Challenges in Climate Change and Environmental Crisis:

Impacts of Aviation Industry on Human, Urban and Natural Environments

Mostafa Jafari, Tehran Process Secretariat for Low Forest Cover Countries (TPS for LFCCs), Iran & International Advisor, Islamic Republic of Iran Meteorological Organization (IRIMO), Iran & Research Institute of Forests and Rangelands (RIFR), Tehran, Iran, & Lead Author, Intergovernmental Panel on Climate Change (IPCC), Geneva, Switzerland

ABSTRACT

Climate change challenges need to be considered in various dimensions. Aviation industry has multiple impacts on human lives such as impacts on the urban and natural environments. Various dimensions of the issue and its importance have been reported by the IPCC, following a request from the ICAO and the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer in 1999. In this paper different related topics have been investigated. Aviation: Development and Improvement, Climate changes as main environmental crisis, causative source of pollutions: Air pollution (GHGs, aerosol, smoke and particulate, dust), water pollution, biodiversity, hazardous materials, and aeronautical noise. Link between aviation impacts and environmental crisis have been discussed. Different perspectives of the aviation challenge briefly are presented: I- Human dimension, II- Urban environment (local, regional, and global), III- Natural environments (terrestrial, aquatic, and atmospheric) and IV- Birds killed by intervention. In concluding remarks two aspects of the issue, A) benefits, and B) impacts have been considered, and in the end some recommendations have been made on Emissions Trading, Environmental Performance, and Technological Developments.

Keywords: *Aviation, Benefits, Climate Change, Emissions, Environmental Crisis, Impacts*

INTRODUCTION AND BACKGROUND

This paper was drafted based on the Special Report that was prepared by the Intergovernmental Panel on Climate Change (IPCC) following a request from the International Civil Aviation Organization (ICAO) and the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer (IPCC, 1999). In this context, the state of understanding of the relevant science of the atmosphere, aviation technology, and socio-economic issues associated with mitigation options is assessed and reported for both subsonic and supersonic fleets. The potential effects that aviation has had in the past and may have in the future on both stratospheric ozone depletion and global climate change are covered; environmental impacts of aviation at the local scale, however, are not addressed. The environmental impact of aviation occurs because aircraft engines emit noise, and particulates

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and gases which contribute to climate change and global dimming

Furthermore, based on the aforementioned report, the paper takes into consideration all the gases and particles emitted by aircraft into the upper atmosphere and the role that they play in modifying the chemical properties of the atmosphere and initiating the formation of condensation trails (contrails) and cirrus clouds. Subsequently, the paper considers

(a) how the radiative properties of the atmosphere can be modified as a result, possibly leading to climate change, and (b) how the ozone layer could be modified, leading to changes in ultraviolet radiation reaching the Earth's surface. The paper also considers how potential changes in aircraft technology, air transport operations, and the institutional, regulatory, and economic framework might affect emissions in the future. The paper does not deal with the effects of engine emissions on local air quality near the surface (IPCC, 1999).

In view that airports constitute considerable part of the communities within which they operate, as such, reducing their impact on the environment is a major focus for many around the world. While much of the current attention is on climate change and reduction of greenhouse gas emissions, it is just one of a number of areas that airports and the rest of the aviation industry are active in the environment (ACI, 2009).

Although the environmental stresses to which man is subjected on the ground are less than those commonly encountered in aviation or under water, they may still exceed an individual's powers of adaptation (Sloan, 1975). Accordingly, several meetings and summits related to the "Aviation & Environment" were held over the past few years around the world, in order to discuss this important issue.

AVIATION: DEVELOPMENT & IMPROVEMENT

The oldest testimonies about man's efforts to learn how to fly dates from the time of ancient civilizations, accordingly, aviation development leads to engine burning, and when aircraft engines burn fuel, they produce emissions that are similar to other emissions resulting from fossil fuel combustion. However, aircraft emissions are unusual in that a significant proportion is emitted at altitude. These emissions give rise to important environmental concerns regarding their global impact and their effect on local air quality. Air travel accounts for 5-14% of global climate emissions and is growing rapidly. Nevertheless, aviation emissions remain unregulated (Carbon Market Watch, 2013).

Development

The results show that due to the high growth rates of international transport expected under the chosen scenario, by 2050 the share of unabated emissions from international aviation and shipping in total greenhouse gas emissions may increase significantly from 0.8% to 2.1% for international aviation (excluding non-CO_2 impacts on global warming) and from 1.0% to 1.5% for international shipping. Although these shares may still seem rather modest, compared to total global allowable emissions in 2050 in a 450 ppm stabilization scenario, unabated emissions from international aviation may have a 6% share (for CO_2 only) and unabated international shipping emissions have a 5% share. Thus, total unregulated bunker emissions account for about 11% of the total global allowable emissions of a 450 ppm scenario (European Commission, 16 May 2007).

Furthermore, the incorporation of the non-CO_2 impacts of aviation on climate change into the UNFCCC accounting scheme for GHG emissions could be considered, since aviation is a special case in this respect where the non-CO_2 impacts make a significant contribution. The inclusion of the global warming impact of non-CO_2 emissions, of which a significant fraction originates from NOx emissions (through ozone formation), would increase the share of international aviation emissions in 2050 from 6% to 17% (European Commission, 16 May 2007).

Improvement

ICAO provides a framework to ensure interoperability between NextGen and other international air traffic modernization efforts, such as Europe's SESAR initiative. The environmental benefit of NextGen and other international modernization initiatives will be reduced fuel burn and carbon dioxide emissions through the elimination of airport congestion and en route delay through an evolving system that is safe, secure, and efficient (AIA, 2008).

ENVIRONMENTAL CRISIS

In light of the aforementioned, in the next two sections the definition of "environment crisis" will be discussed, in addition to the "climate change" as environmental crisis.

What is Environmental Crisis?

It is argued that the current environmental crisis from the perspective of pragmatist philosophy is at least in part a result of an ancient split in western thinking between the physical and human worlds. If progress is to be made toward realistic solutions to this crisis, the irrational aspects of human experience must be made part of the calculus. While scientific understandings of the environment certainly help us to identify environmental problems it must be remembered that solutions to these problems will be forged not only from the facts but also from the scientifically incommensurable yet important facets of human experience – emotion, patriotism, faith, etc. (Jerry Williams, Austin State University).

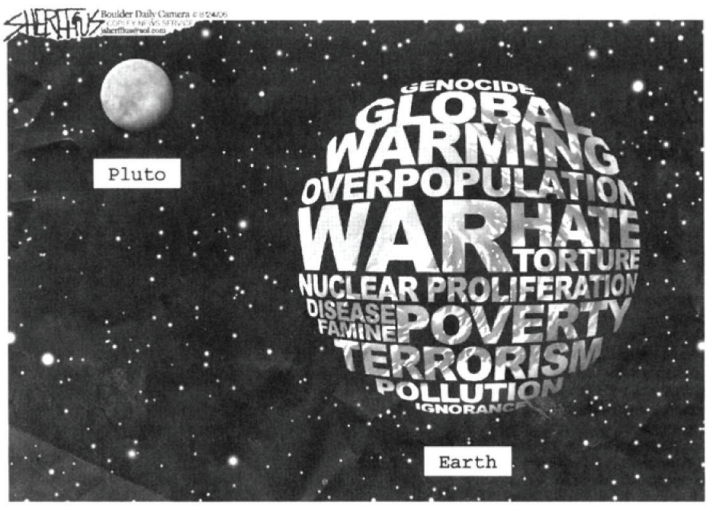
Little doubt exists as to the immediate threat posed by global environmental problems. Resource depletion, global warming, and unprecedented levels of species extinction are evidence that human societies are pushing the limits of the natural world. Two questions, however, seem apparent: how did this happen and what might be done about it? (Jerry Williams, Austin State University). Our plant is facing with different global, regional and local problems which will lead to some kind of environmental disruptions and disturbances (Figure 1).

Climate Change as Main Environmental Crisis

The Earth is rapidly getting warmer. This change in the climate threatens serious and even catastrophic disruption to our societies and to the natural environment on which we depend for food and other vital resources. It is being caused mainly by a build-up of 'greenhouse gases' that are released by human activities, in particular the burning of fossil fuels (coal, oil and gas), deforestation and certain types of agriculture. These gases trap the sun's heat in the atmosphere in the same way as a greenhouse does. Over the course of the 20th century the average surface air temperature increased by around 0.6 °C globally, by almost 1 °C in Europe and by no less than 5 °C in the Arctic. This man-made warming is already having many discernible impacts around the globe. Hence, Climate change can be defined as a change in the "average weather" of a given region experiences, including such factors as storm frequency, temperature, wind patterns and precipitation. The climate change have impacted energy consumption pattern by changing climatic factors (Jafari, 2013). The rate and magnitude of global climate changes over the long term have many implications for natural ecosystems. As society becomes increasingly reliant on the energy consumption, in work and at home and for mobility, which manifested in the heat-trapping nature of the atmosphere to increase.

Climate change will affect all countries but developing countries are particularly vulnerable while being least able to afford the cost of adapting to it (European Commission, August 2005). As our scientific understanding of this situation increases, so does public concern and the requirement for a policy response. Aviation contributes a small but growing proportion to this problem (less than 4% of man-made atmospheric emissions). A key factor however, is that some of aviation's emissions are emitted in the upper atmosphere and may have a more

Figure 1. Plant' problems in global, regional and local levels



Downgraded planets

direct effect. The science of climate change is still relatively new and the future is uncertain. However, there is a broad consensus that policy needs to be enacted now if climate change related problems and costs are to be avoided (EUROCONTROL).

In the same context, historically, aviation's biggest environmental issues have been associated with airports. These remain a major impediment to achieving maximum airport throughput, and without their successful resolution it will be impossible to deliver sufficient capacity. However, when dealing with an average of 25,000 flights per day in European airspace, a large proportion of which could generate contrails, this is no longer a simple problem to solve. It is unlikely, therefore, that fiscal or operational measures will be introduced before 2010 to combat aviation's climate change impact (Mr. Andrew Watt, EUROCONTROL Environment Domain Manager).

Ozone layer sensitivity to GHGs is one of the important targets in climate change negotiations (Figure 2).

CAUSATIVE SOURCE OF POLLUTION: AIR POLLUTION (GHGS, AEROSOL, SMOKE AND PARTICULATE, DUST)

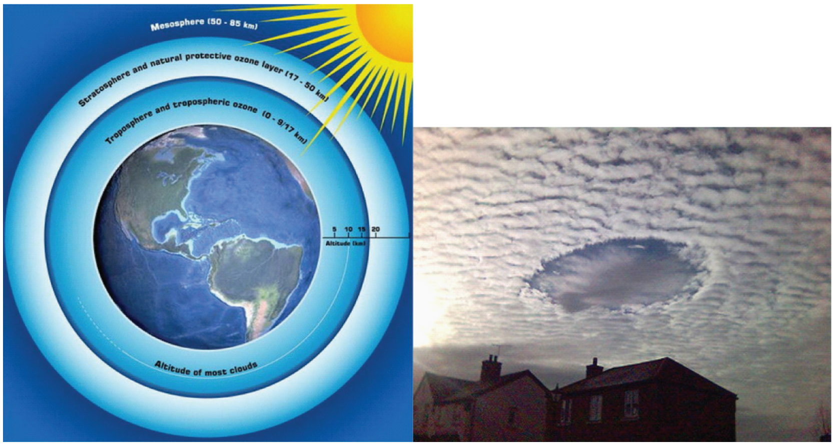
Emission

There are some main gases emissions need to be considered:

Carbon Dioxide, Tropospheric ozone, stratospheric ozone, Sulphur and nitrogen compounds, Smoke and particulates.

Emissions of CO_2 are proportionally related to fuel usage (kerosene) by a factor of ~3.15. Figure 3 shows the development of aviation fuel usage since 1940, along with the revenue passenger kilometres (RPK). A number of events impacting the sector (oil crises, conflicts, disease) show a response in demand and in emissions, and that the sector is remarkably resilient and adaptable to a variety of external pressures. How the current global economic crises will affect aviation remains to be seen but there are early signs of recovery. The usual pattern is a decline or downturn in demand that often recovers after 2 to 3 years, sometimes so strongly that the growth is put back 'on track'.

Figure 2. Ozone layer sensitivity to GHGs



For example, after the early 2000s events, recovery in RPK in some subsequent years was remarkable. The lower panel of Figure 3 shows aviation CO_2 emissions in context with total historical emissions of CO_2 from fossil fuel usage. Emissions of CO_2 (total) as an annual rate increased markedly in the late 1990s and early 2000s. This was not reflected in the early 2000s by the aviation sector, because of suppression of demand in response to the events of 9-11 etc.; another reason why an annual percentage contribution of aviation emissions to total CO_2 emissions can be misleading when not placed in a longer-term perspective, as Figure 3 shows (ICAO, 2010).

The lower panel of Figure 3 shows the growth in CO_2 emissions in Tg CO_2 yr-1 (per year) for all fossil fuel combustion and from aviation (left-hand axis), and the fraction of total anthropogenic

CO_2 emissions represented by aviation CO_2 emissions (%) (right-hand axis). Note the x10 scaling of aviation CO_2 emissions. This figure was taken from Lee *et al*. (2009).

Air Quality

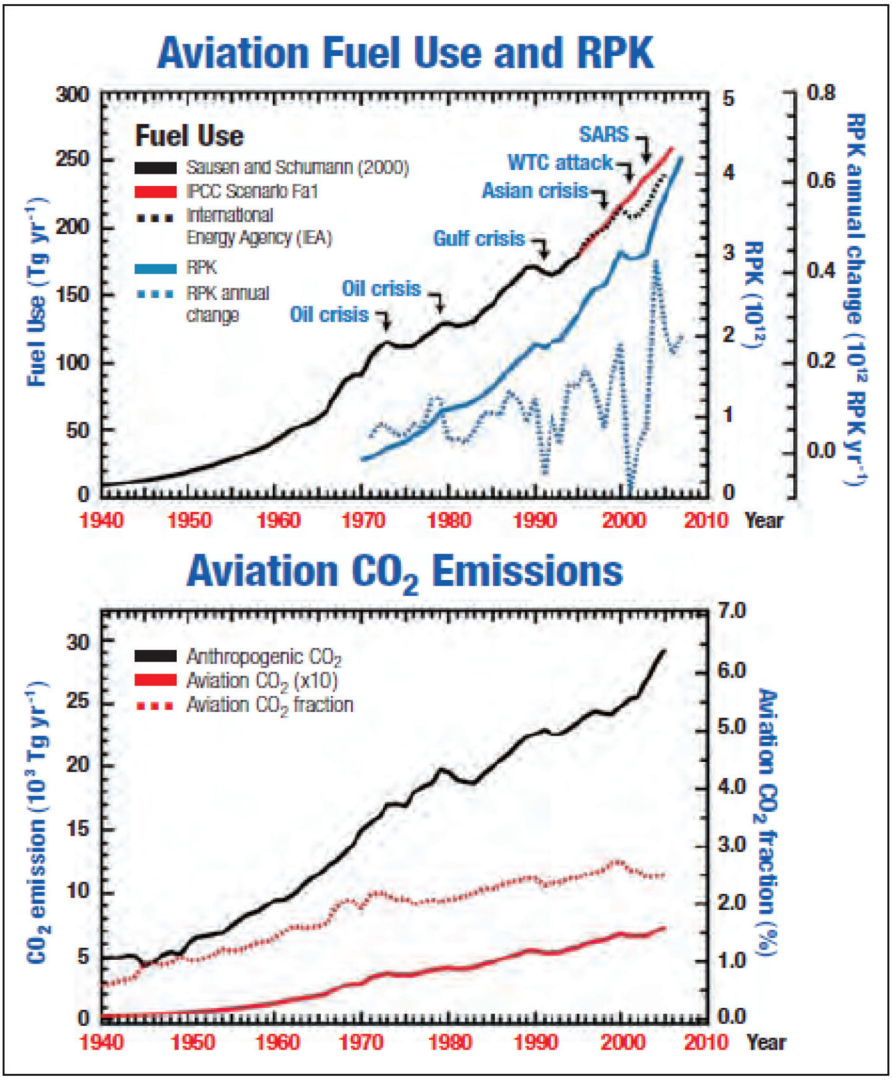
Aviation air quality concerns are principally related to the areas on and around airports. Further, for most airports the most significant air quality related emissions presently come from ground transport (cars, buses, trains etc). However, because of factors such as growth in demand, more public transport access to airports, and the long service life of aircraft, it is widely expected that aircraft will eventually become the dominant air quality related pollution source for many airports. The significance of aviation's impact on air quality will vary depending on many other factors such as, background pollution levels, other sources of pollution, weather and proximity of residential areas. Around many airports some large emission sources already exist (power stations, factories) that are not related to the airport at all. Also local roads and motorways, even roads associated with an airport, may be heavily used by non-airport traffic.

The chief local air quality relevant emissions attributed to aircraft operations at airports are as follows:

Oxides of Nitrogen (NOx), Carbon Monoxide (CO), Unburnt hydrocarbons (CH_4 and VOCs), Sulphur Dioxide (SO_2), Fine Particulate Matter (PM10 and PM2.5), and Odour.

These are produced by aircraft engines, auxiliary power units, apron vehicles, de-icing, and apron spillages of fuel and chemicals. Local factor influence the significance of individual emissions species for each airport, but often NOx is by far the most abundant and is often considered the most significant pollutant from an air quality standpoint.

Figure 3. Aviation fuel usage, RPK, and the annual change in RPK (Note offset zero) over time. (ICAO, 2010)



WATER POLLUTION

1. **Sea Level:** One of the key factors to evaluate for many impact studies in low lying coastal regions is the current level of the sea relative to the land. Globally, Eustatic sea level (the volume of water in the oceans) appears to have been rising during the past century. However, there are large regional deviations in relative sea level from this global trend due to local land movements. Subsidence, due to tectonic movements, sedimentation, or human extraction of groundwater or oil, enhances relative sea-level rise. Uplift, due to post glacial isostatic rebound or tectonic processes, reduces or reverses sea level rise. As a reference, most studies of vulnerability to sea-level rise use the mean sea-level at a single date. For instance, studies employing

the IPCC Common Methodology use the level in 1990. However, to assess coastal vulnerability to sea-level effects, baseline tide gauge and wave height observations are required. These reflect tidal variations in combination with the effects of weather such as severe storms and atmospheric pressure variations.

2. **Inland Water Levels:** The levels of lakes, rivers and groundwater also vary with time, usually for reasons related to the natural balance between water inflow (due to precipitation and runoff) and losses (due to evaporation and seepage). Human intervention can also affect water levels, through flow regulation and impoundment, land use changes, water abstraction and effluent return and large scale river diversions. Sometimes these fluctuations in levels can be very large (often much larger than mean changes anticipated in the future). Thus, where time series are available, it is important to be able to identify the likely causes of fluctuations (i.e. natural or anthropogenic), as this information could influence the selection of an appropriate baseline period.
3. **Other Impacted Sectors Include:** Land cover and land use, Soil, Agricultural practices, and Biodiversity.

HAZARDOUS MATERIALS

Hazardous Materials in the Vancouver International Airport (as an Example)

The Airport Authority, airlines, fuellers, car rental companies, couriers, maintenance shops, construction companies and a number of other tenants located on Sea island use hazardous chemical products in their operations. Hazardous materials are also produced as waste products of some airport-related operations.

Chemical products and wastes considered hazardous materials may include:

- Flammable liquids (aviation fuel, jet fuel, solvent, paint)
- Compressed gases (propane, natural gas, nitrogen, oxygen)
- Corrosives (batteries, battery acid, sodium hypochlorite)
- Poisonous or infectious chemicals (medical samples, syringes)
- Others (PCBs, waste oil, and asbestos)

The majority of hazardous wastes generated by the Airport Authority include waste oil, waste paint, antifreeze, waste fuel, batteries and oil filters. These materials are generated during spill clean-ups, vehicle preventative maintenance and line painting, among other things.

The Airport Authority has designated areas where hazardous materials can be stored. All wastes are inventoried and labeled prior to being shipped offsite for disposal or recycling.

NOISE

A major concern for communities surrounding many airports is the noise that aircraft make, particularly during take-off and landing. This is a focus for ACI and their member airports and, even though noise from new aircraft has been substantially reduced in the past 10 years (and is expected to be further reduced in the next decade), it remains an important issue.

Aeronautical Noise

Noise associated with an airport can be attributed to a number of sources or activities, such as:

- Aircraft take-offs and landings
- Aircraft over-lights of residential neighborhoods
- Engine run-ups, which are tests performed on aircraft engines and systems after maintenance to ensure they are functioning safely
- Reverse thrust, which is used to slow an aircraft when landing on the runway
- General noise from ground service equipment

LINK BETWEEN AVIATION IMPACTS AND ENVIRONMENTAL CRISIS

Recognizing the relationship between aviation and the environment, Association of Asia Pacific Airlines (AAPA) strives to continually consider solutions to mitigate the environmental impacts. Environmental impacts are seen as systemic beyond the control of the operators. Inefficient management of airspace, restrictive operational procedures and inadequate infrastructure can inadvertently offset the investments by airlines to mitigate its effects on the environment (AAPA, 2006).

The Aviation Challenge

The Asia Pacific Region is predicted to be the largest and fastest growing aviation market in the world, outstripping the United States and Europe. Notwithstanding this the aviation industry is facing enormous challenges. Volatile oil prices, a slowing world economy, falling revenue, rising fuels costs and increasing pressures due to environmental considerations (Figure 4) such as global warming and climate change, all point to the need for a major review of the way we plan for, not just aviation needs, but for our transportation systems as a whole (WSROC LIMITED, 2009).

Aviation's fuel consumption and emission production had an increasing rate in the past decades (Figures 5, 6, 7, 8, 9 and 10) and it has been forecasted which it will be increasing in the future (Figures 11, 12 and 13).

Climate change outlook: Figure 13 provides results for global full-flight fuel burn for 2006, 2016, 2026, 2036 and 2050. These results are for both domestic and international traffic combined.

Different Perspectives: Human Dimension

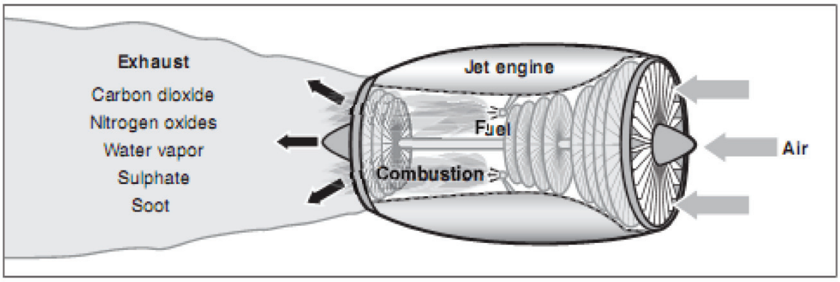
People living near airports have long suffered from aircraft noise, traffic congestion and air pollution. Indeed communities around airports have been concerned about these issues for years. However new evidence shows that air travel is contributing towards a far greater threat as Climate Change (Friends of the Earth).

Global warming could lead to the displacement of millions of people. Rising sea levels, floods and drought could make former land inhabitable. Changing weather patterns could effect food crops and accelerate water shortages. According to a Red Cross report in 1999 for the first time environmental refugees out numbered those displaced by war (Friends of the Earth). We need to mitigate land-based greenhouse gases, without compromising food security and environmental goals? (Smith *et al*., 2013).

Aircraft emissions can also have a significant effect at ground level. Air and ground traffic at major airports can lead to pollution levels as high as city centers. A recent study of Gatwick airport predicts that NOx emissions from cars could decrease by 75% by 2000 due largely to cleaner vehicles, but aircraft emissions of NOx are expected to double by 2008. As a result the National Air Quality standards for nitrogen dioxide (NO_2) may be exceeded

Figure 4. Aviation' impact on wildlife

Figure 5. Selected greenhouse gases and other emissions from aircraft at cruising altitude



Source: GAO.

in nearby towns (Friends of the Earth). Lee *et. al*. (2013) research show that emissions near cruise altitudes (9–11km in altitude) rather than emissions during landing and take-off are responsible for most of the total odd-nitrogen (NOy), ozone (O3) and aerosol perturbations near the ground with a noticeable seasonal difference (Lee *et. al*. 2013).

A report undertaken for the Health Council of the Netherlands reveals airports have a negative impact on public health. The Health Council has called for public health impact assessments of airports that would assess the cumulative way people are exposed to hazards including air pollution, noise and safety from airport operations (Friends of the Earth).

1. **Urban Environment (Local, Regional, Global):** Concerns about the environmental consequences of aviation have increasingly focused on emissions from airport operations - including emissions from aircraft; the ground equipment that services aircraft; and the vehicles that transport passengers to, from, and within airport grounds. According to the Environmental Protection Agency (EPA), aviation activities result

Figure 6. Source of EU GHGs emissions. (European Commission, August 2005, Environment fact sheet: Climate Change).

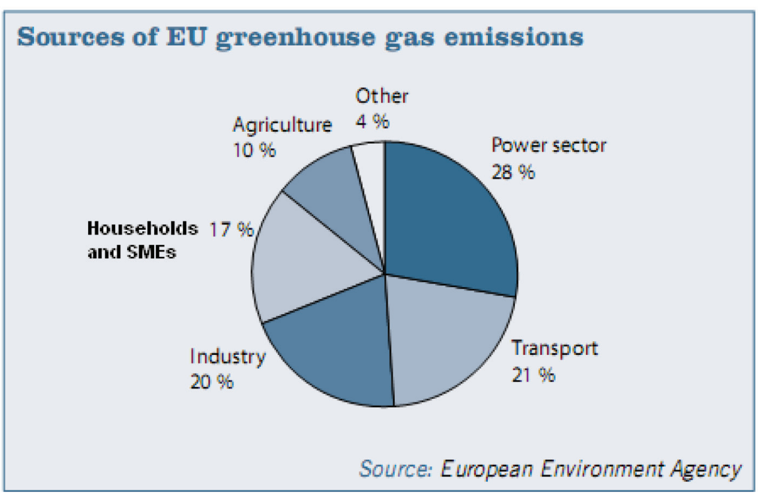
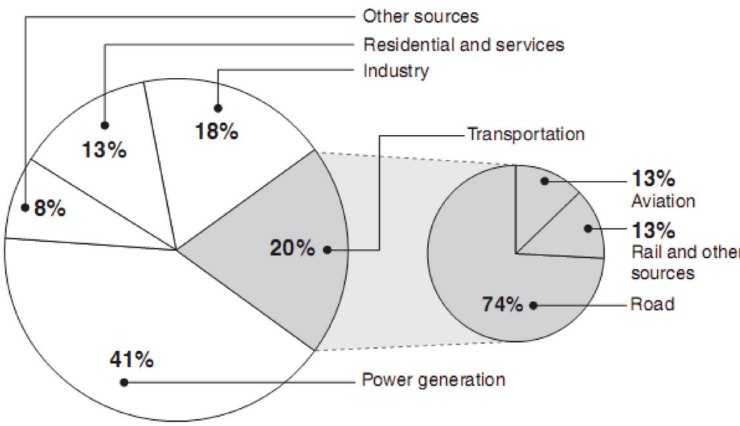


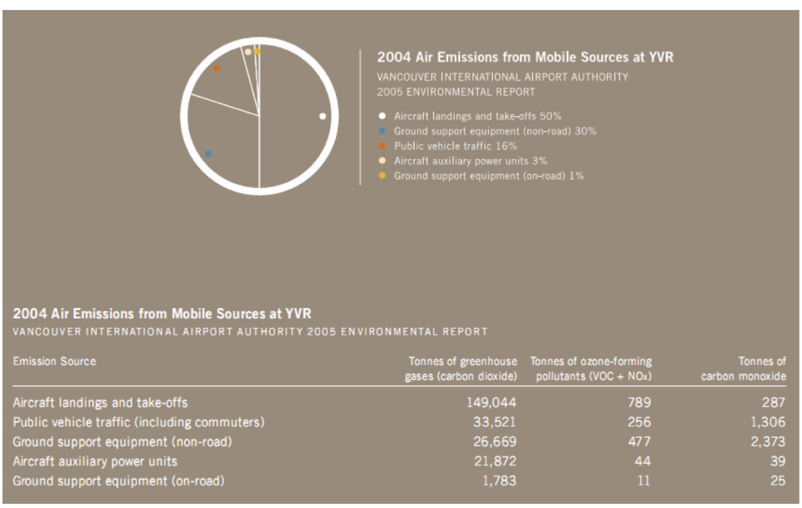
Figure 7. Global transportation's and global aviation's contributions to carbon dioxide emissions, 2004



Sources: GAO presentation of International Energy Agency and IPCC data.

in the emission of pollutants that account for less than 1 percent [note: This estimate pertains to aircraft emissions, and it does not include emissions from other sources at airports, such as vehicles and equipment that service aircraft. According to EPA, in areas that do not meet federal Clean Air Act requirements for ozone (which is formed from nitrogen oxides and volatile organic compounds), aircraft emissions are estimated to contribute as much as 3 percent of this pollutant.] of the total local air pollution in the United States, but the contribution of these pollutants in areas surrounding airports can be much larger.

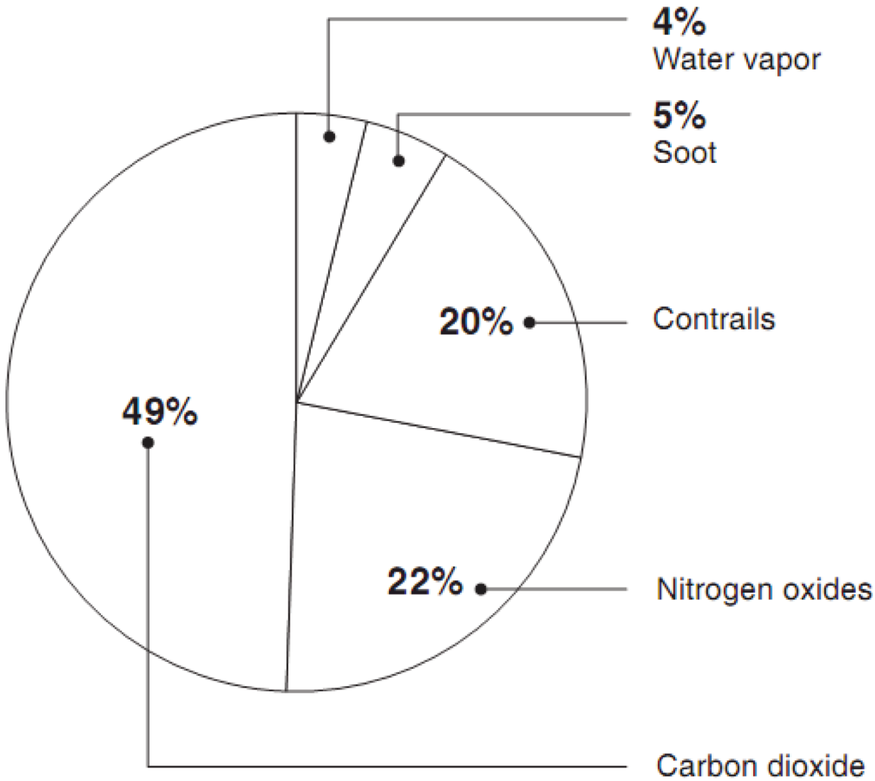
Figure 8. Air emissions from mobile sources at YVR (Vancouver International Airport Authority, 2004, an example)



2004 Air Emissions from Mobile Sources at YVR
VANCOUVER INTERNATIONAL AIRPORT AUTHORITY 2005 ENVIRONMENTAL REPORT

Emission Source	Tonnes of greenhouse gases (carbon dioxide)	Tonnes of ozone-forming pollutants (VOC + NOx)	Tonnes of carbon monoxide
Aircraft landings and take-offs	149,044	789	287
Public vehicle traffic (including commuters)	33,521	256	1,306
Ground support equipment (non-road)	26,669	477	2,373
Aircraft auxiliary power units	21,872	44	39
Ground support equipment (on-road)	1,783	11	25

Figure 9. Estimated relative contribution of aviation emissions to positive radiative forcing



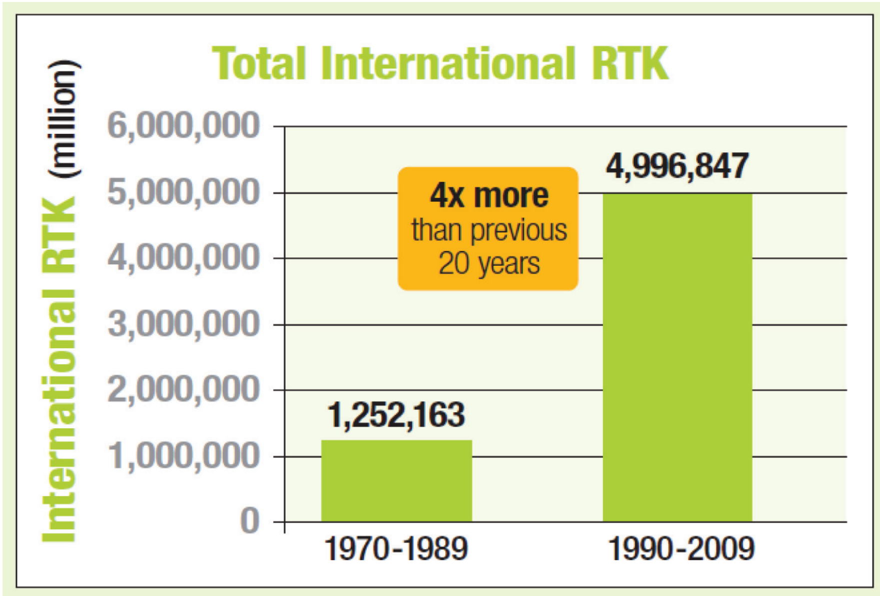
Source: GAO presentation of IPCC reported study.

Likewise, aviation-related pollutants such as Nitrogen Oxide, which contributes to ozone formation, are expected to increase based on forecasted growth in the aviation sector. Better scientific understanding of the potential health effects of certain aviation emissions and the contribution of aviation emissions, such as Carbon Dioxide, to climate change have also intensified the concerns about the overall impact of aviation emissions. As communities have gained more awareness of the health and environmental effects of aviation emissions, opposition to airport expansion projects, which has thus far focused primarily on aviation noise, has broadened to include emissions.

In addition, airport expansion projects, which can result in increased emissions, must comply with federal Clean Air Act (CAA) requirements. Expanding airport capacity will be necessary to accommodate both the predicted increases in air traffic that are envisioned for the coming decades and the development of the Next Generation Air Transportation System, which is intended to handle those increases. Addressing the effects of airport ground emissions and other types of aviation emissions is expected to be a major challenge to aviation growth in the coming decades (GAO-09-37, Nov. 2008).

Aircraft engines produce emissions that are similar to other emissions resulting from any oil based fuel combustion. These, like any exhaust emissions, can affect local air quality at ground level. It is emissions from aircraft below 1,000 ft above the ground (typically

Figure 10. Total international aviation traffic (1970 – 2009 RTK) (ICAO, 2010)



around 3 kilometers from departure or, for arrivals, around 6 kilometers from touchdown) that are chiefly involved in influencing local air quality. These emissions disperse with the wind and blend with emissions from other sources such as domestic heating emissions, factory emissions and transport pollution.

2. **Natural Environments (Terrestrial, Aquatic, Atmospheric):** Pollutants and climate change with affect on all types of environments namely terrestrial, aquatic and atmospheric. These effects include human, animals, plants and all nonliving materials.

Results of studies in the California have emphasized the strong linkage between levels of air pollution-related atmospheric nitrogen (N) inputs into mountain watersheds and levels

Figure 11. Total fuel consumption and fuel efficiency of U.S. airlines (an example)

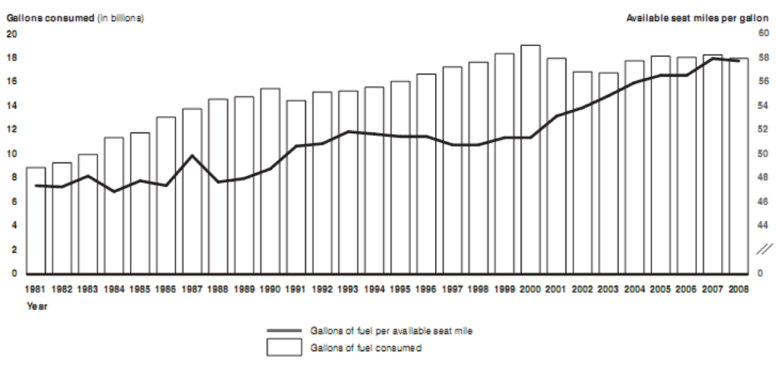
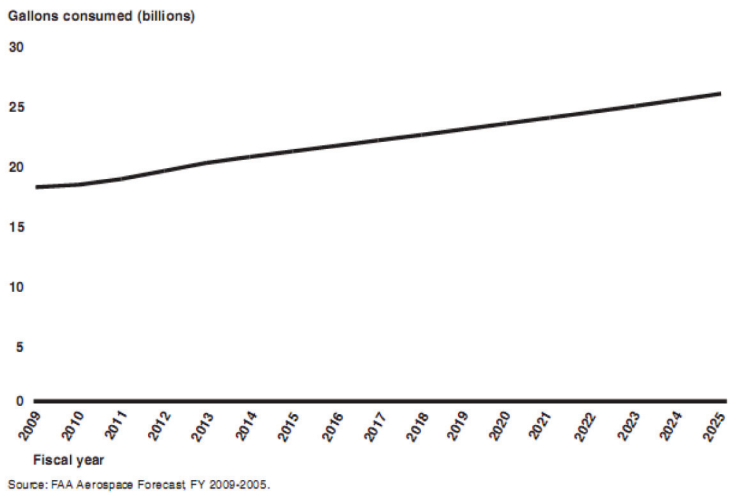


Figure 12. Forecasted fuel consumption by U.S. airlines (an example)



of nitrate in surface and subsurface drainage waters (Fenn et al., 2005).

Due to the interaction of N deposition with land management activities, it is possible that past, present, and future land management practices (including fire suppression, introduction of invasive species, and forestry practices) could minimize or exacerbate the adverse effects of N deposition on terrestrial and aquatic ecosystems. Hydrologic flow paths in a watershed also influence the impact of atmospheric N deposition on aquatic ecosystems (Figure 14).

In summary, chronic N deposition results in excess N in terrestrial, riparian, and aquatic habitats. This dramatic change in the chemical environment of these habitats has high potential

Figure 13. Total global aircraft fuel burn 2006 to 2050 (ICAO, 2010)

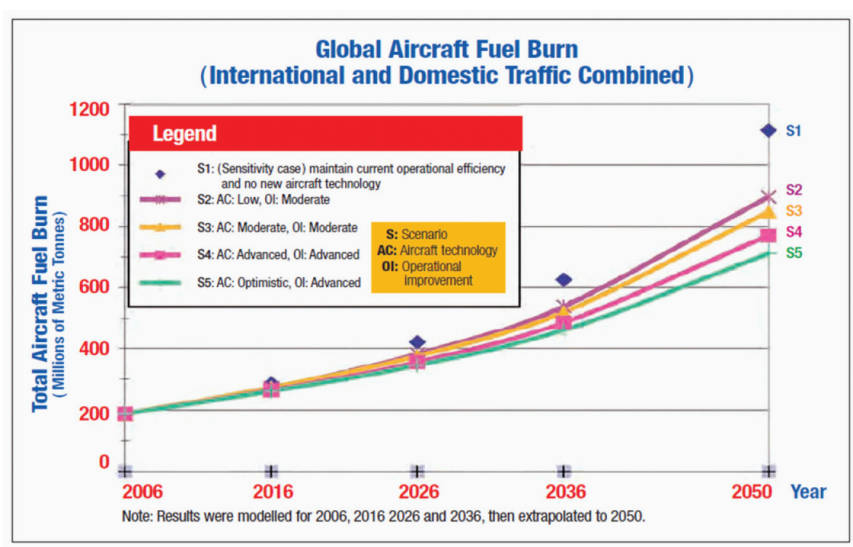


Figure 14. Conflict of technology and nature

to upset the normal communities of vegetation, microbes, and micro- and macro-flora and fauna either via direct effects on sensitive organisms or via cascading effects on the food chain (Fenn et al., 2005).

3. **Birds Killed by Intervention:** In 2005, approximately 1.6 million birds were moved away from aircraft operating areas using a variety of harassment techniques, including pyrotechnics, sirens, lights, propane cannons and specially trained Border Collies. This represents a 7% increase over 2004.

While habitat management and harassment techniques are the primary tools used, killing occurs when the officer perceives wildlife behavior to be a safety risk. This may consist of an immediate risk to an approaching aircraft, or a potential or chronic risk that has increased to unacceptable levels. In 2005, 1.060 birds were killed by control officers.

In 2005, 222 birds were killed in 155 bird-strikes with aircraft, a 34% increase over 2004. However, compared with 2004, a larger portion of the bird-strikes in 2005 involved barn swallows, which, because of their small size, pose less of a safety risk than larger bird species.

Factors that contribute to bird-strikes include aircraft operations, environmental conditions and variability in bird population. In 2005, ducks, dunlin, starlings and swallows accounted for more than 86% of birds killed by aircraft and control officers at YVR.

CONCLUDING REMARKS

Aviation is a global enterprise that requires uniform international product acceptance and operating procedures. However, recent European actions threaten the ability of the International Civil Aviation Organization (ICAO) to establish global standards and practices that foster continued growth while reducing the impact of aviation on the environment (AIA, 2008).

The United States provides 25 percent of ICAO's budget, which enables U.S. specialists to fill a large number of ICAO technical leadership and staff positions. U.S. leadership in ICAO, combined with the technical expertise of the Committee on Aviation Environmental Protection (CAEP), provides a framework to ensure that U.S. aviation environmental issues are well represented in the global aviation community (AIA, 2008).

The International Energy Agency (IEA) estimates that world energy demand will increase by over 50% between now and 2030 if policies remain unchanged, with more than 60% of the increase coming from developing and emerging countries. This would mean an increase of 52% in emissions of carbon dioxide (CO_2), the main greenhouse gas (European Commission, March 2006).

Aviation releases gases and particulates which alter the atmospheric composition, thus contributing to climate change. Although aviation's contribution is still small compared to other sources of human emissions, the rapid growth of air traffic is increasing the impact of aviation on climate. Even though there has been significant improvement in aircraft technology and operational efficiency, this has not been enough to neutralize the effect of increased traffic, and the growth in emissions is likely to continue in the next decades. If the present trend continues, it is expected that emissions from international flights from EU airports will increase by 150% by 2012 in comparison to 1990 levels. One of the effects of aircrafts is the emission of water vapor, which at high altitude often triggers the formation of condensation trails, i.e. line-shaped ice clouds that are also called "contrails", which tend to warm the Earth's surface by trapping outgoing heat emitted by the Earth and the atmosphere. Furthermore, such contrails may develop into cirrus clouds, which are suspected of having a significant warming effect, but this remains uncertain. It became necessary to improve the understanding of the resulting impact of contrails on climate (European Commission, 13 July 2006).

Acting responsibly in concert with ICAO, international aviation has demonstrated a history of reducing aviation's environmental impact. For example, over the past 40 years, carbon dioxide emissions have been reduced by 70 percent. An international approach remains critical; and, because of ICAO's leadership role, national, regional, and local solutions have not been successful (AIA, 2008).

Demand for air transport is continually growing and, if this demand is to be met with all the attendant benefits, society must also accept the costs (noise, pollution, climate change, risk, resource use etc). Thus, if aviation is to continue to play its role in our present concept of sustainability, where possible it must achieve a balance of social, economic and environmental imperatives. It is also clear therefore, that all practical opportunities to minimise these adverse costs should be achieved, otherwise aviation will not achieve the required balanced. And if the balance cannot be achieved, society will then face difficult decisions regarding the global economy and global mobility (EUROCONTROL).

Benefits

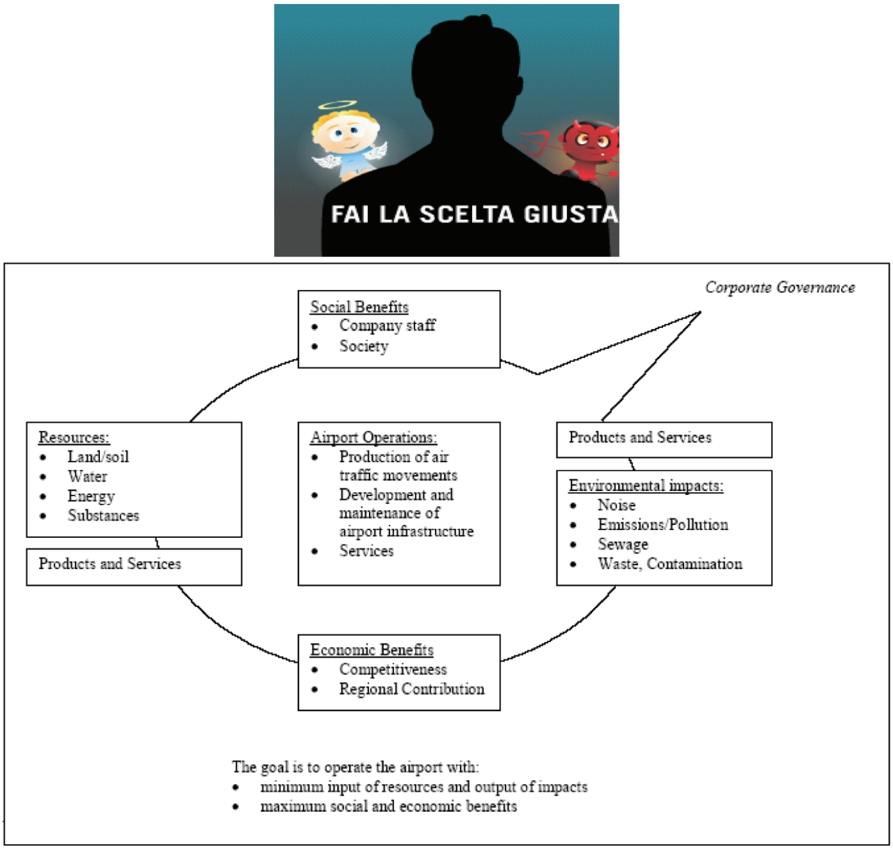
Aviation brings several sustainability issues related to the benefits including: Freedom of mobility, Leisure, Improvement to health through poverty reduction, Cultural enrichment and diversity, Employment, Technology transfer, Major direct, secondary and indirect economic improvement, Global business links, Military security, and Positive globalization effects.

1. **Impacts:** Aviation also provides costs including: Finite resource depletion, Noise, Atmospheric emissions (air quality, ozone depletion, acid rain and climate change), Water and land pollution, Waste products, Negative globalization effects, Associated adverse health impacts, and Accidents **(**EUROCONTROL**).**

In conclusion, it is the goal of the airport to keep these aspects in a balance that secures future operations (Frantz Buch Knudsen, 2004).

Considering the **costs and benefits** of different types of transportations may provide a suitable ground to be able to reduce emissions and increase efficiency (Figures 15 and 16).

Figure 15. Airport operations: Benefits and impacts

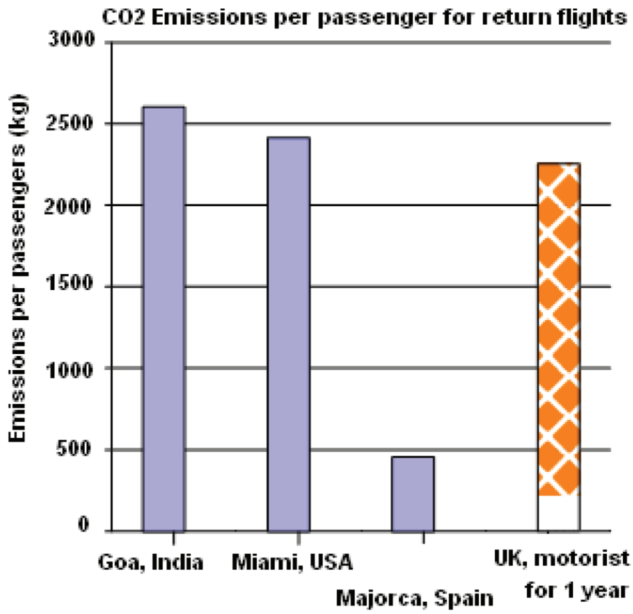


RECOMMENDATIONS

The cap on emission allowances for the sectors covered by the system - power generation, energy-intensive manufacturing industry and, from 2012, aviation - will be cut in a linear fashion every year from 2013, with the result that the number of emission allowances available in 2020 will be 21% below 2005 levels. The international aviation is large and rapidly growing source of GHG emissions yet it is not covered by the Kyoto Protocol. The post-2012 agreement must include emission reduction targets for this industry. In addition, countries should work together through the International Civil Aviation Organization (ICAO) to agree global measures by 2010, which should be approved by 2011. Market-based instruments, including emissions trading, can ensure that emission reductions from this sector are achieved cost-effectively (European Commission, 2009).

The continuing increase in demand for commercial aviation transport raises questions about the effects of resulting emissions on the environment (Lee *et al.,* 2013). The international aviation and shipping sectors are projected to contribute significantly to global emissions of greenhouse gases (GHGs), in particular carbon dioxide (CO_2). These so-called bunker emissions are, however, not yet regulated by international policies formulated by the United Nations Framework Convention on Climate Change (UNFCCC) or the Kyoto Protocol. One of the reasons why international bunker emissions are not yet regulated is due to the unclear situation regarding who is responsible

Figure 16. CO_2 emissions per passenger per return flight



Graph based on results of a Dutch study (Energy and emissions profiles of aircraft and other modes of transport over European Distances, Centre for Energy Conservation and Environmental Technology, Delft, Netherlands, 1997) and 1998 transport statistics from the Department of Environment, Transport & Regions.

for these emissions. In this regard, the European Union (EU) indicated in its Environmental Council decision in 2004 that international bunker emissions should be included in climate policy arrangements for the post-2012 period (European Commission, 16 May 2007).

Aviation emissions from developed countries should be capped at 2005 levels. While "Emissions trading and offsetting offer useful short to medium term flexibility for meeting aviation targets", in the long run the industry will need to make deep cuts in its own emissions, according to the Committee on Climate Change (CCC) (Climate Committee, Sep 9, 2009). In December last year the Committee reported that to achieve an overall cut in UK emissions of 80% while allowing aviation emissions to grow in the short term, other sectors would need to make even greater reductions. In January the government announced a special target for aviation - that by 2050 emissions should be brought down to 2005 levels (Note: The Department for Transport's UK Air Passenger Demand and CO_2 Forecasts, published in January 2009 gave aviation emissions figures of 16.9 $MtCO_2$ in 1990, and 37.5 $MtCO_2$ in 2005). This in fact allows aviation emissions to increase by 120%

compared with 1990 levels, while other sectors are required to make 90% reductions.

To have a chance of bringing the UK's aviation emissions back down to 2005 levels by 2050 the government will need to look again at the expansion plans they set out for UK airports in 2003. Aviation emissions have more than doubled since 1990 and are set to carry on rising under government growth projections.

Emissions Trading

Emissions Trading Aviation plays a significant role in the economic and social development of the European Union. The industry also acknowledges its impact on the environment and is committed to delivering an ongoing program of environmental improvement. It aims to ensure the reduction of its environmental impact through research and development, technological innovation and revised operational procedures.

Environmental Performance

ADS members are involved in a range of initiatives and programs aimed at reducing the impact of their operations and products on the environment. Much of the information they gather in relation to environmental performance is published through their annual environmental reports.

A|D|S wants to demonstrate that its members are making ongoing environmental improvements, through the sustainable manufacture and consumption of their products, as well as improvements at their sites.

Technological Developments

UK aerospace is working towards the 2020 targets set by ACARE which challenge the European aerospace industry to reduce fuel consumption and CO_2 emissions by 50%, NOx emissions by 80% and perceived external noise by 50%. The ACARE targets represent a doubling of the historical rate of improvement. Delivery against the ACARE targets will require a series of step changes in the industry's ability to design, manufacture and operate aircraft.

The sector continues to make good progress, having improved fuel efficiency by 50% and reduced noise by 75% in the last 30 years. Current products reflect this ongoing commitment to further reductions in noise and emissions. For example, the Airbus A380 has NOx emissions 31% lower than those currently set by ICAO. The A380 has enabled further aerodynamic improvements to be realized with a noise footprint of half that of the Boeing 747-200 (ACARE).

In the United States, the Next Generation Air Transportation System, or NextGen, developed by the Joint Planning and Development Office (JPDO) will pull together operational and technological advancements to reduce the environmental effects of aviation. Successful deployment of NextGen is the key to U.S. leadership in the global aviation community and ICAO (AIA, 2008).

ICAO provides a framework to ensure interoperability between NextGen and other international air traffic modernization efforts, such as Europe's SESAR initiative. The environmental benefit of NextGen and other international modernization initiatives will be reduced fuel burn and carbon dioxide emissions through the elimination of airport congestion and en route delay through an evolving system that is safe, secure, and efficient (AIA, 2008).

In the coming century, the impact of air travel on the environment will become an increasingly powerful influence on aircraft design. Unless the impact per passenger kilometre can be reduced substantially relative to today's levels, environmental factors will increasingly limit the expansion of air travel and the social benefits that it brings. The three main impacts are noise, air pollution around airports and changes to atmospheric composition and climate as a result of aircraft emissions at altitude. The Air Travel - Greener by Design programme to assess the technological, design and operational possibilities for reducing these impacts. If these opportunities are pursued, the aircraft in production in 2050 could be very different from those of 2005 (Green, 2006).

Aviation is a growing contributor to climate change, with unique impacts due to the altitude of emissions. If existing traffic growth rates continue, radical engineering solutions will be required to prevent aviation becoming one of the dominant contributors to climate change.

The engineering options for mitigating the climate impacts of aviation using aircraft and airspace technologies can be reviewed. These options include not only improvements in fuel efficiency, which would reduce CO_2 emissions, but also measures to reduce non-CO_2 impacts including the formation of persistent contrails. Integrated solutions to optimize environmental performance will require changes to airframes, engines, avionics, air traffic control systems and airspace design (Williams, 2007).

A recent British study has analyzed the most important factors influencing the warming effect on climate from condensation trails formed from the water vapor emitted by aircrafts at high altitude. The results of the study suggest that shifting air traffic from night-time to daytime may help to minimize the climate effect of aircraft condensation trails, thus reducing the climate impact of aviation (European Commission, 13 July 2006).

Recommendations by UK Friends of the Earth (Friends of the Earth)

- Choose to fly less frequently whether for business or pleasure
- Consider taking a train as an alternative to domestic or short hop flights
- Investigate teleconferencing as an alternative to business flights
- Support the domestic tourist industry and plan more holidays in the UK

Recommendations by AIA Urge the Candidates to

- Continue U.S. commitment to ICAO as the pre-eminent global body responsible for all aviation environmental matters.
- Ensure strong public-private partnership engagement in the definition and execution of U.S. international aviation programs within the ICAO framework.

Toward an International Aviation Emissions Agreement

It is impossible to predict the eventual stopping place of the climate change discourse. If current evidence is to be believed, international dialogue will intensify as we draw nearer to the hypothesized "zero hour" of irreparable catastrophe. Stepping back from any prophesies of doom, Havel and Sanchez (2012) have concluded with two statements that they believe encapsulate their Article's contribution to the discourse. First, a plausible aviation emissions reduction agreement can ensure that aviation "does its part" by reducing the sector's emissions to a sustainable level without sacrificing its economic viability. Second, the convergence of stakeholder interests within international aviation will further ensure that the agreement can serve as a lead sector for future (and wider) international collaboration on climate change. And although the agreement framework proposed is incremental rather than "big bang," the principle of International Paretianism indicates that the former is more feasible than the latter. Under the canopy of a sectoral treaty among like-minded states, international aviation can responsibly reduce its environmental impact while remaining a force for dynamic economic growth in the coming century (Havel and Sanchez, 2012).

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APPENDIX

Table 1. Glossary, acronyms and abbriviations

Term	Description
AAPA	Association of Asia Pacific Airlines
A|D|S	A|D|S is the trade body advancing UK AeroSpace, Defence and Security industries with Farnborough International Limited as a wholly-owned subsidiary. A|D|S also encompasses the British Aviation Group (BAG). It is formed from the merger of the Association of Police and Public Security Suppliers (APPSS), the Defence Manufacturers Association (DMA) and the Society of British Aerospace Companies (SBAC).
ACARE	the Advisory Council on Aeronautics Research in Europe
ACI	Airports Council International
AIA	Aerospace Industries Association
APPSS	the Association of Police and Public Security Suppliers
BAG	the British Aviation Group
CAA	Clean Air Act
CAEP	the Committee on Aviation Environmental Protection (CAEP) of ICAO
CCC	the Committee on Climate Change The Committee on Climate Change (CCC) is an independent body established under the Climate Change Act to advise the UK Government on setting carbon budgets, and to report to Parliament on the progress made in reducing greenhouse gas emissions. http://www.theccc.org.uk/home
CO	Carbon Monoxide
CO_2	Carbon dioxide
Contrails	Condensation trails
DMA	the Defense Manufacturers Association
EEA	European Environment Agency
EPA	United States Environmental Protection Agency
EU	the European Union
EUROCONTROL	The European Organization for the safety of Air Navigation
EC	European Commission
FoE	Friends of the Earth,
GAO	United States Government Accountability Office
GHGs	The Greenhouse Gases
ICAO	the International Civil Aviation Organization
IEA	The International Energy Agency (IEA) of EU
IPCC	Intergovernmental Panel on Climate Change
JPDO	the Joint Planning and Development Office
NextGen,	the United States, the Next Generation Air Transportation System
NOx	Oxides of Nitrogen
PM10	particulate matter or fine particles, thoracic fraction, <=10 μm
PM2.5	particulate matter or fine particles, respirable fraction, <=2.5 μm

continued on following page

Table 1. Continued

Term	Description
PM1	particulate matter (PM) or fine particles, PM1, <=1 µm PM10-PM2.5 (coarse fraction), 2.5 µm - 10 µm Ultrafine (UFP or UP), <=0.1 µm
RTK	The total Revenue Tonne Kilometre
SBAC	the Society of British Aerospace Companies
SESAR	Single European Skies (SESAR), Europe's SESAR initiative
SMEs	Small- and Medium Size Enterprises
SO_2	Sulphur Dioxide
UNFCCC	the United Nations Framework Convention on Climate Change
VOCs	Volatile Organic Compounds (VOCs) are organic chemical compounds that have high enough vapor pressures under normal conditions to significantly vaporize and enter the atmosphere
WSROC LIMITED	Western Sydney Regional Organization of Councils Ltd,
YVR	Vancouver International Airport