above the forecast level. This is the positive driver to a continued reduction in emissions.

Fig 2.2: Fuel Cost trend as a Percentage of Operating Costs



Source: Derived from IATA Fuel Analysis reports 2006

The IPCC report indicates that the industry has reduced fuel consumption by 70% over the last 40 years. It is not however a fast enough rate of fuel efficiency to outpace the growth of the industry, so the industry recognises more needs to be done to ensure that aircraft can be used efficiently. No one needs to tell airlines to minimise the use of fuel. However, if we are to make step changes in technology on both the fuel side and the airframe side, we need to recognise that there are some structural impediments to progress. Firstly the duopoly of major aircraft manufacturers have very little incentive to go beyond traditional airline types because of the massive development costs of new aircraft programmes. Thus both Boeing and Airbus concentrate on avionics and layout, and of course price. Since contrary to the case made by some campaigners the industry receives no direct subsidy, this means that the enormous cost involved in developing new technology will continue to be borne by the industry in the price of new aircraft. Since many governments believe that the industry should be heavily taxed that makes it more difficult to generate the investment needed.

Local Air Quality

The main ground level "culprits" of environmental concern are the ultra fine particles known PM10 or particulate matter. These "particulates" are basically smoke and dust and can be responsible for breathing problems, particularly the presence of respiratory diseases such as asthma and bronchitis. Yet just because they are present in the vicinity of airports does not mean that that they are necessarily caused by air transport.

One of the many side effects of airport development and the growth in air transport, in the absence of good surface public transport, is a marked increase in private car use. This in effect means that the increase in road traffic can lead to increases in particulate pollution, especially since much of the increase in traffic involves diesel fuel. Aviation is nevertheless blamed as the cause of deterioration in local air quality.[19] For example, for London Heathrow to secure a third runway it must achieve stringent local air quality targets by 2010 according to the Government's White Paper on Air Transport .[20]

In fact, air transport is generally responsible for less than 10% of emissions which affect local air quality. The emission of NOx, volatile organic compounds (VOCs) and particulate matter (PM) are thought to have potentially health threatening effects. There is evidence from some studies of NOx and VOCs reacting with ground level ozone to form a "chemical cocktail" which is thought responsible for responsible for respiratory complaints. It is difficult to give the prevalence of other pollution sources or to apportion these effects directly to air transport, but the industry recognises the need to improve local air quality.

[19] UK Parliamentary Office of Science and Technology (POST) Aviation and the Environment Report 195, April 2003

[20] Department for Transport: White Paper on Air Transport Progress Report December 2006 (UK Government Dec 2006)

When we consider fuel consumption, the aviation industry has made enormous strides, improving fuel consumption by 70% and gaseous emissions such as CO_2 and hydrocarbons by 50% and 90%.[21] However, advances in engine technology designed to improve overall environmental benefits also tend to increase the production of particulate matter. The development of the low emissions TALON II combustor unit for example reduced NOx by a quarter, but at the expense of increasing smoke from 30% to 90%. Similar results are recorded in the other direction: the Dual Annular Combustor (DAC) with the production of particulate falling at the expense of increased hydrocarbon emissions.[22] This is because the technology has to fit within increasingly constrained design parameters, designed to combat varied environmental effects. This is in effect is an engineering problem, which could be improved by a step change in design (IATA 2004). There will be the opportunity, as new future aircraft come on to the drawing board, to develop new design options, propulsion methods and technologies which will allow such a step change. This will be discussed in detail in section 5. However new engine technology such as the Affordable Near Term Emissions (ANTLE) project and the CLEAN project for environmentally friendly engine components are key technical programmes. Objectives of an 80% reduction in NOx relative to current standards would also include a 20% reduction in CO_2

With present generation technology such as the new Airbus A380, A350 and the Boeing 787 Dreamliner, considerable improvements in ground level emissions will be realised. According to the Committee on Aviation Environmental Protection (CAEP), an industry research and evaluation body to promote environmental performance, by 2022 around 15,000 new generation aircraft will be in the world's airline fleets resulting in a marked decrease in emissions.

Meanwhile, as with noise, a stringent set of standards currently in place will deliver incremental improvements in air quality performance. The current CAEP/4 standard reduces allowable NOx by 16% for engine designs conceived after 2003. In 2004 CAEP/6, which will apply to engines designed after 2008, will improve this by a further 12% and this will deliver a decrease in NOx of 40% compared to the mid 1990s level.

Yet as we emphasised earlier, the real source of ground level pollution is not aircraft emissions but the nature of overall airport activity. Airport infrastructure plays a crucial role here. According to IATA that role can be mitigated by:

- Optimising airport design to reduce taxi times, unnecessary aircraft and ground vehicle idling and reducing aircraft gate waiting times.
- Ensure cleaner and more efficient ground service equipment fitting existing clean road technology as available and providing fixed ground power to reduce APU use.
- Monitor the electricity consumption of passenger and baggage systems, air conditioning and lighting etc.
- Switching to alternative heating methods such as geothermal energy, solar power and combined heat and power plants.

[21] IATA Environmental Review 2004
[22] IATA Environmental Review 2004

- Conserving energy in office buildings with automated regulation of heating, lighting and air conditioning, coupled with energy conservation policies to reduce energy use.
- Providing public transport infrastructure such as electric trains and clean powered buses, as well as promoting cycling etc, and encouraging car pooling.
- Introducing emissions related airport charges to accelerate reductions.[23]

These improvements in ground level emissions can all be achieved, but the essential issue is that we need to remember that one effect of increased air traffic may well be a rise in the number of those affected by air quality-related complaints. The actual extent to which air transport is directly responsible cannot be assumed. The origin of a disease and its causes, given the confluence of economic activity around airports, needs to be identified as attributable to air transport. Just as it would be wrong for the industry to ignore real public concern about emissions, it is also wrong for emotive campaigning to castigate air transport as the sole culprit for the negative effects of climate change, noise and the deterioration of local air quality. It would also be wrongheaded to ignore the standards straightjacket which the industry operates under or the very real progress that technology can bring.

Compared with other transport industries the aviation industry has achieved more technological breakthroughs than any transport sector. Indeed it has shown a remarkable capacity for innovative development. It has generated new materials, new types of engines and completely new airframes to name but three key achievements. Fuel economy and efficiency have been vastly improved. This is an industry that can tackle technological challenges and come up with cost effective solutions. The noise impact of aircraft has been improved dramatically since the 1970s yet, as we have pointed out, noise reduction has sometimes been achieved at the expense of other environmental impacts. The industry has now set itself research goals for improving fuel efficiency even further with the object of not only reducing fuel consumption but also reducing oxides of nitrogen, CO_2 emissions and perceived external noise.

[23] Balanced with a revenue neutral approach, mindful of differing size and capacity issues and "trade offs" in other forms of pollution

Chapter 3: What could be Lost: the Economic and Social Benefits of Air Transport

The problem with any single-issue campaign is that it simplifies the issue under discussion. This in turn leads to simplistic proposals, which on examination often turn out to be impractical, because in the very process of focusing on one issue to the exclusion of others, the wider implications of those proposals have not been considered. We all see this in our lives everyday. The assault on air transport is an example of single-issue thinking.

If we cut back or reduce air transport on environmental grounds what would be the consequences in economic and social terms? Or, to put it more bluntly how would most of the world's countries function? While we agree that air transport does have an environmental impact this does need to be seen in a wider context. This context is its social and economic benefits.

Imagine the world without air transport. It's not easy to envisage. It becomes clear that when we visualise the planet without air transport, the world and our lives are significantly impoverished. Many of the economic and social benefits we take for granted would become impossible. The connectivity and speed which air transport provides, allow the global economy to function. Access to air transport is vital for social and economic mobility as emerging countries such as India, China and Brazil, demonstrate.

The crucial role air transport plays in facilitating access of people and products to markets and thereby increasing overall economic growth makes it the fulcrum of the world economy. Its role in facilitating and developing economic hubs such as Singapore, London, New York, Frankfurt and Dubai, proves its role as an economic generator. Air transport also provides respite from the isolation of geography, which affects most of Africa and the poorer regions of the world. Without it many countries would simply be unable to develop alternative transport networks. The industry is truly crucial to world economic and social development.

Air Transport and The Economy: Some sources of our research

This part of the report draws on extensively-researched work from some key economic bodies and academic institutions. It sets out the very real benefits which air transport brings and the huge role it plays in economic growth. The first source we have used is the Oxford Economic Forecasting (OEF) report on the contribution of air transport to the UK economy. That report outlines in a very specific way the vital role which air transport plays in building and underpinning the UK's key comparative economic advantages. It assesses the impact of air transport on jobs, growth, market access, tourism and the location of firms and individuals.[24]

We have also drawn on a key report of the Air Transport Action Group (ATAG), an industry research and advocacy body which promotes the benefits of air transport in a global

24 Oxford Economic Forecasting; "Contribution of Air Transport to the UK Economy" (OEF 2006)

context, as well as significant academic articles and texts, which take a critical view of the economic and social benefits of air transport. In addition, we refer to institutional studies and reviews such as those from the Government and think tanks, particularly within the UK and Europe. This chapter also looks at the benefits and alleged pitfalls of tourism and food exports facilitated by the growth in air transport, and at the critical role which aviation plays as the transport network for the global economy.

Aviation and the Economy: The UK Case

The UK Government has come under a concerted attack from environmentalists for authorising a major policy review on air transport. The review, which reported in 2003, recommends the construction of several runways in the South East and the regions.[25] The review anticipates that growth in air passengers will increase from 230 million passengers per annum at present to about 380–500 million by 2030. This growing demand for air transport with the growth in particular of low cost carriers means additional runways will be needed at Stansted and a third runway at London Heathrow. This is necessary to retain Heathrow's status as a leading global hub. However, this expansion will also mean that tough environmental targets need to be met.

In addition, new runways will be built at Edinburgh and terminal improvements and runway re-alignments will take place at other locations. The UK government has already committed itself through a legal undertaking, not to build at Gatwick; Britain's biggest leisure hub. This overdue capacity, which has been derided as "predict and provide[26]" and turning Britain into "Airstrip One" is vital overdue capacity which Britain needs if it is to continue to enjoy the economic and social benefits of air transport. Let's examine those benefits using the case of the UK.

According to Oxford Economic Forecasting (OEF), the aviation industry makes a significant contribution to the UK economy. It contributes around £11.4 billion directly to the economy, which is approximately 1.1% of UK economic activity. It also provides 200,000 direct jobs and about 520,000 in total including the supply chain, (e.g. retail, catering, engineering support). It also directly stimulates jobs in tourism and those people whose jobs are dependent upon aviation activity. Furthermore it also contributes around £3.6 billion to the UK government's finances, which is equivalent to 1% of GDP. The industry also sustains the UK's tourism industry servicing London as a major world city. About three quarters of

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[25] UK Government White Paper on Air Transport December 2003

[26] The term "Predict and provide" is often used as a rhetorical trump card in the debate on transport policy. It's based on the notion that government predicts a high demand and the passenger number rises to fulfil the prophecy. In essence it argues that government "over-provides" runways for example, by "predicting" that passenger growth will be high. The solution is not to provide runways and passenger demand will melt away. Its illogical and impractical and often used by environmentalists and policy makers critical of air transport. The reference is drawn from the UK's road building programme in the 1960's and 70's, where construction of motorways was seen to have lead to an increased number of vehicles. However it's based on the premise that if you do not provide growth it will not happen, and people will make do. Road traffic would have grown in line with economic growth and the growth of cities. Motorways were empty for a while but if we hadn't built them we'd be worse off. It's the same with Air Transport. Runways are bursting at the seams so there is no "Predict and Provide" in reality we are providing after prediction. As a concept it does nothing to promote proper forward planning and makes legislators wary of providing capacity ahead of growth.

international visitors to the UK arrive by air (see table 3.3) Tourist spending generates about 170,000 jobs.

The industry also plays a vital part in supporting the UK's role in international trade and industry: 55% of the UK's manufactured exports outside of the EU are transported by air. Generally these goods are of high added value and low weight; the typical characteristics of goods transported by air. Many of the key imports, which increase the productivity of the UK economy, also come by air: 60% of imports of machinery, mechanical appliances and electrical equipment come by air. The UK's need, as a mature service-based economy, means that air transport is more important than ever. Access to the emerging markets of China, India and Brazil is particularly important and is likely to become even more important. For it is these powerhouse economies which are driving world trade.

Table 3.1: UK Exports By Air To Selected Countries

	Value of exports by air	Value total by all modes	% by air
China	1.0	2.8	34.8
India	1.9	2.8	69.0
USA	13.9	30.7	45.4

The presence of good air transport links drives investment decisions. According to OEF, a quarter of companies cite proximity to air services as an important factor influencing their decision when investing in the UK. One in ten companies have cited the absence of good air links in their decision not to invest in the UK, with a third of those deciding finally not to invest in the UK at all on the strength of this issue. Some firms cited the possible curtailment of next-day express freight services as a reason to quit the UK for mainland Europe.[27] Indeed express package services are the oil in the gears of the global economy; without the same day or next day delivery of critical parts, components and documentation, trade is slowed and growth impeded. Countries representing 90% of the world's GDP are accessible from the UK in 24 to 48 hours by air, which is equivalent to around 55% of exports.[28] The express package service is vital to the adaptability and flexibility of businesses especially those operating in a global economy. For example, many computer repairs for companies such as Dell and Lexmark are made possible by such express services. Many small businesses, vital for the growth of the UK, can use these links to customise and tailor their products to a variety of markets and deliver them with very short lead times.

Imports are just as important, allowing consumers access to cheaper products, allowing business to source suppliers globally whilst retaining knowledge based and headquarters functions in the UK..

The future of the UK's trading relationships is bound up with good air transport links. By about the mid 2020s – if current trade patterns continue – the UK will have increased its exports to emerging markets by more than 50%, whilst trade with the EU will decline

[27] The Economic impact of Express Carriers for UK PLC, Oxford Economic Forecasting, Mott MacDonald, (Jan 2006)

[28] The Economic impact of Express Carriers for UK PLC, Oxford Economic Forecasting, Mott MacDonald, (Jan 2006)

below 50% of total UK exports. Since air transport is used much less within the EU, where there is alternative transport infrastructure, particularly cheaper road and rail transport, the need for air transport will increase. OEF expects the proportion of exports by value to non- EU countries to increase by about 15%. In fact, as the world economy grows and countries such as the UK develop their role as high value exporters of goods and services, the nature of these exports with their low weight to value ratio is likely to grow faster than this.

Importance of Air Transport to a Knowledge Economy

The UK, like many other "post industrial" advanced nations, is developing a combination of high added value manufacturing, research, education and a unique spread of financial and consultancy services. The UK is particularly strong in biotechnology, pharmaceuticals and financial services. It also has a role as a global educator, with prestigious universities and research institutes drawing students and scholars from all over the world. The UK's key role at the centre of world financial markets with most of the global investment banks maintaining a large presence in London is crucial. This cluster of financial service industries is a key factor in the UK's role in the world economy and is very much dependent upon good air transport links. Over half of the respondents to the OEF survey saw this as vital.[29] In terms of the UK's balance of payments, air transport makes a significant contribution. Around £7 billion in total exports is derived from air transport, which is 7% of the UK's exports of services.

Air transport is also a high investment sector in its own right. Between 2000 and 2004, UK airlines and airports together invested over £27 billion. The aerospace industry (including the defence industry) invested a further £3.4 billion. This represents around 3.5% of UK business investment. This high level of capital investment also correlates with high worker productivity and with higher than average output per worker. A consequence of this is that air transport has higher than average earnings (around 11% higher). So there are also considerable economic benefits to the UK from air transport.

The Social Benefits of UK Air Transport

The availability of affordable flights, in contrast to the expensive and even elitist nature of air travel that used to be the case, has brought foreign travel and holidays within the reach of the majority of the population. The opportunity to enjoy relaxing holidays and leisure, especially an extended break abroad, is a key social benefit and in this the UK has excelled. Indeed if we weight the proportion of the UK's tourism industry which is dependent upon air transport and consider that tourism accounts for 4% of the UK's GDP, then arguably the impact of air transport is if anything understated by OEF. The benefits of tourism are of course principally economic ones. Tourism and leisure are key economic foundations of an advanced knowledge based economy, where individuals earning high salaries relative to

29 Indeed this is a by product of the opposition to air transport emanating originally from those concerned about the local impact of airport development. It has actually led to a net contraction in the range of services which can be offered from Heathrow as the UK's major hub, indicating that its ability to compete with other international hubs such as Frankfurt, Schipol and Charles de Gaulle, is already compromised.

the rest of the world tend to take their leisure in those areas thus spreading the benefits of economic growth. In addition, low cost fares based on efficient aircraft utilisation, high frequency and high load factor have been developed from the UK further stimulating that effect.

Aviation is often denigrated as a luxury form of travel with little overall benefit to society, used mainly by the middle and upper classes and business people. The fact that people on quite moderate incomes can fly more and more, and that they can benefit from the opportunities flying can bring, is dismissed because they don't fly as often as wealthy people. In one press release an environmental pressure group records the fact that 62% of the UK population doesn't fly, which means 38% or 23 million do. This bald statistic makes no attempt to factor out the very old or young, the 15% who have an innate fear of flying or other factors. The CAA has cited evidence that only 6% of those in social classes D and E actually fly. According to the CAA, 55% of budget airline passengers have a household income of more than £35,500, with two-thirds of that number coming from households that earn more than £46,000. This has been seized on by those hostile to air transport. The Greater London Authority (GLA) found that the proportion of the population flying hadn't changed in terms of social composition that much between 1996 and 2002. That's an unsurprising finding. The more interesting comparison would be with 1976, where we would certainly detect a revolution in the social class of air passengers. The richer a country becomes the less exclusive air transport becomes. As more people can afford to fly, air transport reaches down to every level of society. Aviation is a crucial industry which makes the world go round.

The mobility that air transport brings is clearly seen in the UK, where low cost routes are enabling foreign tourists to visit the UK in greater numbers. These low cost routes are also ideally suited for business travel and help small firms develop markets and source labour particularly from the emerging new European economies such as Poland, Hungary, Estonia and the Czech Republic. Air transport is also the essential transport link for a country which has high levels of migration and immigration such as the UK. With a history of migration, many individuals visit friends and relatives abroad in countries such as Canada, Pakistan and Australia. It would be well nigh impossible for such links to be maintained without air transport. These links also help to facilitate economic exchange.

The new wave of immigration would not be possible without air transport. Admittedly the new immigration is controversial. However, it is arguable that with regular air transport links, immigration becomes more fluid and dynamic because immigrants are more able to work for short concentrated periods and return home with capital. Because of the route networks offered by the airlines, there is greater access to key cities such as Manchester, Birmingham, Newcastle, Edinburgh and Glasgow, all of which also have major intercontinental direct flights and many more via hubs such as Amsterdam, Paris and Dubai. These air routes are a significant factor in regional economic development and ensure that the UK operates as an integrated global economy. Without these air links it is doubtful whether there would be the level of economic growth in these regions. This confirms the view that investment location decisions are heavily based upon available transport networks.[30] For global access, air travel cannot be replaced.

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30 McQuaid, Smyth and Cooper. The Importance of transport in Business Location decisions

Tourism

In 2005 tourism generated £47 billion or nearly 4% of GDP, and accounted for 3.5% of total employment.[31] Access to foreign countries and new leisure experiences is also a significant social benefit, increasing the quality of life and welfare of UK citizens, as well as providing the incomes of many.[32] Tourism depends upon a number of factors: the position and geography of a country, its scenery its weather and its cultural and historical endowments. Britain comes out on top on many of these key tourism factors and air transport once again is at the centre.

Tourism is a two-way street and the UK sends many tourists abroad mainly to countries where sunny weather can be guaranteed, as well as to cities such as New York, Paris and further afield. Tourism by UK residents to areas like Spain, Greece and Italy is a considerable driver of economic growth in those areas.

Table 3.2: UK Residents Visits and Spending Abroad by Purpose of visit 1985–2005

Year	Foreign holidays taken by UK residents (m)	Visiting friends and relatives abroad (m)	Business travel (m)	Total	Total expenditure (£bns)
1985	14.8	2.6	3.1	21.6	4.8
1995	27.8	4.9	6.1	41.3	15.3
2000	36.7	7.1	8.9	56.8	24.2
2005	44.1	10.6	8.5	66.4	32.1

Source: UK Office of National Statistics. (ONS) Travel trends 2005

Table 3.3: Overseas Resident Visits Nights and Spending in UK 1985–2005

Year	Visits (thousands)	Nights (millions)	Spending (£ million)	Total expenditure in constant (1995) prices (£ms)
1985	14.4	167.0	5.4	9.9
1995	23.5	220.3	11.8	11.8
2000	25.2	203.8	12.8	11.1
2005	29.7	249.2	14.2	10.7

Source: UK Office of National Statistics. (ONS) Travel trends 2005

Roughly 80% of tourist journeys are made by air, which indicates the dependence of UK tourism on the airline industry. Both tourism abroad and tourist spending abroad have roughly doubled in the 20 year period between 1985 and 2005. However, back in 1979 only 9.8 million journeys were made on holiday, 2.5 million on business and 2.1 million visiting friends and relatives (VFR). That is a total of 15,446 journeys and only £2 billion in spending. By 2005, total journeys made by tourists had quadrupled and spending had increased 16 fold.

[31] World Travel and Tourism Council (2006)
[32] Department for Trade and industry; UK Competitiveness Survey 2005

In 1979, 63% of outgoing and 61% of incoming tourist journeys were made by air compared to 80% now. However 76% of spending by overseas residents in 1979 was accounted for by air travellers. That proportion had risen to 87% by 2005. It is often said that because the UK has a net imbalance in tourism that this is somehow bad for the economy. This is based on the fact that the outflow of UK tourists in terms of spending is not balanced by the inflow of foreign tourists. Yet the nature of these balances is very much influenced by the level of spending on exchange rate movements. Put simply, air passengers stay longer and spend more, accounting for over a third to a fifth of all spending.[33]

The Global Impact of Air transport on the Economy

The air transport industry is a huge industry globally. It contributes around £450 billion to world GDP or roughly 2.5%. The industry generates about 29 million jobs globally; 5 million of these jobs are direct with 4.3 million of these in the airline and airport industry. A further 6 million exist because of the air transport supply chain. 2.7 million jobs are "induced" (i.e. created) by the spending of air transport employees. A massive 15.5 million are provided via tourism with 6.7 million direct jobs and the rest are due to the "catalytic" impact of air transport on tourism. Tourism and the air transport industry combined are responsible for about 8% of GDP. A quarter of all global sales are dependent on air transport. Thus the industry is a massive driver of the world economy. The industry also boosts productivity as we have seen above in the case study of the UK. Air transport can drive an entire economy. Singapore Changi airport for example is responsible for nearly 9% of the nation's GDP.[34] Dubai's growth as a business and leisure crossroads would be impossible without its massive airport hub. Schipol airport in Amsterdam continues the Netherlands proud history as a trading nation responsible for 2% of GDP.[35]

The industry is also a massive force in uniting the world: 40% of the value of inter-regional trade in manufactured goods goes by air. About a quarter of the total value of international trade in manufactured goods is flown to its market. Aviation also helps to support people in difficult environments. One of the foremost examples is the role of air transport in times of famine, crisis and war. Where development is slow and an economy is held back, the air transport sector is one of the few dynamic and modern industries to exist. For example 170,000 air transport jobs are supported in Africa.

Many of these jobs provide a "skills cluster" which enables other parts of the economy to benefit.[36] Many environmentalists bemoan the detrimental effect they assume arises from the access which air transport permits. Yet the tiny Caribbean Island of Costa Rica has benefited from a decision to focus on eco tourism mainly from the US, Canada and Europe, in order to halt the process of deforestation. With alternative incomes from tourism the country was able to develop. Tourism in Africa has benefited enormously, also[37]. It is often said that the damage which air transport does to the developing world outweighs any benefits yet, as the next section will demonstrate, air transport is a positive force for

33 UK Office of National Statistics ONS International Passenger Survey
34 Economic Impact of Changi Airport; national University of Singapore (2001)
35 Air Transport Action Group "The Economic and Social Benefits of Air Transport" ATAG
36 Air Transport Action Group ; the Economic and Social benefits of Air Transport (2005)
37 Quoted in ATAG above

development. So if we are serious about eradicating the scourge of poverty, then the access to markets which air transport brings is essential. Kenya's agricultural exports such as fresh vegetables and cut flowers are the second biggest earner of foreign exchange. Colombia, a poor country with some undesirable exports, is able to satisfy demand for its flowers, vegetables and clothing, thus sending around 16% of its exports by air, mainly to the US. Many Caribbean countries rely on the export of fruit and fresh fish by air, again to the US.

Food Miles or Fair Miles: Fresh Flowers and Green Beans

The vital role of air transport in allowing the export of key products from poor countries has been a major factor in increasing the incomes of the poor. (Sachs et al).[38] For example, the cut flowers from countries such as Uganda and Ethiopia are only available in richer European markets because air transport allows them to be freighted quickly before they perish. They would never survive a sea journey and the convenience of air transport allows them to be enjoyed in the West whilst providing a vital higher value agricultural market for cash crops. Those who question the "air miles" used often forget the massive energy used in hothouse environments in Europe compared to the natural low energy growing environments of Africa. Many people are unaware that some of this traffic is carried in the hold of passenger aircraft, which would otherwise be returning with empty holds.

While it is true that some of these flowers and other products such as exotic fruits, vegetables and seafood are sometimes carried on separate freight aircraft, this fact must be balanced against the time penalty of marine transport and the nature of the products themselves. The argument that we should only buy local produce to minimise air transport is mean-minded and leads to higher prices in the west and poorer income in Africa. According to UK development experts, the International Institute for Environment and Development (IIED), those who use the concept of "food miles" to restrict imports from Africa are misguided.[39]

These experts go on to explain that such a move could hurt the world's poor, whilst conferring, at best, a marginal improvement to the environment. One of the report's authors, James Vorley, suggests that that although airfreight is very controversial from a climate-change perspective, it must be put into the context of the overall 'environmental footprint' of the total UK food system. It has both domestic and international elements, some of which — such as clearing Amazon forests to grow soy to feed 'produced in UK livestock — are usually hidden.

"Export horticulture is one of the few genuine opportunities to bring direct and indirect benefits to the rural poor in developing countries," says Vorley. "Air freight is currently the only possible mode of transport from most of Africa for highly perishable produce. More than one million people in sub-Saharan Africa depend on this trade for their livelihoods."

38 Sach's, Jeffrey "Make Poverty History" Penguin Books Ltd (2005)

39 'Fair Miles – The Concept Of Food Miles Through A Sustainable Development Lens', McGregor, James and Vorley, Bill IIED, (October 2006)

Airfreight of fresh fruits and vegetables from sub-Saharan Africa accounts for less than 0.1% of total carbon UK emissions," says Vorley. "Far greater emissions result from the domestic transport of food goods within the country. The UK must first look to the huge impacts of our food system at home before pulling up the ladder on Africa."

Indeed as we compiled this report, Kenyan farmers were said to be distressed by a decision of one leading UK supermarket to restrict the imports of air- freighted goods by half. To the farmers of Kenya, the income from air-freighted produce is not incidental. According to the Fresh Produce Exporters Association of Kenya, fresh flowers, fruit and vegetables make up 65% of all exports to the EU.

Pulling up the drawbridge on both economic and social opportunity for Africa and other poor regions would be the consequences of drastic restraints on air transport. The air transport industry is the engine of the world economy. When people assert that air transport is a wasteful and extravagant luxury, they ignore these very real benefits. At the outset we have acknowledged that air transport does indeed contribute to climate change through the emission of greenhouse gases. However that really does need to be put in perspective as we show in the next chapter.

The economic and social benefits of air transport are often overlooked. This is largely because we take them for granted. Those who argue for the curtailment of air transport need to think through what they are proposing. They need to address the consequences of such a move. The UK, for example, with its historic dependence on international trade, is especially vulnerable to any curtailment of air traffic. The environmental impact of air transport is an important issue but it does need to be viewed in all its complexity and set in the context of other forms of economic activity and modes of transport. We turn to that in our next chapter.

Chapter 4: Understanding the Causes of Climate Change

The causes of climate change are a controversial subject. It is not our intention here to debate the various scientific positions that have been taken up on this issue. However, there does seem to be agreement that greenhouse emissions are a major element in climate change. This then raises the obvious question as to what are the sources of these emissions? The environmentalists and policymakers seem to be intent on pointing the finger at the airline industry. This is completely misplaced and flies in the face of the facts.

So air transport is often seen as the bogeyman for environmentalists and policymakers. Few fields of scientific research are more affected by selective use of data, hyperbole and inflated forecasts of impending growth than when environmentalists study air transport. It is as if they cannot believe the evidence on air transport and therefore argue that its real impact on the environment is much higher. In order to substantiate their argument they often inflate their statistics. For example, the scenarios used by the Tyndall Centre, based as they are on constant exponential growth, would apparently require five new Heathrows to be built every five years.[40] As we have shown, aviation's true impact upon the environment is limited and its assumed growth as a proportion is predicated upon the fall in other emissions. These emissions can be mitigated by developing alternative fuel sources and through other technical innovations. Air Transport, because it is dependent on fossil fuel has less latitude in this regard and yet, as this chapter will show, makes significant progress. There have been step changes in efficiency of fuel burn, in engine emissions performance and in aircraft operational performance as well as in some technologies which will mitigate aviations' environmental impact even further.

Air transport is still responsible, according to the Stern report, for 2.5% to 5% of global emissions and though that proportion may be growing it is still a small percentage of the overall growth in carbon dioxide and other emissions affecting climate change.[41] Air transport is also responsible for a small proportion of the emissions emanating from transport. For example in the UK, even though the amount of CO_2 emitted by air transport has doubled, it has done so from a low base. Between 1990 and 2005 aviation accounted for about 8 million tonnes.

Other sources of carbon emission such as energy generation and manufacturing have reduced their output of carbon dioxide, yet their share of total carbon emissions remains massive. The increase in road transport emissions in the 15 year period (1990–2005) denoted in Fig 4.1 from 109 to 120 million tonnes of carbon eclipsed the total contribution of air transport.

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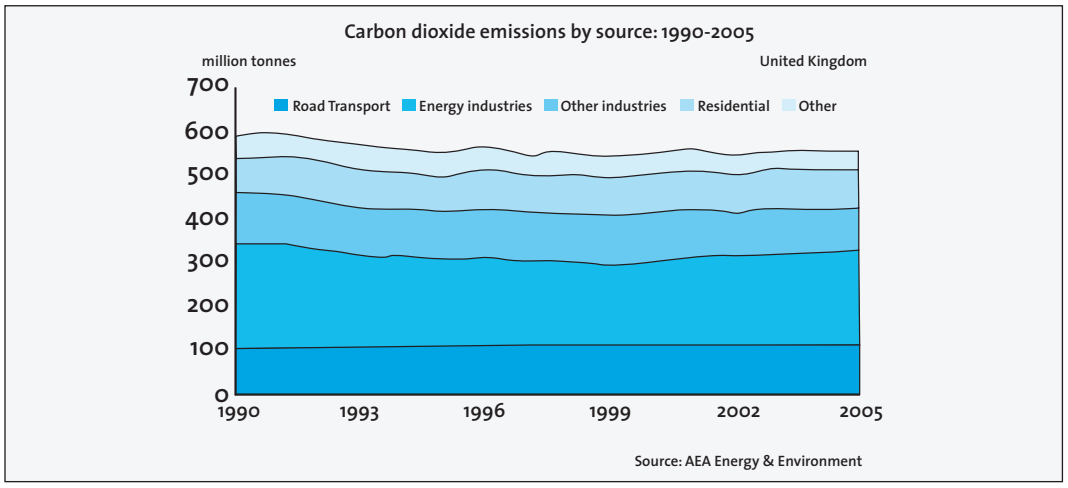
40 House of Commons Environmental Audit Committee Third report 2004

41 The Economics of Climate Change: Review conducted by Sir Nicholas Stern; HM Treasury October 2006.

The absence of a discrete aircraft emissions 'signature' in Fig 4.1 below, alongside those of road, residential and industrial, accurately reflects the true context of aviation in overall emissions. This graph represents the emission output as determined by the UK Environment Agency. Aviation is just not on the radar screen as a big polluter and only when delving deeper, as shown in Fig 4.2, can we identify a distinct aviation emissions trend based on fuel uplift. This graph plots the trend in UK carbon dioxide from UK bunkers i.e. fuel supplies used by both internal and external parties. In the case of aviation it can be seen that the two emissions taking account of all aviation demand have roughly doubled in the 15 years. That new figure of about 8 million tonnes is a small proportion of the overall figure. It is only 7% of the road emission figure for example, less than 4% of the figure for energy emissions and less than one tenth of the emissions from domestic energy use. In addition, most shipping which visits the UK is refuelled outside the UK, explaining the low reporting of UK shipping fuel. Of course we acknowledge that aviations impact is set to grow but it is growing from, and will remain, a low overall percentage of emissions.

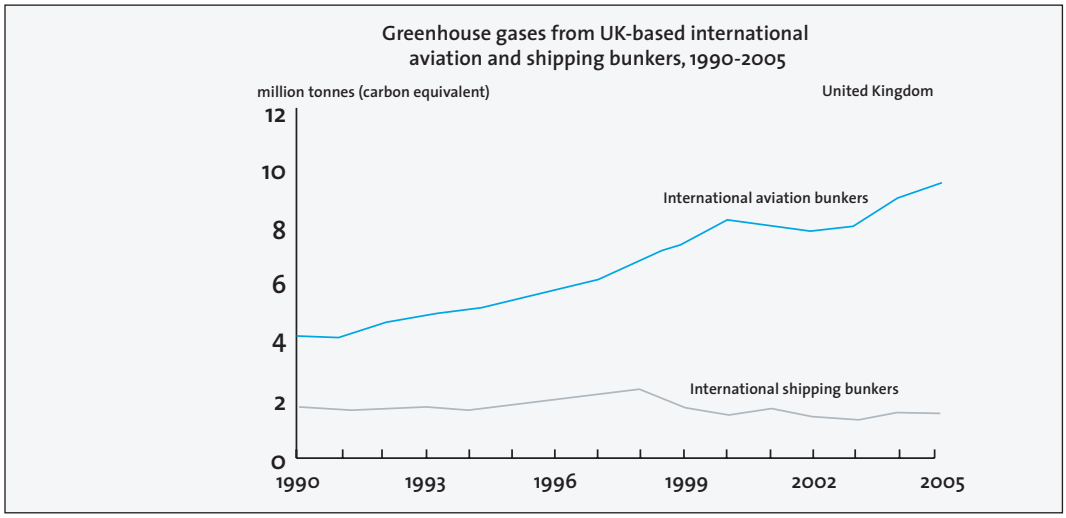
Fig 4.1 UK Carbon dioxide emissions by source: 1990–2005



	million tonnes (carbon dioxide equivalent)					
	1990	1995	2000	2003	2004	2005
Road transport	109	111	116	118	119	120
Energy industries	236	199	191	208	207	208
Other industries	114	107	109	100	98	99
Residential	79	80	86	86	87	83
Other (mainly commercial & public sectors)	51	52	48	45	45	46

Source AEA/DEFRA 2006

Fig 4.2: Greenhouse Gas Emissions Trend UK Aviation 1990–2005



Emissions Start at Home: The Contribution of Home Energy Use

Approaching airports on wintry mornings pilots can identify the houses which are poorly insulated. They are those where the frost has been melted by the escape of heat through the roof. This waste and inefficiency is a key issue in the generation of CO2 and other gases. Whilst it has become fashionable to attack the so called "hyper-mobility" of western societies with increased demand for transport as the culprit, the biggest emissions' footprint is on the home hearth and on the office carpet.

It is mainly in our homes and businesses and through simple over-consumption of fossil-generated fuel, compounded by our inefficiency in retaining heat, that we lose most energy. This is energy which has to be continually and wastefully re-generated. Households are responsible in the UK at least for 25% of energy consumption. Only 35% of UK homes are, according to a recent government report, sufficiently well insulated to retain heat, with one energy expert calling most UK homes "tunnels built for the escape of warm air".

That means the energy wasted in inadequate insulation of homes dwarfs the contribution of air transport which, as we've pointed out, accounts for only 0.5% of carbon emissions. Even if we applied the disputed radiative forcing factor of 2.7, we would have a total contribution of at most 1.4% when accounting for international traffic between 7 and 14%.[42]

That overall percentage may well grow but only to an upper estimate of about 6% according to the IPCC. Even if we assume that a 15% share of carbon emissions is possible by 2050, according to the unconstrained growth scenario, then air transport is still an insignificant contributor to climate change. Indeed the hysteria over the environmental

42 Forster, P M. de F., Shine, K P., Stuber, N (2006) "*It is premature to include non-CO2 effects of aviation in emission trading schemes*". Funded by a NERC research fellowship and the European Union Framework 6 Integrated Project (QUANTIFY). This latest research throws severe doubt on whether this multiplier should be used at all in emissions discussion but as it is used with abandon by critics we will deal with it throughout the report when calculating the effect of air transport

effects of air transport suggest that it's visibility and profile as an industry may make it more of a target than more mundane sources of climate changing pollution such as car use and home energy consumption. For example, enforcing building regulation to a higher standard and ensuring that revolutionary new designs such as the German "Passivhaus" concept could save more carbon energy than tinkering with aviation.

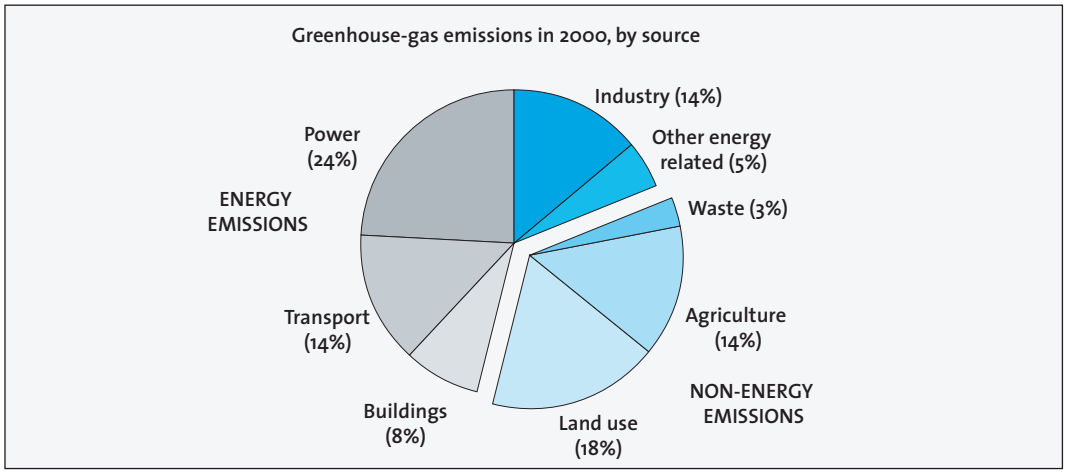
Pollution at Work: the Contribution of Industry and Retail

Industry uses a lot of carbon energy to build products, to heat and maintain offices and that excludes the transport of people and goods to and from markets and locations. For that reason it is responsible for around 26% of emissions in the UK and comparable levels in other industrial nations.[43] The Stern Report identifies industrial emissions as contributing 14% of total global CO2 emissions, a lower figure accounting for the non industrialised world. Heavy manufacturing and fuel intensive production take up the majority. The iron and steel industry alone is responsible for 26% of these industrial emissions. Chemicals and petrochemicals, including plastics, are responsible for 18% of the total emissions for manufacturing and construction or 2.5% of the total. [44] High energy consumption is the nature of advanced industrial development. However, there is also plenty of scope for savings. Just as fuel is a massive expense for the aviation industry, energy efficiency is a major driver for business efficiency.

Because of a phenomenon known as "Khazzoom-Brookes Postulate" efficiency savings in such sectors often lead to an increase in energy consumption overall.[45] The cost of running shopping malls falls so the consequence is that more shopping malls are opened. The same phenomenon operates at the level of the domestic consumer. More energy savings produce more disposable income, which leads to more gadgets bought which then consume more energy and so on. The possibilities for alternative fuel use within industry and a reduction in the fossil fuel needs is significant, but it can be seen that this sector will dwarf the consumption which comes from air transport.

43 United Kingdom Department of Environment Food and Rural Affairs (DEFRA) Environmental Statistics 2006
44 Stern, Nicholas: 'The Economics of Climate Change' (HM Treasury 2006)
45 Khazzoom J D., Brookes, F.; 'Economic Implications For Mandated Efficiency Standards For Household Appliances'. (Energy Journal Volume 1: (1980)

Figure 4.3: Greenhouse gas emissions by source



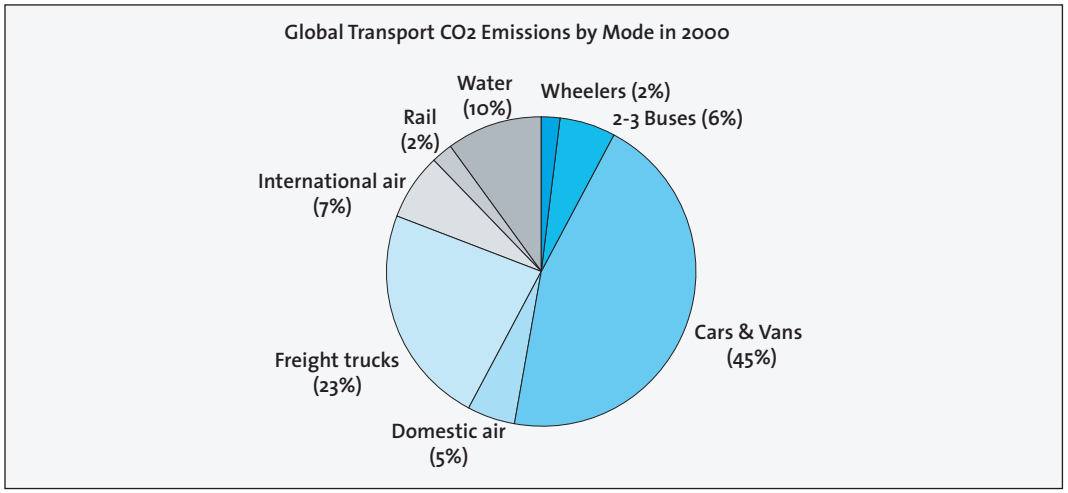
Source: Stern report Annex 7 (d)

Driving Climate change: The Contribution of Other Transport Modes to Global Emissions

The share of transport emissions for the estimates used in the Stern report is 14% of total global CO2. Of that cars and other road vehicles are responsible for 74% of emissions. Water-borne transport which includes oceanic shipping and canal traffic, as well as ferry services, accounts for 10% of emissions. Rail is responsible for 2% of the 14% of emissions generated by transport. Air transport is responsible for 12% of transport emissions.

With the growth in world trade and the ballooning growth of developing economies, we can expect to see a massive increase in car use as well as a growth in oceanic shipping. Air transport is currently responsible for 12% of the emissions from incoming domestic and international flights. Yet whilst air transport is expected to grow it will only account for some 2.–3% of global emissions by 2050.

Figure 4.4: Emissions by Mode of Transport (2000)



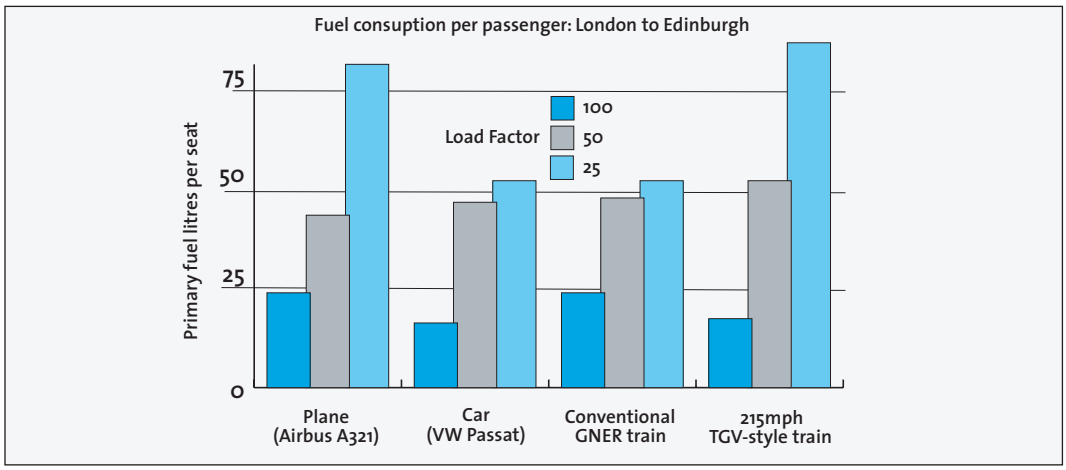
Road traffic is responsible for the overwhelming weight of carbon emissions, although, like aviation, the automotive sector has a good record of developing technological solutions. The removal of lead from petrol, the development of catalytic converters to allow unleaded fuel to be burned and a massive research programme into biofuels and electric propulsion are all examples of how the road sector can reduce its emissions as it grows. The situation is similar for air transport.

Rail's low level of emissions is a reflection of its restriction to a few areas of the world; principally in Europe. Passenger train services are sparse throughout the wider world.

It is often asserted that fast high speed trains competing from city centre to city centre obviate the need for air transport and would be much more environmentally sustainable. Yet when we compare the relative utilisation and speed factors even an arch opponent of aviation such as the radical environmental journalist George Monbiot reckons that air transport would be more carbon efficient over a relatively short haul journey such as London-Edinburgh than the much vaunted high speed train.[46] Monbiot cites research by Professor Roger Kemp of Lancaster University. Kemp suggests that a standard high speed train travelling at roughly 350 kph, would consume the equivalent of 22 litres of fuel per seat on the journey. Compare that to a typical airliner, such as the A321 which would consume 20 litres per seat at 900kph . Indeed, Monbiot argues that the existence of such a high speed line would draw passengers away from the more environmentally efficient land option of coach travel.

46 Monbiot, George, *Heat*: How to Stop the Planet Burning; Penguin Allen Lane 2006

Fig 4.5: Relative Emissions Performance by Mode of Transport



Source: Kemp, University of Lancaster

According to Dr Kenji Takeda, an aeronautical scientist at Southampton University, there is even a case which can be inferred from this data for encouraging people to shift from car to plane. He reasons that available airline capacity operating at maximum utilisation would be more efficient than many car journeys in terms of emissions per passenger kilometre for many long distance journey undertaken by car.[47]

Paul Upham, a research fellow at the Tyndall Centre, which researches sustainable ways of tackling climate change, believes that the environmental performance of air transport has been underestimated. He has used the European Environment Agency's preferred measure of fuel consumption, "Corinair", to compare a journey from Manchester to Guernsey. A fully-loaded Saab 200 turbo-prop on this route produces 103kg of CO_2 per passenger, while a Nissan Micra carrying one emits 226kg. Obviously, that figure is cut dramatically if two or more people are sharing the car. But Upham admits he was "very surprised" at the finding.[48]

Upham argues: "Planes aren't the evil things relative to cars that people imagine," he says. Trains are still the least polluting form of transport for longer journeys. But even trains have their own carbon load, and not all trains are equal: diesels are more polluting than electric trains, for example. In the UK only 40% of trains run on electrified tracks, the vast bulk on the commuter routes of the South East.

A recent calculation by the Environmental Change Institute at Oxford University showed that it was more polluting in terms of energy use to get to Paris by Eurostar than it was to jump on a full low cost flight. Many environmentalists are concerned about high speed rail in any case, principally the energy cost; much of which is generated by fossil fuel.[49]

47 Interview with Author Southampton University February 16th 2007
48 Upham, P. (Tyndall Centre 2005)
49 UK Parliamentary Environmental Audit Committee Questions 620–629 07.07.06

Getting the Train to Look Like a Plane

In trying to square the circle between the speed of air transport and the environmental efficiency of trains, many politicians and policy makers continually raise the issue of major magnetic levitation or 'maglev' projects. The idea is that if we could get people to use an "aircraft like" train moving at 350–500 Kilometres per hour, we could entice people away from actual air travel.

However, the electricity to power such trains would come from renewable sources, although given the decline in anticipated oil reserves that might not be possible. The fact is that most on stream available generation capacity will come from fossil based fuels in the medium term, many of which are likely to use coal.[50] The best current example of maglev technology in operation is at the new Shanghai's airport where, arguably, the rapid rail does what rail does best: feed people to city centres over short and medium distances. However, the Shanghai maglev cost $1.2 billion (£600 million for a distance of 30 kilometres. That works out at £30 million per mile. The cost is prohibitive while the land use issues of major rail construction, through built-up urban environments and rural farmland, are often underestimated. A proposed trial maglev between Glasgow and Edinburgh would cost around £4 billion pounds for 50 miles of track. Maglev projects are enormously expensive, requiring over-ground flyways and tunnelling. The fastest even require pressurisation like a conventional aircraft. A scheme to link Tokyo and Osaka with a maglev could cost £82 billion. These are enormous costs to set against air travel which makes a relatively small impact on the environment. The construction process alone would probably go some way to wiping out the assumed environmental benefits. If the costs were borne by taxpayers this would be grossly inefficient and unsustainable. Even the French TGV Mediterranée cost £15 million per mile and maglev costs are much higher. In any case according to one expert, over really long distances (> 900 miles) ultra high speed rail would never compete with air transport in terms of either speed or efficiency.[51] These are medium distances for airlines so the likes of Paris-Oslo or Madrid-Munich and virtually all intercontinental travel would be out of reach for high speed trains on that basis. 80% of aviation's greenhouse gas emissions are related to passenger flights exceeding 1,500 kilometres or 900 miles. For these journeys there is currently no practical alternative either on efficiency or environmental grounds. There comes a point where the assumed goal of environmental efficiency needs to be traded against the use of existing capacity. If even a fraction of the amounts some politicians are dreaming of channelling into maglev type projects were put into research for fuel efficient aircraft and propulsion systems, there would be much greater benefits.

Sea Transport

One mode of travel which cannot compete with the speed of air travel for passengers but which is highly efficient for moving much of the world's heavy freight and raw materials is oceanic shipping. Again it is often suggested that instead of using airliners to fly to distant

[50] As oil and gas reserves deplete in the long future coal based electricity generation will become much more economically viable, thus increasing the carbon content of the generation mix

[51] Suppes, G.J. 'A Perspective on Maglev Transit and Introduction of the PRT Maglev' Department of Chemical & Petroleum Engineering University Kansas

lands we should instead use ships. Some individuals make a virtue out of taking three to six months out of their lives to travel by ship to places like Australia, but for most people this is not practical. However ships, as currently configured for passenger operation, are hugely more carbon inefficient than air travel. The QE2 which bears comparison with any other cruise liner burns nearly 8 times as much carbon as an airliner on a round trip to New York. Of course no one in the luxury cruise market tries to sell sea passengers voyages on their environmental footprint but the fact is that many uninformed people assume that shipping is a sustainable alternative to aviation. They imply that that if we just "slowed down a bit and curbed our need for instant mobility" we could gain the benefits of travel whilst not harming the environment. Shipping however even on ferry journeys such as the crossing from the UK to Ireland and on the long drive cruises to Norway is much more environmentally damaging than air transport. According to a new report commissioned for the EU, the average ship consumes, about five to ten times as much carbon as an aircraft.

According to the EU Commission, ships are fast becoming the biggest source of air pollution in the EU. Unless more action is taken they are set to emit more than all land sources combined by 2020.[52] In 2000, EU-flagged ships also emitted almost 200 million tonnes of CO2.. This is significantly more than emissions from EU aviation.[53] The difficulty of moving massive weights of cargo across distance using a massive structure like a ship cannot be underestimated. Shipping is likely to be the preferred method for moving the bulk of the world's goods and the contribution of shipping globally is still only 10% of overall transport emissions.[54] However it does indicate once again the need to get the environmental impact of flying into perspective.

The contribution of air transport to global emissions is rarely, if ever, seen in its proper context. By comparison with other forms of transport, let alone other contributors to climate change, the air transport industry is a small contributor to carbon emissions. This fact is just ignored. Even when radiative forcing (a disputed multiplier of the effect on the upper atmosphere) is taken into account, the contribution to global emissions by the air transport is still much lower than the contribution from other sources. Moreover, the air transport industry is well aware of its impact and is seeking as it has always done to control its environmental footprint by harnessing the incentive to economic efficiency and the spur of technological development to ensure that these impacts are further minimised.

52 EU DG TREN Clean Air for Europe impact assessment, p31 (2005).
53 EU DG TREN Ship emissions assignment report, p160 (2005).
54 The Economics Of Climate Change (Stern review. HM Treasury Dec 2005 (Annex 7c)

Chapter 5: Flying Smarter: Operational And Technical Solutions To Reduce Emissions

The global airline industry has worked ceaselessly and especially since the mid–1990s, to reduce its environmental impact. And in a very short timescale it has already achieved a great deal. Over the last 10 years alone fuel efficiency has increased by 20%. The average aircraft now produces 3.5 litres of CO_2 per passenger. Noise impacts have improved dramatically with a reduction of 20 decibels over the last 40 years with a planned reduction of a further 10% by 2030. Visible smoke and hydrocarbons have been virtually eliminated from modern aircraft and the nitrous oxides from aircraft engines have been cut in half over the last 15 years. This is significant progress by any measure.

As has already been emphasised, fuel is a major driver for efficiency and costs, so airlines must utilise their aircraft to the maximum which is in contrast to other types of transport where subsidy has the opposite effect. The air transport industry also wants to minimise its impact on the environment as much as it can by improving its operational efficiency and by harnessing future technology. This chapter looks at what the industry is currently doing to meet this challenge and what it can do in the future. We focus firstly, on the issue of air traffic management, where there is huge scope at national, regional and global level to generate efficiencies.

ATC (air traffic control) segregation: A waste of airspace?

Two of the paradoxes of the global airline industry are, firstly, that it has tended to be characterised by national ownership and protected markets, and, secondly, that its invisible infrastructure, the airways, are nothing more than a patchwork of national air traffic control authorities. Yet this is supposed to be a global industry.

Each nation presides over its often tiny patch of sky. The emphasis is on protecting national air sovereignty and extracting effectively what are no more than aerial tithes from the world's airlines, rather than increasing the efficiency of throughput of air traffic. Of course aerial sovereignty is an issue for nations, but there are surmountable barriers to efficiency. There will always be military requirements and a need for nations to close their airspace, but in truth the functioning of our air traffic control systems could be improve hugely by better co-ordination, that is, by ensuring that countries which are close together route traffic in a way that allows airlines to fly their most efficient routes. This would bring an improvement in emissions globally of up to 18% which would be a huge gain, although the positive feedback of better managed capacity could bring even greater gains.[55] This is factored into the industry's environmental mitigation requirements as outline in the IPCC report.

55 IPCC "Special Report Aviation and the Global Atmosphere (1999)

The first issues to consider are the efficiency of national air traffic systems. Can the flow of aircraft during both terminal approaches and "overflights" be marshalled in such a way that safe separation is maintained at all stages and efficient direct routings are maintained? It seems that many countries cannot answer this question in the affirmative. For various reasons, air traffic control systems have evolved using different layers of technology. Much of this technology only operates safely and efficiently in small blocks. This is sometimes overlaid with better technology but this then produces a mixture of systems, which can be dangerous. From the point of view of pilots as the end users of air traffic control (ATC) services, ATC need to be safe, clear, transparent and consistent. Often this is not the case. Recently the 'Global Voice of Pilots', the International Federation of Air Line Pilot Associations (IFALPA), criticised the Brazilian ATC system, where radar use is combined with traditional "surveillance" and "talk down" approaches and where communication is often impaired. [56]

IFALPA rightly concentrates on safety, but safety is a systems issue and the organisation is concerned that the government's lack of effective oversight is the real cause of deficiencies in Brazilian ATC and of shortcomings elsewhere. In Africa, for example, there are several air traffic control authorities which are deficient to the extent that IFALPA has awarded them black stars, deeming them unsafe.[57] Put simply ATC systems are often un-coordinated at national level and they need to be better managed. There is considerable scope for these services to be provided regionally across a number of countries. There is also an acute need for investment which poor countries cannot meet although considerable finance has been channelled into infrastructure improvements in the past. There needs to be a partnership between advanced providers in the developed nations and those emerging aviation nations with funding earmarked and policed by ICAO.

If ATC is better managed, then a positive by-product of this will be better routing, better aircraft utilisation and therefore less fuel burn and emissions. The average operating cost of a large aircraft according to IATA is about £50–60 per minute. The minutes wasted include a significant volume of fuel. At average fuel consumption rate there is in fact massive waste. Better airspace design and management is a key part of reducing this. An aircraft flying just 4,000 ft below its optimum cruise altitude will use 400 kgs of extra fuel per hour. Differences between aircraft types can also be a factor. Two leading aerospace academics argue that there are huge fuel savings to be gained from an effective system of flight path performance categorisation.[58] IATA estimates the cost at around 10 pence per mile. Multiplying this by the number of flights it's easy to see that savings could amount £2 million per aircraft per year.

56 IFALPA Safety Bulletin 29th January 2007. The recent crash in Brazil of an American aircraft brought into sharp relief the deficiencies of ATC and for a time disabled the national air transport system, wreaking economic havoc.

57 See Proceedings of Aviation Safety and Security Africa Johannesburg 18–20th July 2006

58 Cavcar, A, Cavcar, M,. 'Impact Of Aircraft Performance Differences On Fuel Consumption Of Aircraft In Air Traffic Management Environments'. Aircraft Engineering And Aerospace Technology Vol 76 No. 5. 2004 (pp205–215

This cost saving imperative has a massive environmental "pay off" as fuel is the source of most emissions. Over the last decade, air traffic in the European states has grown by more than 50%. Europe now has close to 8.5 million flights per year and up to 28,000 flights on busiest days. Even so, airspace capacity has been increased by 80% since 1990. However, Europe needs to make better use of its airspace. The European Commissioner for Transport claimed that the Single European Sky (SES) initiative would enable reductions of emissions from aircraft by 4–6% per flight through the use of more efficient trajectories (Flight International, 22 November 2005).

Congestion and Capacity Shortages: Hampering Environmental Improvement

Fuel and resources are also wasted on the ground. Those who are most voluble about additional airport development as envisaged in the UK Government White Paper of 2003[59] are most likely to benefit from any increase in provision. The reason is simple: with more space to manoeuvre, optimal runway space to use and more direct approaches, operational efficiency can be enhanced. Noise effects can be minimised as can the fuel burn which contributes to pollution.

The continual opposition worldwide to airport development makes it very difficult to build airport capacity. Campaigners such as those around Stansted and Heathrow for example campaigned for a new airport at Cliffe on the Kent coast. Others dreamed of a seaborne airport off the coast of Essex, linked by fast train services. Campaigners wanted to move the airport away from its current location. Indeed some Heathrow campaigners wanted to create an international hub at Stansted, and reduce Heathrow to a city centre airport for business only.[60] Setting aside this "NIMBY" (not in my back yard) approach, the economic benefits to the nation as a whole are considerable. The construction of two additional runways in the South East would bring £17 billion in benefits according to a major UK government study of the role of transport infrastructure.[61]

Congestion in the skies is exacerbated by the lack of airport capacity. The Eurocontrol Report on 'Challenges to Growth 2004' pointed out that, taking a growth scenario of 4.3% p.a., more than 60 European airports will be congested by 2025 and the top 20 airports will be saturated at least 8–10 hours per day. There is an urgent need to develop new airport infrastructure whenever and wherever it is possible. However at airports where expansion is not feasible, efforts should be focused on making the best use of existing capacity.[62]

The key argument of campaigners is that expanding an airport like Heathrow is madness.[63] However, once an airport has been developed over many years the efficiency of building

59 Future of Air Transport: UK Government Website 2003
60 Stop Stansted Expansion Website. Nov 2003
61 Transport's Role in Improving the UK's Productivity and Competitiveness. UK Govt: The Eddington Transport Study (Dec 2006) Campaigners have been quick to rubbish Eddington's report. They see him as a Nuclear engineer and former Airline CEO as the worst possible individual to oversee a study of transport infrastructure. Its precisely because he is aware of the economic benefits and the environmental pitfalls of transport policy that the government asked him to undertake the study. So far critics have not provided convincing alternatives nor discredited his data or findings.
62 "Challenges to growth in 2004" Eurocontrol 2003
63 This is based on the common sense assumption that the airport is already congested.

upon and using existing facilities is unanswerable. The airport is also central to the economic success of the area. If Heathrow was removed from the economy of West London it would leave a gigantic economic hole. That gap would not necessarily be filled by building it in another location; traffic might well migrate to other European hubs.[64] Many point to the movement of Hong Kong's inner city Kai Tak to Chep Lap Kok, but this is a bad comparison, as this was an elderly airport with no land available to build. However as the case of Schipol airport shows, if the runway capacity cannot be fully utilised because of noise constraints and other local environmental constraints, then the operational efficiency of movements will be compromised. Aircraft will be queuing up to land and depart and will be burning more fuel. Therefore the emissions reduction will not occur to the maximum extent possible.

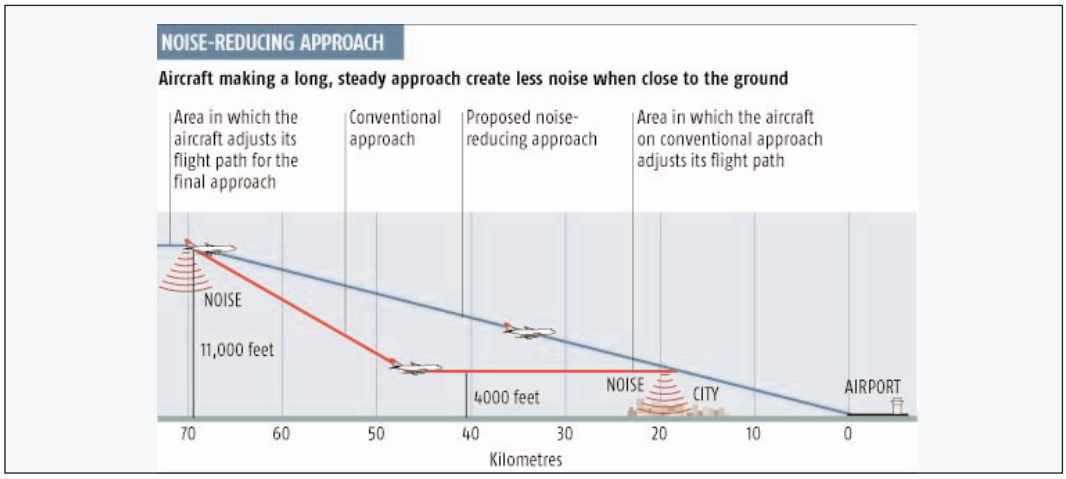
Flying A "Greener Approach"

Bound up with the issues of more efficient use of ATC capacity and improved infrastructure, is the possibility of major improvement in aircraft operating procedures. These are reaping dividends in terms of environmental performance, whilst technology develops better design and new types of fuel. Airlines can use a variety of measures many of which depend upon the operating skills of the pilot and the controller. A continuous descent approach (CDA) is one example. Instead of the normal inefficient stepped approach, with a CDA there are no noisy and fuel 'thirsty' level offs along the descent path. This helps reduce emissions as well as shrinking the noise footprint. Single engine taxi procedures, whereby a two engined aircraft is manoeuvred around the apron with only one engine running, also helps to deliver better environmental performance.[65] The flight profile of the aircraft in terms of flap deployment etc, operating the most fuel efficient speeds and altitudes, loading the optimum fuel required for the route and measures to minimise the weight all help because they conserve fuel. Frugality on fuel is the key to better environmental performance.

ICAO published guidance on such environmental efficiency issues in 2004[66] For example SAS utilises CDA at Stockholm's Arlanda Airport. Pilots communicate with ATC over a data link. Pilots and controllers work together to operate a "green approach". The flight crew enter data into the Flight Management System which is then downloaded to a ground based specialist known as the Arrival Manager. Using the ACARS[67] system (Aircraft Communications Addressing and Reporting System) and SAS's own operational data a "green approach" will be made in light to medium traffic saving over 100 kgs of fuel per approach. The same approach used in dense traffic with better ATC could reap savings of more than double that level.[68] These are significant gains.[69]

64 Department for Transport White Paper Progress Report
65 ICAO ';Operational Opportunities to Minimize Fuel Use and Reduce Emissions' (ICAO circular no 303, 2004)
66 Operational Opportunities to Minimize Fuel Use and Reduce Emission (ICAO circular no 303, 2004)
67 (Aircraft Communication, Address and Recording System), A system of air to ground communication used in commercial aircraft.
68 *Airlines International* April/May 2006
69 See *New Scientist* Nov 24th 2003.

Fig 5.1: Continuous Descent Approach Path



Source: NewScientist.com

One other possible direction for the application of advanced ATC technology is in the issue of contrail avoidance. If aircraft could avoid patterns of moist air and fly avoidance paths then the additional impacts beyond CO2 could be minimised. The meteorological information required to identify contrail paths could be incorporated into flight plans. Displaying contrail activity as an environmental hazard could become a feature of new developments in avionics and taking avoiding action would then become commonplace much as aircraft currently use technology to avoid the hazard of thunderstorms.

Efficiency in capacity utilisation the best operational solution

The most significant issue therefore in terms of operating efficiency and in terms of the environmental impact is load factor. Because environmental impact is contributed per seat, it's important that aircraft are as fully loaded as possible. Thus load factors of 75% and above are optimal. Most flights operate with high load factors in contrast to other modes of transport. Sometimes a busy high speed trains such Eurostar or the Virgin West Coast service in the UK all have load factors as low as 40 percent. A recent train accident revealed the train to have a load factor of below 25%.[70] Rail load factors are low generally because rail is subsidised, whereas airlines by contrast have every incentive to axe routes which perform below a criteria known as "break even load factor", which denotes the level at which a flight becomes uneconomic relative to the capacity flown.

Without an honest comparison of rail and aircraft load factors it is not possible to properly evaluate the comparative efficiency of both. In any case we mustn't forget that the most likely alternative to flying is not the train but driving. The UK Commission For Integrated Transport estimate that if 10% of the current 8 million passengers who fly between England and Scotland switched to rail, there would be insufficient capacity on the trains to

[70] The Virgin train derailment in Cumbria 22.02.07 had nine coaches of 48, a capacity of 439 and a load factor of 23%

absorb them.[71] The only alternative would be by coach or car. Most people will see a car journey as preferable to the slow journey south by coach. Load factors on average cars will be around 25%, as most cars are single occupant, therefore the fuel consumption over distance is poorer. There is also some evidence that flying point-to-point can reduce the environmental impact, although there is also an advantage in having economies of scale and scope through hubs. (see panel below)

In a recent study published by Cranfield University, five long-haul markets were evaluated both on a hub-to-hub and hub by-pass (point-to-point) basis. The transatlantic and Europe/Asia routes studied were Glasgow/Chicago, London/San Diego, Hamburg/Tokyo, Glasgow/Dallas and Hamburg/Dallas. It was found that the noise and emissions social cost impact of the point-to-point networks was significantly lower than the hub-to-hub in all cases. The difference in environmental costs ranged between 25 percent and 73 percent, depending on the concentration of population around the airports and the degree to which the hub routing involved extra mileage. The difference increased to a range of 56 percent to 115 percent, if a stimulation factor of 25 percent was applied to the non-stop market. The environmental cost-saving for the non-stop flight amounted to just under 20 percent of the total aircraft operating costs of one of the cases considered. Not only is point-to-point less expensive to operate, it is also better for the environment. (source Boeing Website 2007)

The quiet revolution in modern aircraft technology

After improving ATC and infrastructure, it is clear that the airline industry is still left with a conundrum. It burns fossil fuel and there is as yet no viable synthetic replacement for kerosene. However, modern aircraft are reaping incremental savings in fuel and thus minimising the environmental impact considerably. Much of this technology is improving a technology dating from the 1950s, i.e. the basic jet engine. But the structural efficiency of aircraft is improving too. The introduction of lightweight alloys and composite materials has ensured lower weight, and better engine performance, as we have seen above, has directly reduced emissions. The development of better types of combustion unit such as the Dual Annular Combustor (DAC) (see chapter 3), will ensure that the precious fossil fuels used in aviation are minimised in the next generation of aircraft. This fuel saving is roughly 2% per year annually which amounts to a major saving in fuel efficiency over time.

[71] Commission for Integrated Transport CFIT "Road Rail Comparison; Capacity issues" November 2003. This is also the estimate of the IPCC on the amount of rail and coach substation which could take place in Europe. (IPCC 1999).

Fly lower: the options

Flying lower is also an option in the armoury of reducing the environmental impacts of aircraft in flight. The best example is turboprop aircraft which tend to emit less kerosene and contrails because they tend to fly lower than jet aircraft. Many regional operators use these aircraft the world over; the most efficient new generation turboprop aircraft use just 59% of the fuel per passenger mile as a conventional passenger jet. Turboprops also operate at lower altitudes so they are able to create fewer contrails. However turboprops would not be appropriate for distances above about 2000 km and many environmentalists are already complaining that regional city to city connections are unnecessary. This argument is nonsensical for it cites the high speed rail as an alternative. As we've already seen, rail load factors can be much lower than an efficiently loaded aircraft, and the duration and inconvenience, for example, of a rail connection from Aberdeen to Bristol is such that regional operations whether by jet or turboprop can often be the environmentally efficient as well as the faster option.

A turboprop consumes less than 0.2kgs of kerosene per passenger per kilometre. Therefore on business routes such as Southampton-Frankfurt or Bristol-Edinburgh, these aircraft are very efficient. Taking into account its climbing and cruising characteristics, a new generation turboprop such as the Dash 8-Q400 can match a jet for speed. Flybe, the UK low fare regional airline, is promoting the fact that its fleet of Bombardier Q400s burn half the fuel of a 50-seat jet.[72] So turboprop aircraft are eminently suitable for many routes. Regional jets are also efficient with the new generation of jets such as the Embraer 170–190 and the new CRJ (Canadian Regional Jet) operating on much less fuel than standard jets and with increased range becoming suitable for more markets; though there are obstacles.[73]

The Alternative fuel conundrum

There are no practical alternatives to kerosene according to IPCC[74]. This leaves the industry with a fuel headache. The airline industry has long experimented with alternative fuel. For example there is a Brazilian version called PROSENE involved mixing vegetable oil with aviation kerosene. When South Africa was under international sanctions in the apartheid era, the country developed a fuel alternative for aviation known as SASOL, a blend of half synthetic kerosene and half crude oil.[75] Of course the refining process uses up a great deal of energy, while the efficiency, that is the amount of fuel generated for inputs, is variable. However, what is clear is that in a world of unstable oil prices and diminishing supply, airlines need alternative fuel technologies. When considering fuel requirements for aircraft we need to keep in mind two severely limiting parameters which don't constrain ground

72 Flybe website

73 The spread of regional jets is however held back by the desire of airline operators to pay professional pilots on regional jets much less than they would be paid on standard narrowbodies. Operators try to equate the lower pay scales for both regional turboprops and jets to lower operating profits, yet they trumpet the profitability of operations conducted using such aircraft.

74 IPCC "Aviation and the Global Atmosphere" 1999

75 Air Transport Action Group website "Fuel Consumption and Alternative Fuels" http//ww.atag.org. 23.02.07

transport. Firstly, aircraft need to be of relatively light weight; secondly, aircraft fuel, because it takes up space, has to have a high ratio of energy content per unit. In other words more pounds of thrust for the pound!

Various solutions have been proposed. For example, one possibility is the use of hydrogen, which generates no greenhouse gases, but because of its chemical properties would require aircraft to become much larger, in effect flying hydrogen tanks. Boeing conducted research which showed that a hydrogen-fuelled B737 would require tanks to be situated in a much wider cabin. Because the insulation equipment for hydrogen storage would take up most of the wings this would be impractical. Even if hydrogen could be compressed into a suitable space – a major challenge for chemistry and physics – it would still emit considerable extra amounts of water vapour. The science suggests that tripling the water vapour could, through contrails, cause cirrus-forming contrails in the troposphere where aircraft tend to fly. Once again, the level of scientific knowledge on these issues is developing so we need to be cautious.

Another big problem is finding a supply of "green" hydrogen. Most commercially produced hydrogen is synthesised in refineries from fossil fuels such as natural gas. Critics call this "black hydrogen" because carbon dioxide is generated as a by-product, cancelling out many of the potential benefits. Hydrogen could in future be used for auxiliary applications such as the APUs and on other non thrust type power requirements. This will thus require less fuel to be carried. Other solutions such as the use of solar power etc to at least supplement some of the power generated by fuel can be explored. The next section looks at some of the technical advances which could, if funded and developed, deliver a substantial environmental dividend.

The Shape of Things to Come: Future aviation technology

There is no shortage of innovative technology. Drag is one the biggest contributors to reduced fuel efficiency, so reducing drag could have real benefits. The best aerodynamic solution is to ensure that the envelope of air closest to the surface of an aircraft can flow smoothly: the so-called "laminar flow technology" (LFT). The turbulence which is created when this flow is disturbed is responsible for the drag inducing turbulence which impedes the efficiency of the aircraft and consumes more fuel and generates noise. Laminar flow techniques involve peppering the wing with tiny holes. This sucks air into an integral fan which reforms the flow of air over the wing. Initial tests on the technology have resulted in savings of 20% on all types of aircraft although durability is an unresolved issue at this time.[76]

Another idea for drag reduction which ingeniously combines LFT with a re-shaped fuselage is the so called "Goldschmied effect." Though tested only on submarines, the drag reduction principles were modelled in a wind tunnel for aircraft. The tests suggested spectacular reductions in drag for aircraft. The results found that the technique might reduce the power requirement of aircraft by up to 60%. One less radical variant has been tested theoretically and could generate fuel savings of 20%. With high stable fuel prices

76 Quoted in Bennet Davis 'Green Skies Thinking: Eight Radical Ways to A Cleaner Flying Future' *New Scientist* 24th Feb 2007.

and the incentive to reduce emissions via the emissions trading system, such technology could return. These possible technologies require further research and development funding; the £2 billion per year which has been taken from the industry in the UK through APD would constitute a good stream of research funding.

Struts have not been used on aircraft since the earlier days of flight. However they could make a comeback as an aeronautical solution to the thrust requirement of modern aircraft wings. Aircraft wings are a massive component of the weight and drag penalty of a modern airliner. The idea of a strut braced wing would allow wings to be lengthened without the requirement to pack them with fuel tanks. This aerodynamic buttress could reduce wing weight by about a quarter and fuel consumption by up to one fifth.

There are other less "blue sky" research options. Propfans which have been tested by Boeing could reduce fuel burn and thus on short to medium haul aircraft by around 30%. These are major gains. Propfans are best up to 3000 kilometres but they could be responsible for a substantial proportion of the world's air miles and reduce emission accordingly.

The massive delta wing shaped aircraft last seen on Britain's cold war bomber fleets and on Concorde should make a comeback also. In a genuine piece of innovative research a team from Cambridge (UK) and Massachusetts Institute of Technology have developed a massive flying wing shaped aircraft which would, because of its aerodynamic efficiency, consume much less fuel (about 25%) and would also reduce noise dramatically. According to the UK Aviation Environmental Research Body "Greener by Design", the Blended Wing design might produce only 10% of the greenhouse emissions of conventional aircraft. It would also be very quiet. Hence it's other variant the Silent Aircraft project. According to the UK Royal Commission on Environmental Pollution the aircraft could make a significant impact on the environmental performance of air transport.[77]

However, this Blended Wing concept has many difficulties, not least passenger experience. The idea of sitting in a windowless box instead of a cylindrical tube may not be appealing to passengers. Secondly the very shape of such flying wing cabin would make the routine rolls and pitches of a normal flight very difficult to absorb for passengers at the extremes of the cabin. However, like all challenges the ingenuity of our scientists and engineers can usually find solutions with enough funding.

The industry has already committed itself to a sub-sonic future. A proposed generation of new supersonic aircraft, such as Boeing's sonic cruiser, were abandoned on the basis that they were both fuel hungry and more damaging to the upper atmosphere. But the ingenuity of the industry is ceaseless and it can't be ruled out that with different fuels and aerodynamics, supersonic transport might be both feasible and sustainable.

There are a range of approaches to drive down aircraft emissions and the aircraft industry has been working on a number of solutions. Fuel efficiencies need to be improved in the air and on the ground and this will happen. But the level of emissions is also affected by airport capacity and infrastructure. That is a factor that lays outside the control of the

77 Royal Commission on Environmental Pollution

airline industries. The use of alternative fuels is another possibility in the pursuit of lower emissions but this will require considerable investment in research and development. In its aim to use cleaner technologies, the air transport industry needs to be encouraged. Just fining airlines or imposing punitive taxes on them will not help in this regard. It certainly will do nothing to solve the problems of the climate change.

We believe that there is a need for a global solution to emissions trading so that the industry can help to manage aviation's contribution to climate change. This is the subject of our final chapter.

Chapter 6: Reaching a global solution

Meeting the external costs of air transport

All forms of transport have an environmental impact and their impact needs to be mitigated. This has become generally accepted, and air transport is no exception. We recognise that air transport does have an environmental cost and that the industry needs to meet what is rather precisely termed its "independently verifiable external costs". That means meeting the cost of its effect on the global environment, and doing this in a considered and rational way. Unfortunately, many campaigners and some opportunistic policy-makers would like to extract environmental tithes from the industry, rather than try to use proven approaches that have been successful in other industries. The 'tax and ground' approach would fail for reasons we'll explore below.

The overriding issue in this debate is identifying the external cost of aviation. According to Pearce and Pearce (2000) the externally verifiable costs of aviation were (in 1999) £1bn.[78] Air transport in the UK has grown from about 175 million passengers in 1999 to about 228 million in 2005. That's a growth in passenger numbers of about 30%. This would be expected to increase any duties or taxes by an equivalent amount. Yet the government doubled APD the Air Passenger Duty which it extracts from air transport passengers in December 06 Budget. The tax is designed to compensate for the fact that there is no international agreement for the taxation of air transport and officially to balance the fact that aviation, because of international treaties, is not subject to the "luxury" tax which commonly applies to transport. In reality it is tawdry tax gathering exercise.

The first problem in estimating the true contribution of air transport is to calculate the cost of carbon. There are widely varying definition of carbon pricing with most estimates suggesting that each tonne of carbon costs in negative impacts £10 or €15. For air transport, however, the government assumes a level of £70 or €100 per tonne. This is designed to take account of the impacts of as yet scientifically unclear non CO2 emissions which aviation is responsible for at the upper environment level. These figures are based on multiplying the UK aviation Carbon Emissions of 30 million in 2000 by a factor of 2.3. In addition, some assumptions which are made in the IPCC's growth projections for carbon emissions are set aside.[79] Assuming growth scenarios of the kind outlined in the UK Government White Paper, this is well above the level of duty needed for air transport to meet its true environmental costs. In addition The Dutch environmental consultancy CE Delft have produced research to inform the EU proposed emissions trading system which suggests much lower weighted carbon costs for short haul passengers, the bulk of flying in the UK.

78 Pearce and Pearce Cost of carbon for UK Aviation (DFT 2000)

79 For example the assumption that existing aircraft types do not get more fuel efficient engines, directly contradicts the IPCC forecasts. This is a major assumption, which in all reasonableness should not have been made. These "guesstimates" allow the UK government to assume a cost of £4.8 billion for aviation in 2020, as the cost of carbon inflates by roughly £1 per tonne per year. That would mean in constant prices roughly £20 for a short haul passenger and £40 for a long haul passenger.

The UK government's methods of estimating the carbon cost of a typical short haul journey have been challenged by the UK airline lobby group, the British Air transport Association (BATA). BATA questions the valuation of UK aviation carbon costs and cite UK Government figures for the year 2004.[80] BATA combines these estimates with the CC DELFT report and produces similar answers with only a 5 per cent variation in estimates of carbon cost per passenger. This brings the carbon cost of a short haul journey to around £3.67 on average. With APD doubled now to £10 per short haul and a proportionate increase in long haul and premium journeys, it seems that aviation is paying well above the true cost of its external impacts on the environment. In fact this means aviation is paying a cost which is roughly double its true environmental impact.[81]

Is Aviation Subsidised?

It is common amongst those hostile to air transport to portray the industry as subsidised and featherbedded. Aviation, it is asserted, benefits from having zero tax on fuel and zero Value Added Tax (VAT), unlike other transport sectors which are taxed. Therefore, the logic states, air transport is not constrained and will grow uncontrollably. This is a weak argument which is based on omission. The main omission is the fact that aviation pays its own infrastructure costs entirely, of which more below. In fact aviation makes a net contribution to the public purse. The argument is designed to give the impression that other transport modes pay high taxes. In reality they pay zero or nominal fuel taxes which are often rebated through a complex series of grants. In the UK for example trains pay a €5 cent charge per litre, shipping pays no fuel tax, and buses are given rebates. Value Added Tax is not generally applied to public transport.

The anti-air transport lobby like to paint aviation as a luxury option out of the reach of ordinary citizens, and see tax on aviation as a form of luxury tax. Whether our detractors like aviation or not, aviation is a form of mass public transport, and mass transport is not taxed. But there is one exception to this: in the UK, and increasingly in other European countries, the aviation passenger pay departure taxes. For example, in the UK Air Passenger Duty costs passengers about £2 billion (€3 billion) plus tax take per year. The notion that aviation is not taxed will come as news to most airline passengers! Aviation is already heavily taxed. Passengers are taxed for their own security, they pay a substantial part of increase fuel costs and generally the industry pays for its own infrastructure. Aviation is often compared with the rail system. The two should be complementary, however, when environmentalists suggest that air transport is subsidised, they are completely wrong.

One of the key arguments of aviation critics is that the industry benefits from a raft of subsidies mainly on the cost of fuel, which is not taxed. This subsidy regime, it is argued, allows aviation to grow in an unconstrained fashion. Some argue that the ability of low cost airlines and increasingly their network competitors to advertise ultra low fares is an indicator of that subsidy, rather than astute yield management and an ultra efficient cost base. The fact is that taking infrastructure and operating subsidies into account the

80 Carbon Cost of UK Civil Air Transport July 2004 UK Department for Transport)
81 British Air Transport Association oral evidence to UK House of Lords EU Select Committee 17th Oct 2005

industry pays more than its fair share. In the UK according to an analysis by IATA, for example, the industry paid a net contribution of €4.6 per journey. In Germany it paid €7.5 and in France €8.4.[82] According to UNITE, a European transport Economics study, air transport make the highest net contribution of all transport modes.

Consider the subsidy position of railways. Already the UK railways are looking for an extra £18 billion in infrastructure subsidy; this can be added to the £5 billion in direct operating subsidy already received. In terms of net subsidy per passenger, air passengers make a net contribution, before revised APD levels, of £4.15, whilst rail is subsidised to the tune of £1.61 per passenger and buses by £0.15 per passenger.[83] In Germany according to the Association of European Airlines (AEA) user charges and taxes on aviation infrastructure generate €103 per 1,000 passenger kilometres. This is compared to expenditure of €93 million on infrastructure. This results in a net surplus of €10 per revenue kilometre. Compare this with German rail infrastructure which cost €88 per revenue kilometre and loses €54 per revenue kilometre in revenue when infrastructure is taken into account. This is a tax on every citizen and indeed there is evidence to show that rail subsidies benefit the better off. The best evidence available indicates that the external costs of UK air transport amount to about €1.5 billion.[84] That is exactly what is paid in Air Passenger Duty, which is a tax on air passengers directly. Air transport far from benefiting from the tax system is, relative to other transport modes, penalised by it.

This is especially so when we account for the net contribution on a per passenger basis. In the UK for example the airline industry made a net contribution of €659 million per annum in 1998. Road transport, mainly car and road haulage users, made a €31 million contribution. However, that is over a much larger number of journeys and, therefore, the cost borne by the passenger amounts to €0.5 per journey. Air passengers in the UK paid roughly 10 times that. The users of other modes such as rail are subsidised by between €2 and 2.5 per passenger. Taking taxes alone, with the increase in total APD to about €2.7 billion, that cost per passenger is now around €15 per passenger. This is a massive contribution to the national tax take and amounts to a huge net subsidy to the Exchequer. The fact that aviation fuel cannot be taxed for international treaty reasons is more then made up for in the taxes which are levied on the industry. Far from being subsidised our industry is heavily taxed and pays for its own infrastructure. That allows it to make a net contribution to the Exchequer.

If tax isn't the answer, could targeted "ring fencing" work?

Government has built a strong case for taxing emissions on a national basis, but in reality this simply leads to a patchwork of ill thought out environmental imposts. Furthermore, the actual revenue from APD goes neither to the industry to help offset its environmental costs, nor to develop surface links around airports which would deal with the much more pressing problem of road vehicle pollution, but instead the revenues go straight into general tax funds. This is dishonest and arbitrary and, when its costs are not transparent or

82 Aviation Taxes and Charges IATA Economics briefing No 2 (Geneva 2005)
83 Fiscal Treatment of Public Transport; Examining How Air Transport is taxed in comparison to other forms of Transport. (Volterra Consulting November 2003)
84 External Cost of Air Transport; White Paper on Air Transport (Pearce and Pearce 2003)

are inflated on the basis of assumptions about growth etc., it seems the airline industry is caught in a tax trap.

Taxing Aviation As A Development Tool

As we argued in the introduction, it has become a fashionable development tool to tax air passengers. The Chirac tax (as we show below) is an example. The real effects are of course that aviation has a relatively low contribution to climate change, that might be increased if radiative forcing is taken into account, but it is fanciful to suggest that taxing air transport would solve the problems of the developing world.

In January 2006, when the French president formally floated his proposed scheme at the World Economic Forum in Davos, he said a tax of a few dollars on every airline ticket sold could raise up to $10 billion (£5.7 billion) a year to finance campaigns against diseases in Africa, notably Aids, tuberculosis and malaria. France's finance minister, Thierry Breton, outlined the so-called 'solidarity tax' to a UN meeting in June 2006, saying that with world air traffic growing at an average 9% every year since 1960, it was "one of the most promising solutions for developing countries and for the international architecture of aid". Breton explained his thinking in the following way: airline tickets were an appropriate commodity to tax because airlines benefit from globalisation and pay low taxes, their passengers "are rarely among the poorest citizens", and such a levy had been proved feasible both practically and legally. IATA and most global airlines, including Air France, have attacked this as a stunt which amounts biting the hand that feeds development. Yet it does indicate the view that taxing air transport isn't so much about repairing the environmental damage which airlines can cause but about a finding a convenient cash box for revenue raising and in this case, the favoured projects of world leaders. Since the effects of climate change are not localised, then arguably road transport and industrial emissions contribute more to the climate impacts on the developing world. However it is bad economics and even worse politics to assume that by taxing one section of the global economy you will solve the problems of poverty. Jeffrey Sachs, a leading development economist, estimates that relatively small sums such as £1 billion would send every child in sub Saharan Africa to primary school and a further $3 billion would pay for tuberculosis programmes. Yet is poor logic to assume just because these are relatively small amounts, such sums should be raised from one industry alone. Such projects should, and can, be afforded across the developed world. Advanced countries contribute less than 1% to global development aid for example with the UK and France in their last budgets only agreeing to lift this up to 0.7% of GDP.

Other products which we use in the developed world could be taxed. Mobile phones which consume electricity often generated by carbon, motor vehicles responsible for 75% of emissions, as well as high definition TV sets, could equally be taxed, especially the latter which consumes 10 times the electricity of standard sets. The "Tobin Tax", proposed by the Nobel winning economist James Tobin, on speculative financial flows is one which many countries support. This tax also performs a useful role in regulating international finance flows. Air transport already plays a major role in development as we have discussed in Chapter 3. However there is nothing wrong in each individual choosing to "offset" the cost of a flight and indeed this is a way in which direct aid can go to the poor to help mitigate climate change. We'll discuss this "personal solution" below.

Ring Fencing the Tax revenues from Air Transport

Arguably rather than being allocated to government taxes or even worthy issues such as international development, air transport revenues should be allocated towards environmental progress within the industry. That is the best way of securing the gains of sustainable aviation. Hypothecation is an ugly word for a simple concept. Hypothecation, or ring fencing, earmarks taxes for a singular purpose. In this case the taxes collected from air transport are channelled into directly mitigating its environmental impacts. The $2 billion plus now collected in APD could fund either public transport infrastructure near airports to minimise car use and thus emissions and could also fund a massive research programme at key universities to bring forward new technology as discussed in chapter 5. It's clear that neither national taxation hikes nor international "solidarity" taxes which target air transport alone will address the industry's environmental impact. The first solution will simply use air transport for national taxation, the second will use the industry as an international aid provider, which, however laudable, will not meet the challenges we face. The real solution lies in incentivising air transport to deliver better operation performance and to develop technical solutions. This means introducing a market mechanism which operates automatically to curb emissions by encouraging these dynamic processes.

The starting point for our discussion in the context of aviation is the EU Emissions Trading System (ETS). The US pioneered the use of emissions trading to control sulphur emissions from coal-generating power stations and used these in a variety of other areas. In essence by attaching a price to carbon and capping the amount you can generate, you create a market for its reduction. Put simply one participant in the market will want to emit more carbon and one who has reduced its impact will have permits to sell. They will make a rational trade because the cost of carbon will be reflected in business costs. The company which bought carbon will want to become a seller of permits and will incentivise his buyer to reduce further etc.

Emissions Trading

Imagine an airline operating older aircraft. Each airline faces a carbon cost of £1 million per year. Lets assume the EU wants to cut that by 10%. This caps individual emissions at 900,000 tonnes per year. It then imposes a penalty cost for carbon of say £18 per tonne. Operators will then face penalty payments which could be £1.8 million per year [85] The airline has an incentive to sign leases for new aircraft which are more fuel efficient as it can offset the cost of the emissions it would need to purchase.

85 This might seem like a relatively small amount of money but applying cost benefit analysis and discounting its value, the sum would be considerable.

There are different ways in which emissions trading can be introduced and many of these are worthy of genuine debate and discussion.[86] We won't detain ourselves with a discussion here. Here, however, are some the questions which are raised.[87]

- Should the airline sector be integrated into a generic emissions trading system?
- Should the airline industry have a standalone scheme ?
- Should airlines have "grandfathered" permits whereby the allocation of permits is based on past emissions or should there be an auction process?
- Should the industry be granted emission permits or should it pay for rights out of profits?

There are some concerns amongst environmentalist and policy makers that within the ETS aviation will continue to grow. These are based on the projection of the Tyndall Centre discussed below which assumes unconstrained growth scenarios. However as BA's Chief Economist and Head of Environment, Dr Andrew Sentance, argues, "ETS would allow other sectors to continue to grow as well, if they wished to buy the permits. The trading system would ensure that globally, the target of a 60 per cent reduction required under the UK's Kyoto obligations[88] could be achieved."

The ends are important in this case although many would like to see aviation punished as an essential means to that end. Sentance also disputed the Tyndall Centre's inflated projections and said by 2050 UK aviation emissions would range from 17 per cent of the total – under a scenario of low traffic growth and high fuel efficiency – to 46 per cent of the total – under a scenario where growth was high and fuel efficiency low. He also rejected environmentalists' claims that the scheme would fail in its object if it did not force a cutback in the amount of CO2 jet aircraft inject directly into the stratosphere each day. Green campaigners were wrong to focus on aviation. It is "just one sector", he said, "they should look at the global picture. The emissions trading scheme is the most effective mechanism of reducing the global total."

He indicated that paying for emission permits in the ETS might add €1–€2 (70p–£1.40) to the cost of an average flight ticket. Although environmental campaigners say the increase would be too small to have any effect on reining back the growth in passenger demand, Mr Sentence said: "Every price increase has an effect on demand. Aviation emissions in the EU amount to less than 4% of the EU's total emissions and even factoring in the disputed Non CO2 multiplier of 2.7 this would account for just over 10%. If the new EU member states are added that overall proportion falls.

86 See Frontier Economics *Economic consideration of extending the EU ETS to include Aviation*

87 See UK House of Lords EU Select Committee "Emisssions Trading and UK Aviation" report February 07

88 The Kyoto Protocol is an agreement made under the United Nations Framework Convention on Climate Change (UNFCCC). Countries that ratify this protocol commit to reduce their emissions of carbon dioxide and five other greenhouse gases, or engage in emissions trading if they maintain or increase emissions of these gases. The Kyoto Protocol now covers more than 160 countries globally and over 55% of global greenhouse gas (GHG) emissions.

According to the EU commissioned report which paved the way for bringing aviation into the ETS, CO_2 emissions in the EU 15 from aviation will only grow to 5% by 2030. The economic contribution of aviation and its importance in terms of European integration are likely to outweigh these costs.

However, this slight fall off in demand won't stop people flying so we are left with a question: Do we wish to mitigate aviation's impact or do we wish to eradicate cheap flying? It is clear that emissions trading has problems. For example LCCs believe that it unfairly penalises them as they have ultra high load factors and newer fuel efficient aircraft, compared to some older European airlines which tend to fly older aircraft at low load factors. They thus believe the system should have benchmarks which encourage the adoption of new aircraft and which would help to phase out older aircraft. The Low Fare Airlines also want to see external operators factored into the ETS. Some major airlines have older fleets and will wish to see grandfathering so they can maintain a higher level of emissions. This has generated dissent mainly from the US.

However, although each operator has a differing agenda, what is clear is that the air transport community in Europe is agreed. If we do not use emissions trading we will be confronted with punitive taxes. The industry needs to have a credible mechanism which can be seen to mitigate the impact of air transport on the environment. If we do not develop such a mechanism we will face calls to tax and ground. It is therefore incumbent upon the industry to settle its differences and agree on a global basis the design of such a scheme. The role of ICAO is crucial in this regard and by agreeing on a global basis ICAO can save the industry form the patchwork of arbitrary taxing and duty levelling initiatives to which it is currently subject.

Getting More Personal

We all know that we waste electricity and that we pay scant attention to the amount of energy we consume. It's difficult when you pay your electricity bill directly through the bank electronically to know really how much it costs. It's difficult when we drive our cars to know how much it cost per journey. When did you last check? Do you switch off or to standby? Are you motivated yet to do something about the issues you know you can offset so that you can continue to fly and drive and enjoy all the other aspects of life which are under threat if we do not control our environmental impact. Why? Because in reading this report you should have discovered some breathtaking information about the opportunities we all have to either switch something off or pay a bit more.

As the website Responsible Travel puts it, "The current media focus on environmental issues, while very welcome and long overdue, has led to a lot of bad press for flying. Some might argue that this is a good thing, but it has left the general public with a somewhat skewed view of the impact of flying and many now feel guilty about taking a holiday that involves a flight."

According to a responsibletravel.com straw poll, some tourists think that air travel accounts for around 30% of total emissions whereas, as we have seen, it accounts for nearer 5% of total emissions. And as chapter 4 demonstrated, our home energy consumption accounts for 25%.

Typical household emissions per person per year are calculated to be around 11 tonnes, yet a return flight from London to Barcelona will, according to a carbon offset company using an inflated multiplier, emit approximately 0.26 tonnes per person. Our own estimates, based on IPCC factors and referred to in Chapter 1, suggest this figure could be as low as 0.12 tonnes per passenger. If travellers want to 'afford' a flight with reduced CO_2 emissions, they could begin to think about eliminating some of the 11 tonnes of annual household emissions. Responsible Travel has researched different ways of cutting down carbon emissions and has found a few simple actions that would allow the traveller to 'afford' the CO_2 emissions of a given flight – and the same amount again. We reproduce these offset tables below as "food for thought"

Table 6.1: Emissions Offset Possibilities London to Cairo and Barcelona using the worst case factors

Rtn flight London – Cairo	0.77 tonnes CO_2 per person
Turn down your thermostat by 1°C	0.29
Switch the TV off rather than standby	0.10
Take the underground or bus to work instead of car	0.75
Take a shower instead of a bath (not power shower)	0.20
TOTAL SAVING	1.57

Rtn flight London – Barcelona	0.26 tonnes CO_2 per person
Turn down your thermostat by 1°C	0.29
Switch the TV off rather than standby	0.10
Replace 3 ordinary bulbs with energy-saving ones	0.13
TOTAL SAVING	0.52

Source: Responsibletravel.com

This is an example of what can be achieved at home; however, travellers can also reduce the carbon emissions of their holidays while they are away. In fact, by selecting a particular type of holiday, the traveller could actually be making a positive impact rather than a 'neutral' one.

Responsible travel discovered that a holiday to Peru* which includes stove building in the community (improving combustion, reducing smoke, fumes, heat loss and timber consumption) can cover the carbon emissions from the flight with nearly two tonnes to spare. About 65% of the cost of this holiday (excluding flights) is spent in the local economy; this reduces reliance on natural resources and provides the local population with a viable alternative to what might be deemed less sustainable activities. Not everyone's idea of fun but certainly a worthy offset!

Flying to New York form the UK or vice versa is often seen as the most destructive form of "carbon wasting" behaviour. Yet a moment's research and thought shows that using offsetting and awareness of other personal carbon impacts puts it in perspective. A return flight from London to New York will, according to our estimates, generate 0.77 tonnes of

CO_2. This would cost around £6 to offset. The savings from undertaking some changes in the way we use energy is quite astounding. If you need to use your car, responsible car use is also possible. There are various schemes which cost roughly about 5–10 pence per day depending on engine size. These can be arranged via fuel retailers' websites.

Taking it to another level, this supports the argument that stopping travelling altogether will have a detrimental effect on both local economic development and conservation, thereby holding back carbon reduction initiatives in destinations which need local communities to be educated about their environments and to be able to afford to invest in low carbon technologies.

Justin Francis, co-founder of responsibletravel.com, witnessed first-hand the investment in renewable energy sources as a result of tourism: "In Kenya I visited a Maasai village with solar panels which reduced their dependence on wood and helped address severe deforestation in the area. They had been inspired by the technology in a lodge on their land – from which they earn sufficient income to be able to afford the panels."

UK tourists currently spend around £2 billion a year in developing countries, a figure which comes very close to the Department for International Development (DFID) development budget. Admittedly, not all of this trickles down to local people, but as responsible tourism increases, a good proportion does.

According to Francis: "Air travel contributes to climate change but if we all stopped booking flying and booking responsible holidays then we will also contribute to climate change as both local economic development and conservation would be negatively impacted."

If travellers follow household carbon reduction measures, they will be able to book a responsible holiday safe in the knowledge that they will be emitting less carbon than before and that they will also be supporting local conservation and development – which in turn can help local communities to reduce their own carbon emissions. Moreover, people returning from this type of holiday are more likely to return home with different values regarding the environment, resource preservation and economic wealth, which could lead to more sustainable behaviour in their daily life.

Conclusion

Conclusion: Putting the Environmental Impact of Air transport in Perspective

Throughout this report we have addressed the environmental impact of air transport. We are not disputing the science of climate change. Global warming is occurring. It is more likely than not on the available evidence that this is being caused by an increase in man made CO_2 emission. We think the science is fairly conclusive but, as in all debates, there are legitimate disputes over data and interpretation which may lead to a re-examination of the evidence. As it now stands, the evidence seem to be pointing in the direction of climate change induced by man made emissions. The IPCC, because it is a global project which must integrate a consensus view on the available science, has been consistently cautious and in its latest report it has sounded the alarm bell on climate change. Its Fourth Assessment report indicates:

Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years. The global increases in carbon dioxide concentration are due primarily to fossil fuel use and land use change, while those of methane and nitrous oxide are primarily due to agriculture. [89]

The Stern report, another level-headed analysis, which was criticised by some for being alarmist and by others for being complacent, is clear, "The overwhelming weight of scientific evidence now clearly indicates that climate change is a serious and urgent issue".[90]

So, we have no reason to believe that climate change is not real, nor that aviation plays some part in it. We have good reason to reject the dogmatic anti air transport orthodoxy which seems to have emerged particularly in the UK and Europe. Aviation is under attack from a coalition of interest groups who have wrongly identified the sector as the single most important contributor to climate change. This approach is mirrored by a political desire to use air transport as cash till for governments, resulting in a convenient coalition to levy taxes and charges upon the industry. In this report we've sought to examine the evidence and to put the issue in perspective: Our findings:

- We acknowledge that aviation is responsible for a small proportion of the climate change impact but, through technology, the continual quest for efficiency and market mechanisms, this can be substantially mitigated.

- We know that the industry is a vital pivot in the global economy responsible for 8% of global GDP,, connecting the planet through trade and the flow of people and goods. It bolsters and supports the advanced knowledge industries and high value employment in its own right. The industry also supports development and access to markets for the developing world. Air transport connects the world and its people.

89 IPCC WGI Fourth Assessment Report: Summary for Policymakers Feb 2007
90 Stern, Nicholas (ed) The Economics of Climate Change (HM Treasury October 2006)

- In any case, in terms of global environmental impact, air transport compares favourably with other modes especially when load factor, efficiency congestion and power generation methods are taken into account. In terms of its overall economic contribution its global carbon footprint is relatively small.

- The suggested alternatives to air transport are unrealistic and severely limiting. The desire to replace air transport with rail, domestically and regionally, would lead only to an increase in private car use with negative impacts on the environment. The idea that shipping could take on the long distance role of air transport is fanciful in terms of time penalty and also in that it underestimates the growing environmental impact of shipping. Both approaches are dogmatic and deny consumers real choice.

- Through a tough global standards regime on noise, emissions and air quality the industry has been incentivised to introduce cleaner technology and to prioritise operational efficiency. Projects to discover cleaner propulsion and lightweight structures continue to produce a "greener by design" dividend. Better use of resource and an improvement in public transport to airports promise future dividends such as better local air quality.

- Pilots, as key professionals, can use their skill and expertise to mitigate further the day to day impact of flying, using noise abatement procedures, fuel efficiency and "greener approaches such as CDA. Pilots also need the authorities to play their part in joining up the patchwork of air traffic control capacity, and in allowing the industry to build adequate sustainable infrastructure. That way we can continue to lessen the industry's environmental footprint.

- The idea that the industry is subsidised and untaxed is a myth. That taking into account the subsidy of other modes and the fact that aviation pays its own infrastructure costs and that aircraft pay to land, park and fly, the subsidy lie can be put to rest. Tax hungry finance ministers and those looking to plug global good causes need to recognise that the industry has been largely unprofitable over the cycle because of falling yields. This fall in the price of air travel is not a reflection of reckless subsidy but of the inherent efficiency of the industry.

- The industry should be incentivised further to improve its environmental record through a robust, fair and transparent system of emission trading globally overseen by ICAO. This system should aim to stimulate the replacement of older aircraft and thus bring about further improvements.

- We've also shown that individuals can and should take some responsibility to offset their own impact. There are a variety of ways in which this can be done and we outline some of them.

We are not climate sceptics. We are however, sceptical about the single cause fixation of the environmental movement which labels air transport as the biggest threat to the planet. Clearly other issues are more pressing, as we have shown. Indeed neither the IPCC nor Stern, nor indeed Senator Gore's documentary, identified aviation as a main culprit. Anyone who has looked at the evidence in detail could not come to that simplistic conclusion. Assumptions in scientific and economic debates are important. The IPCC will

produce a revised special report to update its 1999 work on Aviation and the Global Atmosphere, which we expect will show that the impact of aviation will grow. However, we believe it can grow sustainably.

There is some evidence of both saturation in mature markets such as the US and EU. Even for low cost carriers the simple equation between capacity and yield holds true. There comes a point when expansion slows. The airline industry is not a constantly inflating bubble, it is subject to the laws of economics. Indeed through efficiency of utilisation and capacity carriers have able to extract a profit from difficult markets. Substitution and shifting between low costs and network carriers and possible consolidation will ensure that growth is constrained in many markets. Air transport grows ahead of and then comes into line with GDP. Even the stellar growth seen in the Middle East, India and China will stabilise. However as the world develops air transport will grow and if it does not the world economy will be held back.

That's the essential cost benefit equation. If we balance the costs of aviation to the environment with the benefits and if we offset the costs with continued efficiency and mitigation then we can only come to one conclusion: Aviation is vital to the world and sustainable for the planet.

Both the IPCC and Stern recommend the use of emissions trading as a market mechanism something the industry embraces. We hope by writing this report to encourage a sense of proportion and an evidence-based approach which is open and honest about assumptions, as we believe some researchers such as the IPCC and the Royal Commission on Environmental Pollution and Stern have been. We also believe that Tyndall, Friends of the Earth and the Parliamentary Office of Science and technology, as well as a plethora of Non Governmental Organisations (NGOs), local lobby groups and think tanks, have been more captured by green advocacy and a desire to engineer a shift in transport preference than in addressing the environmental impacts of air transport. There are climate scientists and specialists, whom we and others have spoken to and quoted in this report, who are also experts on the aviation industry and its effect on the global economy who have taken a much fairer approach. We may disagree about the forecasts or the implied costs and we certainly wish to see the benefits taken into account, but we definitely agree that there is a problem. It is getting that problem in perspective and developing genuine solutions to the impact of aviation and the environment which we believe is the key issue.

As we have emphasised all along in this report, singling out aviation as a key contributor to climate change does not really take the discussion about how to respond to the issue very far. The air transport industry is in fact a small contributor to the growth in greenhouse gases. We would argue that the industry is taking steps to reduce that contribution still further. The industry will grow in future but we are convinced that with the favourable tailwinds of technological improvement, the spur to continued efficiency and utilisation, and by the use of proportionate market incentives, the industry can continue to play the vital part it does as the fulcrum of our global economy and society.

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Glossary of Useful Terms; General Aviation Terms

A

AEA – Association of European Airlines: a trade association of the international airlines of western Europe.

Air Service: "Air service" means any scheduled air service performed by aircraft for

ASA – Air Services Agreement: a treaty containing bilaterally-agreed legal framework upon which scheduled air services may operate.

ASK – available seat kilometres: the number of seats available for sale multiplied by the distance they flew.

ATC – Air Traffic Control.

ATS – Air Traffic Services: air traffic control facilities.

B

BARUK – Board of Airline Representatives in the UK: the body representing foreign airlines operating to the UK. There are equivalent bodies in other countries on which the UK airlines are represented.

C

CAA – Civil Aviation Authority: the UK's aviation safety and economic regulator (see http://www.caa.co.uk/ for further details of the CAA's responsibilities).

Capacity: the frequency of flights or number of seats which the designated carriers of each side are permitted to operate. These arrangements are usually set out in the Memorandum of Understanding (MOU) and can involve a stated limit on capacity, an agreed step increase in capacity or another formula for covering the need for future growth in capacity.

Chapter 2/3: refers to the noise standards specified in Volume I of Annex 16 to the Chicago Convention. Since 1 April 2002, Chapter 2 aircraft have been banned from operating to EU Member States unless in possession of an exemption granted by a Member State (the Civil Aviation Authority in the UK). Grounds for exemptions are defined by Article 8 of the 92/14/EEC Directive – i.e. operations of an exceptional nature or non-revenue flights, effectively humanitarian flights or head of state flights.

E

Eurocontrol: provider of ATC for overflights of European countries. Civil Aviation Authority collects fees on their behalf and acts to detain aircraft where debts to Eurocontrol have built up.

G

Grandfather rights: an airline that has operated a service from an airport at a particular airport slot in one year's timetable is said to have grandfather rights to that slot in subsequent years. The rights are predominantly only specific to a particular airline, rather than to a size of aircraft or destination.

H

Hub and spoke system: a hub is an airport on which traffic from a number of peripheral points is concentrated, and which is in turn linked by direct flights to peripheral (spoke) points. Such systems can involve linking a gateway airport to a number of domestic points (common in the US) or can be used in change of gauge operations. Compare with point-to-point.

I

IATA – International Air Transport Association: the trade body to which most scheduled international airlines belong. It has traditionally provided a forum in which interline agreements and other commercial arrangements as well as tariffs can be agreed. It has an increasing role in negotiating improved airways and access to airports.

ICAO – International Civil Aviation Organisation: a United Nations body formed in December 1944 under the auspices of the Chicago Convention with the objectives of developing the principles and techniques of international air navigation and fostering the planning and development of international air transport so as to: ensure safe and orderly growth of international aviation throughout the world; encourage the arts of aircraft design and operation for peaceful purposes; encourage the development of airways, airports and air navigation facilities for civil aviation; meet the needs of peoples of the world for safe, regular and efficient and economical air transport; prevent economic waste caused by unreasonable competition; ensure the rights of states are respected; avoid discrimination between states; and promote the safety of flight. Detailed standards and recommendations are included in the Annexes to the Convention e.g. Annex 6 on safety and Annex 9 on "facilitation" (customs, immigration, security checks etc).

L

Load factor: the percentage of seats available that are actually purchased by passengers.

M

MOU – Memorandum of Understanding: a non-binding document agreed between two countries accompanying the air services agreement and including the detailed rights which cannot be contained in the Treaty because they are likely to be updated fairly frequently e.g. capacity limits and fifth freedom rights.

P

Point to Point: a system whereby an airline's route network is composed of a number of city pairs, not necessarily linked by hub airports. This system is favoured by low cost carriers such as Southwest Airlines (in the US), easyJet and Ryanair (in Europe). Compare with hub and spoke.

R

RPK – Revenue Passenger Kilometre: the number of paying passengers carried multiplied by the distance they flew in kilometres.

RTK – Revenue Tonne Kilometre: the tonnage carried multiplied by the distance it is carried.

S

Seat factor: see load factor.

Sector: a journey between two points/cities. A flight may be made up of a series of sectors – for example, London-Kolkata-Dhaka consists of two sectors: London-Kolkata and Kolkata-Dhaka.

Slot: a particular time allocated to an airline to land or take-off from a particular airport. The allocation of slots at co-ordinated airports in the European Union is governed by EC Regulation 95/93 which aims to provide for neutral, transparent and non-discriminatory slot allocation at the more congested Community airports through a co-ordinator independent of Government, airlines and airports. In the United Kingdom the slot co-ordinator is Airport Co-ordination Limited (ACL).

T

Treaty: an agreement concluded in written form between two or more states (or entities such as international organisations having international personality) and governed by international law. A treaty, which may take the form of a convention, an agreement or a protocol, usually consists of a title, a preamble, recitals, a series of numbered articles and a conclusion followed immediately by the signatures.

Y

Yield: the difference between the cost of operation and price charged for carriage.

Common Abbreviations

CAEP Committee on Aviation Environmental Protection
CCX Chicago Climate Exchange
CDA Continuous descent approach
CFC Chlorofluorocarbon
CLEAN Component Validator for Environmentally Friendly Aero Engine Programmes
CO Carbon monoxide
CO_2 Carbon dioxide
COP UNFCCC Conference of the Parties
DAC Dual Annular Combustor
dB Decibel
dB(A) Decibel A-weighted scale
DNL Day-Night Sound Level scale
EAF ENTAF Economics and Forecasting sub group
ECAC European Civil Aviation Conference
EMAS Eco-management and audit scheme
ENTAF IATA Environment Task Force
ERLIG Emissions Related Landing Charges Investigation sub group of ANCAT
ESPR Eco-Smart Propulsion Research Programme
EUROCONTROL European Organisation for Safety and Air Navigation
FAA US Federal Aviation Administration
FANPAC Aero-Acoustics Methods for Fan Noise Prediction and Control
GDP Gross domestic product
GNSS Global navigation satellite system
GPU Ground power unit
GSE Ground support equipment
H_2 Hydrogen
HC Hydrocarbons
HCF Hydrofluorocarbons
HYPR Hypersonic Research Programme
IATA International Air Transport Association
ICAO International Civil Aviation Organization
IPCC Intergovernmental Panel on Climate Change
Leq A measure that takes cumulative sound events (e.g. aircraft movements) into account over a given period of time, e.g. a day or part of a day
LTO Landing and take-off cycle
MAGENTA ICAO Model for Assessing the Global Exposure to the Noise of Transport Aircraft
MTOW Maximum take-off weight
MZFW Maximum zero fuel weight

NASA National Aeronautics and Space Administration
NGO Non-governmental organisation
NO Nitric oxide
NO_2 Nitrogen dioxide
NOX Oxides of nitrogen
OAD ENTAF Operations and Design sub group
OECD Organisation for Economic Co-operation and Development
PM Particulate matter
SARPS ICAO Standards and Recommended Practices
SO_2 Sulphur dioxide
UNFCCC United Nations Framework Convention on Climate Change
VOC Volatile organic compounds
WHO World Health Organization

Glossary of Terms used in Aviation Environmental Research

Aerosols Airborne suspension of small particles.
Aerosol Precursors Gases or chemi-ions that may undergo gas to particle conversion.
Anthropogenic Caused or produced by humans.
Block Time The time elapsed from start of taxi out at origin to the end of taxi in at destination.
Bunker Fuels (International) Fuels consumed for international marine and air transportation.
CH_4 Methane. The second most common gas in the basket of six GHGs controlled by the Kyoto Protocol. Methane has a 100–year GWP of 21.
CO_2 Carbon dioxide. The main GHG, accounting for some 81% of Annex I countries' GHG emissions in 1990, and one of the six GHGs controlled by the Kyoto Protocol. Used as the gas of reference for calculating GWPs, and thus given a 100–year GWP of 1.
Cirrus High, thin clouds composed of mainly ice particles.
Climate Model A numerical representation of the climate system. Climate models are of two basic types: (1) static, in which atmospheric motions are neglected or are represented with a simple parameterization scheme such as diffusion; and (2) dynamic, in which atmospheric motions are explicitly represented with equations. The latter category includes general circulation models (GCMs).
Combustion Efficiency Ratio of the heat released in combustion to the heat available from the fuel.
Condensation The process of phase transition from gas to liquid.
Contrail Condensation trail (i.e., white line-cloud often visible behind aircraft).
Direct Radiative Impact Radiative forcing of aerosols or gases by scattering and absorption of solar and terrestrial radiation.
Emission Index The mass of material or number of particles emitted per burnt mass of fuel (for NO_x in g of equivalent NO_2 per kg of fuel; for hydrocarbons in g of CH_4 per kg of fuel).
Emissions Trading The Kyoto Protocol allows Parties listed in Annex B to participate in trading of their assigned amounts for the purposes of fulfilling their emissions commitments. Parties buying parts of assigned amounts can add these to their assigned amounts under the Protocol, while Parties selling must deduct them. Such trading must be supplemental to domestic actions. The COP is to define the rules and modalities for trading.
Energy Efficiency Ratio of energy output of a conversion process or of a system to its energy input; also known as first-law efficiency.
Engine Pressure Ratio The ratio of the mean total pressure at the last compressor discharge plane of the compressor to the mean total pressure at the compressor entry plane, when the engine is developing its take-off thrust rating (in ISA sea-level static conditions).
Equivalence Ratio Ratio of actual fuel-air ratio to stoichiometric fuel-air ratio.
Feedback When one variable in a system triggers changes in a second variable that in turn ultimately affects the original; a positive feedback intensifies the effect, and a negative reduces the effect.
Greenhouse Gas A gas that absorbs radiation at specific wavelengths within the spectrum of radiation (infrared) emitted by the Earth's surface and by clouds. The gas in turn emits infrared radiation from a level where the temperature is colder than the surface. The net effect is a local trapping of part of the absorbed energy and a tendency to warm the planetary surface. Water vapour (H_2O), carbon dioxide CO_2), nitrous oxide (N_2O), methane (CH_4), and ozone (O_3) are the primary greenhouse gases in the Earth's atmosphere.

Indirect Radiative Impact Radiative forcing induced not directly but by changing other scattering or absorbing components of the atmosphere (clouds or gases).
Jet The continuous strong stream of exhaust gases leaving the engine exit.
Kerosene Hydrocarbon fuel for jet aircraft.
Landing/Take-Off (LTO) Cycle A reference cycle for the calculation and reporting of emissions, composed of four power settings and related operating times for subsonic aircraft engines [Take-Off - 100% power, 0.7 minutes; Climb - 85%, 2.2 minutes; Approach – 30%, 4.0 minutes; Taxi/Ground Idle – 7%, 26.0 minutes].
Life-Cycle Cost The cost of a good or service over its entire lifetime.
Mach Number Speed divided by the local speed of sound.
Mitigation An anthropogenic intervention to reduce the effects of emissions or enhance the sinks of greenhouse gases.
NOx Oxides of nitrogen, defined as the sum of the amounts of nitric oxide (NO) and nitrogen dioxide (NO2) with mass calculated as if the NO were in the form of NO2.
Ozone A gas that is formed naturally in the stratosphere by the action of ultraviolet radiation on oxygen molecules. A molecule of ozone is made of up three atoms of oxygen.
Ozone Hole A substantial reduction below the naturally occurring concentration of ozone, mainly over Antarctica.
Ozone Layer A layer of ozone gas in the stratosphere that shields the Earth from most of the harmful ultraviolet radiation coming from the Sun.
Particulate Mass Emission Index The number of grams of particulate matter generated in the exhaust per kg of fuel burned.
Plume The region behind an aircraft containing the engine exhaust.
Polar Stratospheric Clouds Large, diffuse, ice-particle clouds that form in the stratosphere usually over polar regions.
Radiative Forcing A change in average net radiation (in W m-2) at the top of the troposphere resulting from a change in either solar or infrared radiation due to a change in atmospheric greenhouse gases concentrations; perturbance in the balance between incoming solar radiation and outgoing infrared radiation.
Soot Carbon-containing particles produced as a result of incomplete combustion processes.
Specific Fuel Consumption The fuel flow rate (mass per time) per thrust (force) developed by an engine.
Stakeholders Person or entity holding grants, concessions, or any other type of value which would be affected by a particular action or policy.
Stratosphere The stably stratified atmosphere above the troposphere and below the mesosphere, at about 10– to 50–km altitude, containing the main ozone layer.
Sustainable A term used to characterize human action that can be undertaken in such a manner as to not adversely affect environmental conditions (e.g., soil, water quality, and climate) that are necessary to support those same activities in the future.
Tropopause The boundary between the troposphere and the stratosphere, usually characterized by an abrupt change in lapse rate (vertical temperature gradient).
Troposphere The layer of the atmosphere between the Earth's surface and the tropopause below the stratosphere (i.e., the lowest 10 to 18 km of the atmosphere) where weather processes occur.

Ultraviolet Radiation Energy waves with wavelengths ranging from about 0.005 to 0.4 μm on the electromagnetic spectrum. Most ultraviolet rays coming from the Sun have wavelengths between 0.2 and 0.4 μm. Much of this high-energy radiation is absorbed by the ozone layer in the stratosphere.
Volatiles Particles that evaporate at temperatures less than about 100°C.
Wake The turbulent region behind a body or aircraft.

10 Facts About Aviation and the Environment

1. Aviation accounts for less than 2% of worldwide C02 emissions from fossil fuel, and this could still be within 5-6% even if the industry doubled by 2050 and there were no further technological and operational innovations.

2. Fuel consumption per passenger kilometre has reduced by 70% over the last 40 years.

3. The entire transport sector is responsible for 14% of total C02. Of transport's 14%, road transport is responsible for 75% whilst air travel accounts for only 12%.

4. There is currently no alternative to using fossil fuel in aviation. The price of fuel has increasingly incentivised us to be frugal. As a result aircraft operations have become around 25% more fuel efficient since 1990.

5. Technological improvements have practically eliminated visible smoke and hydrocarbons. Oxides and sulphides of nitrogen and smoke have been progressively reduced by 90% at ground level over the last 40 years.

6. New aircraft are targeted at a fuel efficiency below 3 litres per 100 passenger/Km which is similar to a family compact car but travels 6 times faster.

7. Load factors are commonly, on average, over 75% – around double that of road and rail. From an environmental point of view, aircraft are the best travel solution for journeys of over 250 km. 80% of aviation emissions relate to flights of over 1500 km for which there is no viable alternative.

8. Aviation pays for all its own infrastructure costs ($42 billion – airports, Air Traffic Control, Security). It is often a net contributor to national treasuries. Every air journey in Europe contributes between €5 and €8 per passenger. Rail is effectively subsidised by between €2 and €7 per passenger.

9. Aviation transports 2,000,000,000 passengers annually.

10. Aviation is pivotal to the global economy. It generates 29 million jobs worldwide with an economic impact equivalent to 8% of world GDP when tourism is taken into account.

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