Civil Aviation and Climate Policy: Status, Challenges, and Policies from a Trans-Atlantic Comparative Perspective

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1 Introduction

At a time when the civil aviation industry is suffering from falling demand, record high losses, and several airline insolvencies, one might wonder how it could pose a threat to the global climate. Economic factors, the September 11 terrorist attacks, and the invasion of Iraq—as well as occurrence of Severe Acute Respiratory Syndrome (SARS) in several world regions—have resulted in an unprecedented crisis in the industry.

Particularly since publication of the special report by the Intergovernmental Panel on Climate Change (IPCC), *Aviation and the Global Atmosphere* (Penner et al., 1999), there have been concerns about the industry, in part because the radiative forcing of jet aircraft at cruise altitude may be significantly higher per unit of fossil fuel used than that of other fossil-fuel-using activities. This feature of aviation and civil aviation's high rate of growth—which the industry expects to return to—present a major challenge for climate policy. Much further research is needed on the effects of aviation on the global climate. As well, the potential for mitigating aviation's adverse effects needs to be explored. Although aviation in the Asia-Pacific region could become significant in amount by 2020, today it remains largely concentrated in and between Western Europe and North America, and these regions have the primary obligation to reduce aviation's adverse effects on the global climate. Another challenging matter is that of future fossil fuel availability, which may have a profound impact on aviation activity and its global impacts, and may give the need to prepare for energy constraints at least as much urgency as the need to mitigate aviation's contribution to climate change.

The potential for reduction of energy use and emissions can be fully exploited only if technical and other operational changes as well as demand are addressed, and if relevant actors make their contributions to mitigation in a timely and coordinated manner. The attitudes towards climate change and the points of departure regarding demand for civil aviation and the structure of the aviation industry vary considerably between Western Europe and North America. As a consequence, the prospect of implementation of a coordinated strategy for mitigating the climate impacts of civil aviation may be poor even between these regions that have much more in common than other world regions. The present contribution attempts to demonstrate discrepancies and commonalities in Western Europe and North America and how these may hinder or help mitigation policies.

2 Development, structure of demand and fuel use

2.1 Historic and future development of demand

Air transport's contribution to total transport activity remained insignificant for several decades after the first flight of the Wright Brothers in 1903. Figure 1 shows on a per-capita basis that travel by air took off in the 1950s and is now outpacing travel by rail. The car is still the dominant mode. The reason for this is that access to travel by air is still much more limited than access to car use. Air cargo is insignificant on a per- capita basis although growing at higher rates than air travel. Because of its relatively high cost, air cargo is used primarily for goods that are expensive, urgently needed or perishable.

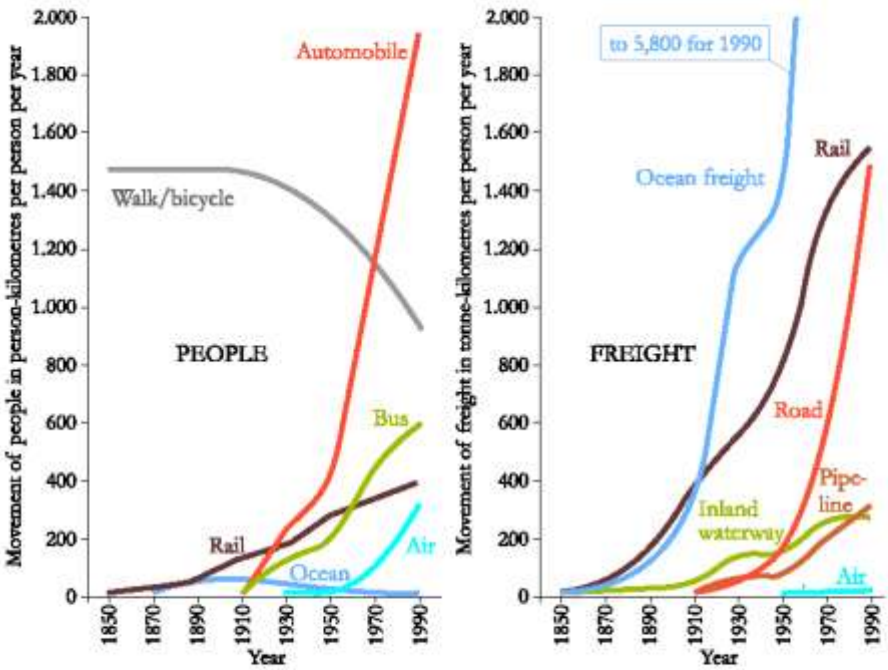

Figure 1. *Worldwide per-capita movement of people and freight, 1850-1990*
Source: Gilbert (2001)

World War II brought about enormous advances in aircraft technology and thus the potential for an economically viable civil aviation industry. Commercial trans-Atlantic service had begun just before the War, using seaplanes, but it was the advent of land-based service in 1945—albeit a costly and time-consuming journey with several stops—that began rapid development towards ever faster, safer, more comfortable, and less costly aviation services. (Holloway, 1999, p. 32) To date, global passenger transport activity by air has roughly reached 50 times the volume of 50 years ago. This has contributed to the increase in travel by all modes by 10 per cent and by 30 per cent in Europe and the US respectively during that same period (Ausubel et al, 1998).

As Figure 2 shows, global demand for aviation services in passenger and cargo operation has been on a steep growth path since the mid-1960s. Notwithstanding fuel price increases and economic recessions, until recently only in one year had activity declined, the result of military action in Iraq in 1991.

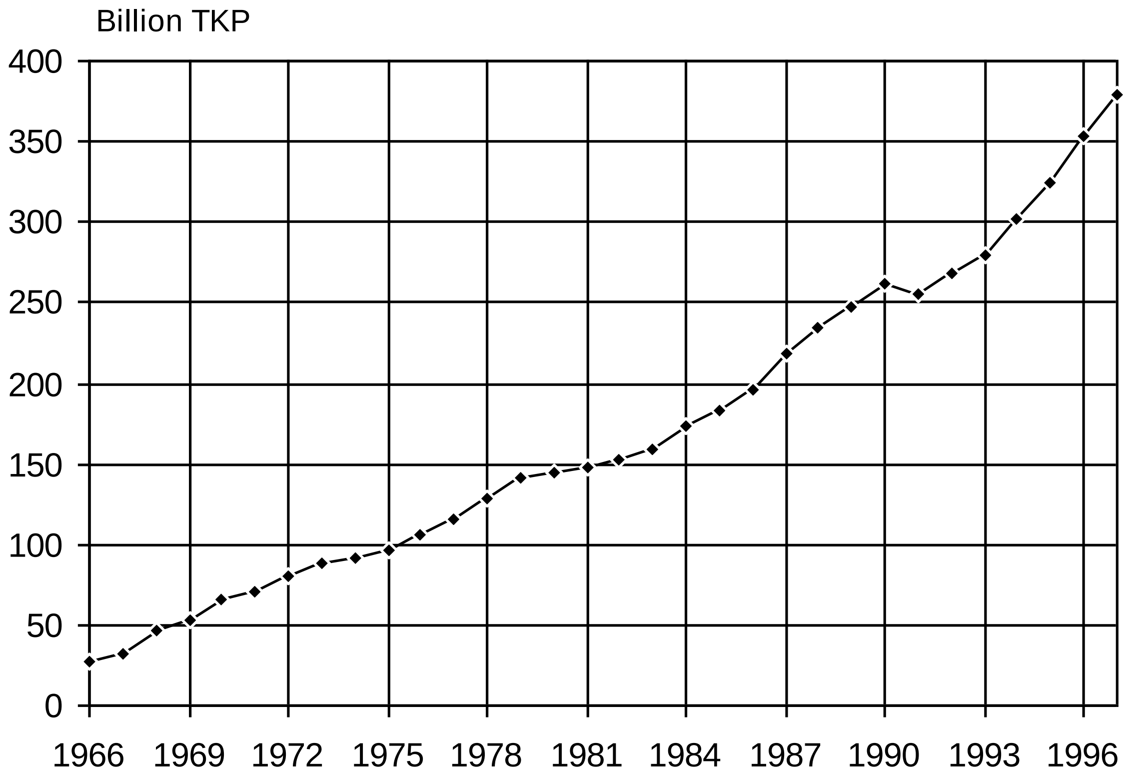

Figure 2. *Traffic of commercial air carriers (unified tonne-kilometres performed for passenger and cargo services)*
Note: All services of scheduled airlines and non-scheduled operators.
Source: ICAO (1999a and other issues)

The current crisis of the aviation industry has been caused by recession in economic activity, the September 2001 terrorist attacks, the March 2003 invasion of Iraq, and the occurrence of SARS. However, many industry experts expect that demand will return to or near its historic development path (see, for example, ICAO, 2003). Some of the current causes of sluggish demand can be regarded as temporary; the impacts of the terrorist attacks and even of SARS could be more permanent. Nevertheless, long-term projections of demand for passenger transport by air assume that civil aviation activity will continue at or near its historic rate of growth. Figure 3 shows the expectations of the aircraft industry that were incorporated in the scenarios used by the IPCC for its assessments of aviation's contribution to climate change. The forecasts of Boeing and Airbus from 2000 expected an increase of annual global passenger kilometres travelled by air by roughly 215 per cent for the 1995 to 2019 period. This is equivalent to an annual growth rate of around five per cent. An authoritative current projection is for longer-term growth by four per cent.

Besides the above-noted risks for long-term development of demand, there have been doubts as to whether the demand projections might materialize because construction of new airports and the extension of existing ones have become time-consuming processes (Humphreys 2003, p. 21). It may be for these uncertainties that the scenario Fa used by the IPCC for its assessment (see Figure 3) is well below the industry expectations. Nevertheless, scenario Fa still represents an increase in passenger travel by air by 450 per cent for the 1995-2050 period. Thus, fuel use by and CO_2 emissions from aviation would rise significantly even if only a fraction of the rise in demand forecast by industry happened.

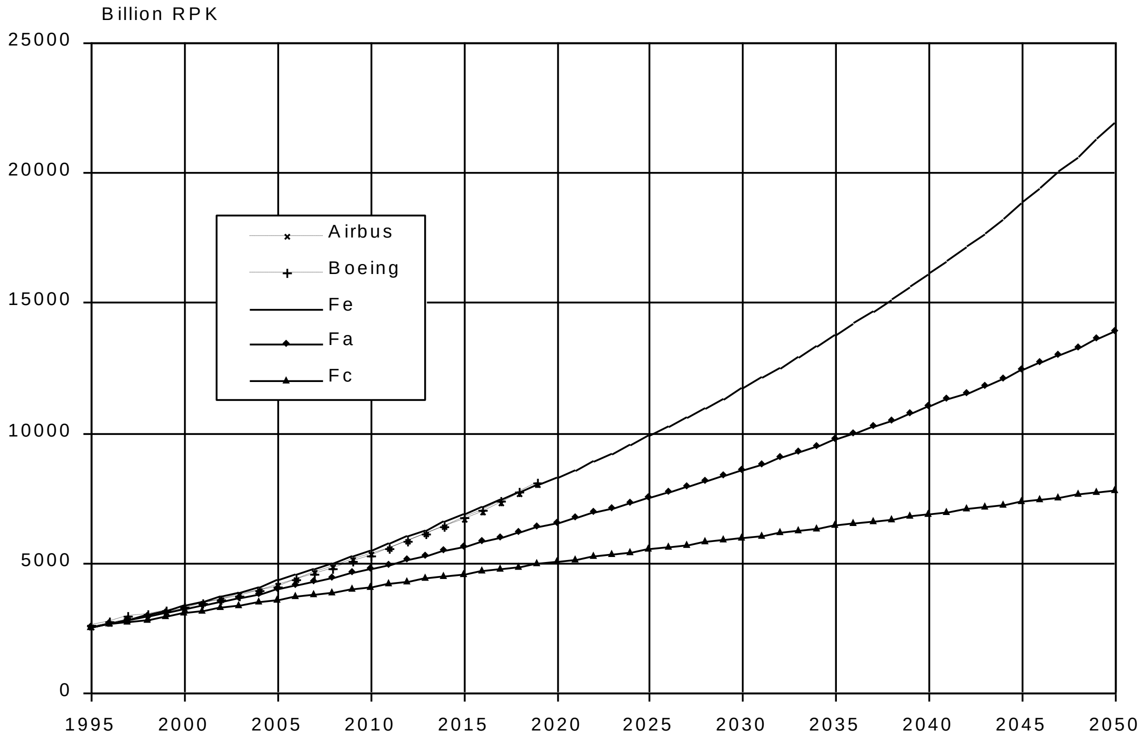

Figure 3. *Long term projections of demand for air travel (revenue passenger-kilometres)*
Note: Fe, Fa, and Fc indicate the various scenarios used by the IPCC for its assessment of aviation's future contribution to climate change.
Source: Airbus (2000), Boeing (2000), IPCC (1999), own interpolations.

2.2 The uneven distribution of global demand

What the figures on total and average air travel per capita do not show is how much of today's air travel occurs in and between regions of the world with high incomes per capita. Estimates of the share of the world's population that has ever flown vary between one per cent (Humphreys, 2003 p. 20) and five per cent (Whitelegg, 2003 p. 235). An average European flies around 2.5 kilometres per day amounting to 15 seconds of daily travel time. U.S. citizens on average spend 70 seconds flying per day. Members of the 'jet set' may reach up to 30 minutes per day (Ausubel et al, 1998).

Figure 4 shows that global demand for air travel is highly concentrated in regions of the world with high incomes per capita. This hints at the potential for growth of demand with growing incomes in other regions of the world. Much air travel is for business meetings and tourism. Air travel and air cargo display somewhat different patterns of geographic distribution. However today most of it is concentrated on North America and Western Europe and to a growing extent Asia. Air cargo handling is more geographically dispersed, with Asia having a relatively larger share because of its importance for global industrial production networks (Pastowski, 2003a).

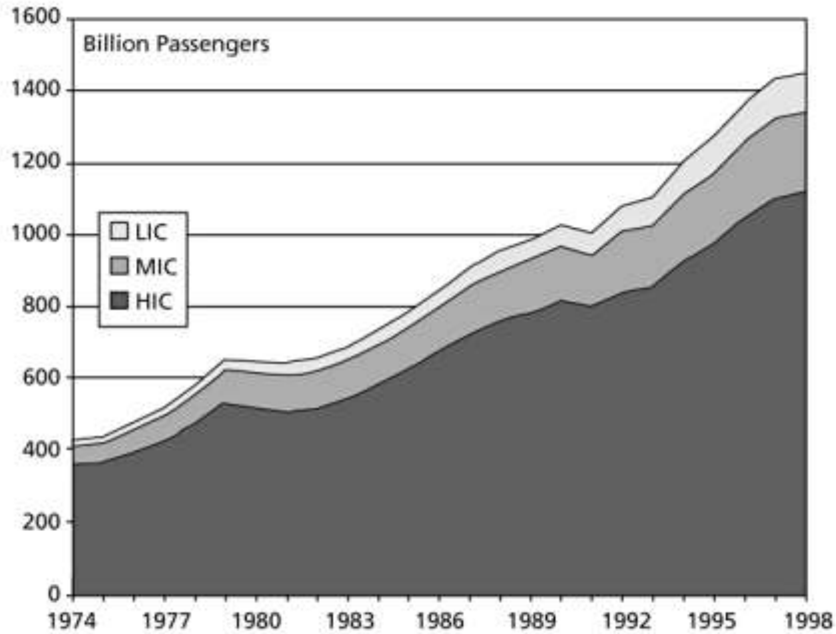

Figure 4. *Domestic and international passengers by income per capita group of country of departure*

Note: HIC high-, MIC medium-, and LIC low-income countries.
Source: World Bank (2000)

Figure 5 shows what Airbus expects with regard to the changes of regional shares of growing aviation demand. The growth in the shares associated with the Asia-Pacific region result from that region's assumed economic growth.

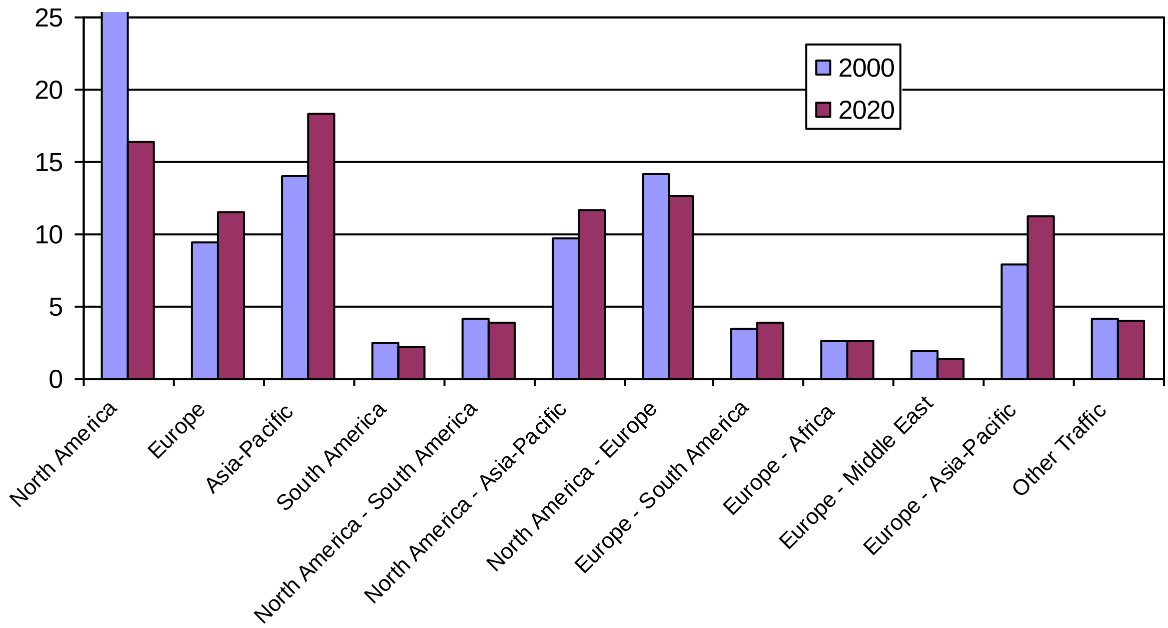

Figure 5. *Shares of regional and interregional passenger traffic in 2000 and 2020 (per cent)*

Source: Airbus (2002)

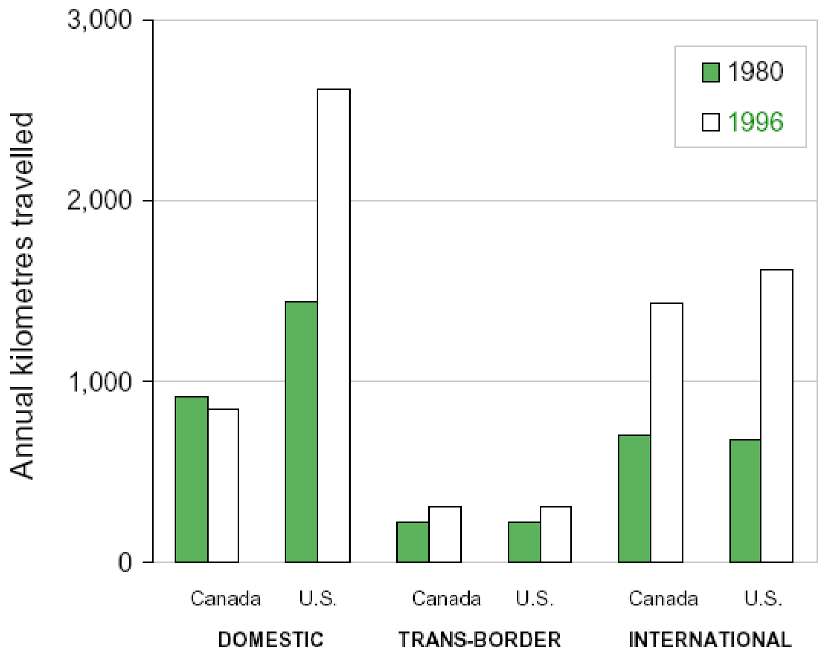

Figure 6**.** *Per-capita travel by air originating in Canada and the United States, 1980 and 1996*

Source: Centre for Sustainable Transportation (2000)

Trips originating in North America have shown particularly large increases overall, with trips within Canada being the significant exception (see Figure 6).

Given the large share of aviation activity in North America and Europe, both regions can be considered to be largely responsible for current and continuing adverse effects and their global implications. Changes in the volume and structure of demand for air travel may influence developments in other regions of the world. Moreover, with Boeing (North America) and Airbus (Europe) being the dominant producers of jet aircraft, technological development of aircraft is to a large extent determined by consumer preferences, interests of airlines, and policies within these regions.

2.3 Fuel use, price and efficiency

Between 1960 and 1990, the average energy intensity of all aviation services fell by about 2.7 per cent per year. The greatest decline—about four per cent annually—occurred between 1974 and 1988 (Michaelis, 1997, p. 21), a period that included the two largest increases in oil prices. These substantial gains in fuel efficiency resulted from technological progress in aircraft technology, fleet renewal, use of larger aircraft, and optimized operational practices that allowed for higher load factors.

It is no surprise that fuel cost has been an important incentive for raising fuel economy. Within the 1966 to 1997 period, the global average share of aircraft fuel and oil in total operating expenses for scheduled airlines changed dramatically (see Figure 7). The lowest shares occurred in 1972 (11 per cent) and again in 1995/1996 (11.4 per cent). Between these years, the share increased dramatically as a result of two significant rises in the oil price reaching its peak level in 1981 (30.2 per cent). Even the lowest shares were well above what might be considered as being insignificant, but the sharp increases following the two oil-price rises substantially raised concern about fuel cost and interest in measures that improved fuel efficiency.

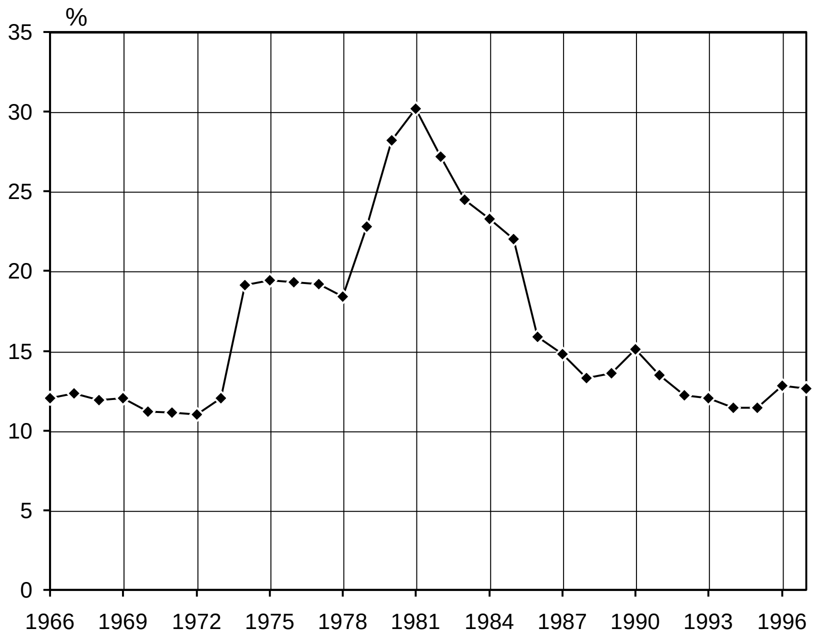

Figure 7. *Share of aircraft fuel and oil in total operating expenses of scheduled airlines*

Source: ICAO 1999a (Table 1-25 and various other issues)

Technological change in general, and in jet engine efficiency in particular, has been a key driving force for reductions in aviation energy use and hence reductions in unit operating cost and ticket prices (Doganis, 1995, pp.1-4). From the beginning, technological progress resulting in higher fuel efficiency has been extremely important for the success of the aviation industry. This is because refuelling cannot occur in the air, except at very high cost, and landing for refuelling severely compromises service quality and operating economics. Moreover, large quantities of fuel are carried at the expense of payload. These factors provide strong incentives to keep fuel use to a minimum. As a result, the aviation industry has been much keener to achieve fuel efficiency gains than other transport industries, for which the quantity of fuel carried is relatively unimportant (maritime shipping) or refuelling is easily accessible under most conditions (passenger cars). Consequently, aviation may be much closer to the physical limits of fuel efficiency; further substantial gains could require large investments in sophisticated new concepts for aircraft and engines.

Major efforts have been made to improve fuel efficiency, but rapid growth in demand has resulted in a substantial increase in fuel use. This can be demonstrated for single airlines (see Figure 8 for the former Swissair), and it is also true for civil aviation in general. The gains in fuel efficiency have always been less than enough to offset the effects of growth in aviation activity. The enormous and successful efforts already undertaken mean that technical fuel efficiency of aircraft and operational practices most likely offer only limited potential for reducing fuel use and related CO_2 emissions.

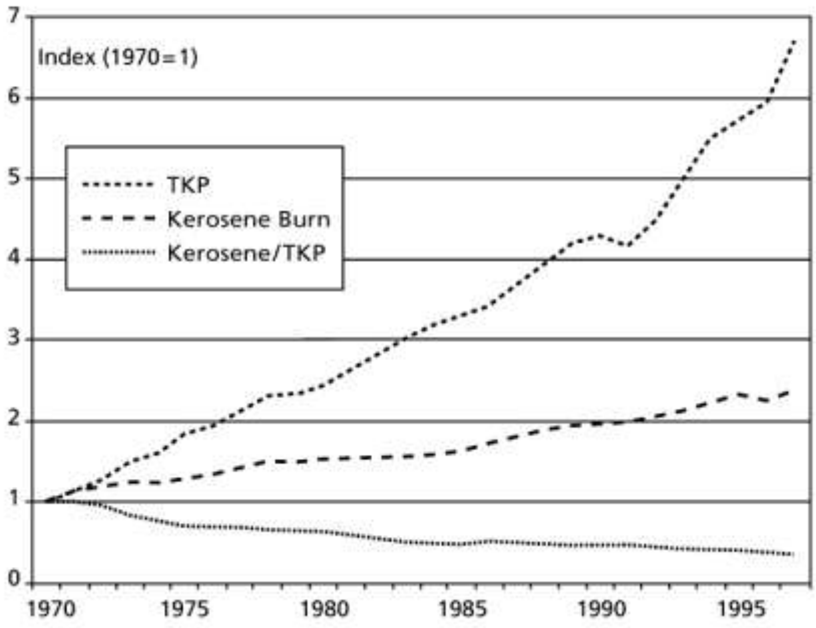

Figure 8. *Long term relative changes in transport activity, fuel consumption and unit fuel consumption for Swissair*

Note: TKP unified tonne-kilometres performed for passenger and cargo operation.

Source: Swissair 2000. Even though Swissair went bankrupt due to an unsuccessful acquisition strategy in a difficult business environment, it remains a good example of an airline with outstanding operational efficiency.

3 Aviation and energy constraints

The existing forecasts of future aviation activity assume that availability of aviation fuel will not restrain growth in aviation activity. An alternative view with growing credibility—although continuing to be controversial—is that world production of liquid fossil fuels will peak within a decade or so. Such fuels are unmatched in their utility for transport purposes because of their high energy density and ready portability. Consequently, potential demand for them could continue to rise, resulting in an era of rapidly escalating prices when production declines. Aviation will be the most affected transport mode because it has the highest fuel costs and the least prospect of switching to alternative fuels. This section briefly discusses the possible peak in production of liquid fossil fuels and its impact on aviation's activity levels and GHG emissions.

Figure 9 shows projections of liquid fossil fuel production associated with an assessment that production will peak in or near 2012. This is a middle-ground projection. Some projections, e.g. that of Groppe (2002), suggest that peak is occurring now (i.e., in or even before 2003). Some projections point to a peak between 2003 and 2010, e.g., Deffeyes (2001) and Bentley (2002). Other projections suggest a later peak, e.g., Birky et al. (2001), who projected a peak in or near 2020. Yet other projections suggest that the peak will be in 2025 or later, if it occurs at all, e.g., IEA (2002) and US EIA (2003). The last two projections assume substantial "reserve renewal" or "reserve growth", concepts that have encountered considerable criticism, e.g., by Laherrère (1999) and by Campbell (2003).

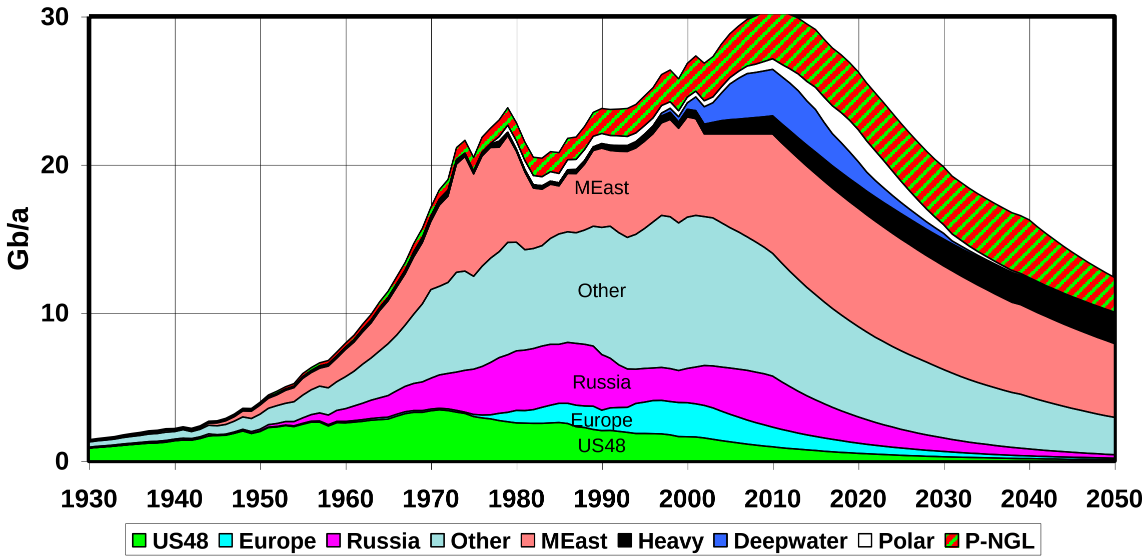

Figure 9. *World production of oil and natural gas liquids, actual and estimates, 1930-2050.*

Note: Production of conventional oil is shown by geographic source. Production of other oil (heavy, deepwater, polar) and natural liquids, notably propane (P-NGL) is shown separately.
Source: ASPO (2003).

One consequence of a production peak such as that indicated in Figure 9 is that several scenarios of greenhouse gas (GHG) production could be invalid, including some of the projections proposed by the IPCC (McCarthy et al., 2001). They would be invalid because insufficient fossil fuel would be burned to provide the expected production of GHGs. Anticipation of a production peak should in no way diminish the importance given to concerns about climate change. Large amounts of GHGs would still be emitted before and after the peak. But, anticipation of an early peak does suggest what may be an even stronger reason for reducing fossil fuel use, namely preparation for an era of energy constraint. Uncertainties in the estimates of both peak oil production (see above) and climate change factors (see, for example, Shaviv and Veizer, 2003) suggest a cautious approach to policy-making that accommodates both kinds of catastrophic possibility.

Although the prospects of climate change and peak oil production require a similar general strategy for mitigation, namely reduced fossil fuel use, there are differences in the degree of urgency of the threats and the reasons that would impel mitigation. Climate change is a distant enough prospect to be an inter-generational issue, and thus not necessarily of immediate concern. Peak oil production could occur early enough to have a profound impact on the lives of most people alive today.

The prospect of extremely high aviation fuel prices during the latter part of the decade from 2010-2020 points to early action that would allow for at least a modest amount of continuing aviation while providing alternatives for medium- and long-distance travel. Such early action could involve two components. One would be a sharp focus on aviation activity that has relative low energy intensity. Such activity would mostly comprise large, well-occupied jet aircraft flying long-distance, non-stop routes. The other component would involve rapid development of low-energy-intensity alternatives, notably surface modes within continents (rail) and between continents (water), and perhaps also airships (dirigibles).

4 Climate impact of civil aviation

Aviation contributes to potential climate change in two ways. The first is that it burns fossil fuel thereby releasing carbon dioxide. In this, it is no different from almost all other transportation, except that the rate of fuel burn per second and per gross tonne-kilometre performed are higher than for other modes.

The second way in which civil aviation contributes to potential climate change is that it results in production of ozone at the boundary of the troposphere and the stratosphere (the tropopause), i.e., at a height of about 10 kilometres. This happens to be the height at which ozone is the most effective as a greenhouse gas, and where it has a relatively long residence time (Lee and Raper, 2003). The result, according to the IPCC (IPCC, 1999), is that burning a litre of jet fuel at the height where most commercial aircraft vehicle-kilometres are performed has two to four times the radiative forcing effect of burning a litre of fuel at sea level. Work done since the IPCC report was prepared appears to support this conclusion (Lee and Raper, 2003).

Ozone is formed at this height because the high temperature causes the nitrogen and oxygen in the air to combine to form first nitric oxide (NO) and then nitrogen dioxide (NO_2), collectively known as nitrogen oxides (NO_x). NO_2 catalyzes production of ozone, essentially through speeding up a naturally occurring process. The process breaks down another greenhouse gas in the atmosphere, methane, but not in sufficient quantities to offset the additional greenhouse effect provided by the added ozone. (Lee and Raper, 2003). The net result is an increase in radiative activity (global warming effect). The process is partly illustrated in Figure 10.

Figure 10 also shows supersonic aircraft, which fly in the stratosphere at about twice the height of regular commercial airliners and do not produce a net global warming effect through ozone production. However, they use much more fuel, thus increasing CO_2 production, and adding water vapour at altitudes where it may have a strong greenhouse effect, although perhaps less than that of ozone formed at the tropopause.

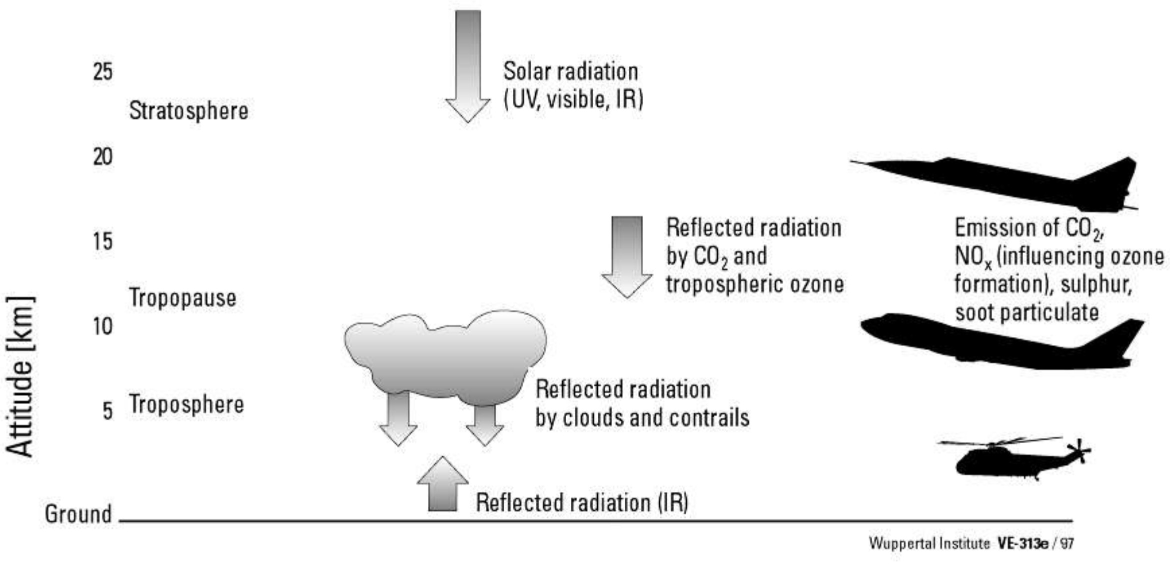

Figure 10**.** *Effects of aviation on the regional and global climate*

Source: Wuppertal Institute

Aircraft flying nearer the earth's surface—e.g., the helicopter in Figure 10—do not result in additional global warming from production of ozone or water vapour, but they use more fuel and thus produce more CO_2. They also produce more NO_x, although not where it contributes substantially to global warming. Aircraft cruise at a height of about 10 kilometres because that is the height at which fuel use is least. It also appears to be the height at which fossil fuel combustion can result in the highest global warming effect.

The additional potential global warming from what can be called the 'altitude effect'—i.e., ozone production at the tropopause—substantially magnifies the potential contribution of aviation to climate change. A possible result is illustrated in Figure 11. In 2030, aviation is projected to use worldwide only half the fuel used by each of cars or trucks, but could be responsible for a substantially greater global warming impact than either of the other modes. Whether sufficient fuel will be available to support the suggested activity levels is unknown (see Section 8 below).

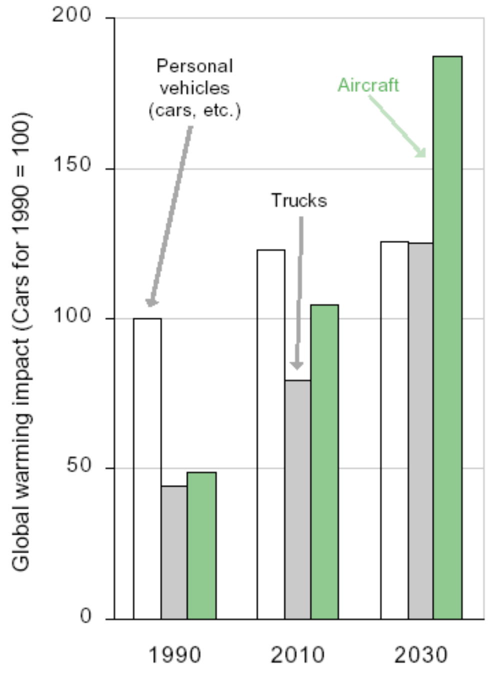

Figure 11**.** *Global warming impact of transport mode, worldwide, 1990-2030*

Source: Centre for Sustainable Transportation (2000)

5 Options and strategies for mitigation of GHG emissions from civil aviation

For the most part limiting the climate impact of civil aviation goes hand in hand with reducing fossil fuel use. An exception would be adoption of lower flight altitudes aimed at reducing radiative forcing associated with NO_X and H_2O. Here, a trade-off is inevitable and needs to be taken into account as lower altitude causes an increase in fuel burn. Except for this, the following can equally be applied to both mitigation of fuel use and radiative forcing.

Climate policy generally is in a situation where there are numerous negotiating activities with limited results. Tackling GHG emissions from civil aviation seems to be even more tricky and cumbersome than for other modes because of the lack of a well-established and agreed scientific basis and the diversity of interests involved. Although some uncertainties remain, the scientific basis has been significantly improved since the Special Report *Aviation and the Global Atmosphere* prepared by the Intergovernmental Panel on Climate Change (Penner et al, 1999) in response to a request by the International Civil Aviation Organization (ICAO). However, just as with climate policy in general, the diversity of interests of the various actors and stakeholders involved remains a decisive obstacle to mitigation. Moreover, the matter of limiting the climate change consequences of civil aviation has not yet reached the stage of international negotiation, except for discussion within ICAO.

In the context of the Framework Convention on Climate Change (FCCC), there is a lack of mechanisms for addressing GHG emissions from international transport. Article 2 of the Kyoto Protocol states that the parties included in Annex I (developed countries) shall pursue limitation or reduction of emissions of GHGs from international aviation by working through ICAO. Emissions that directly result from international civil aviation (combustion and evaporation of fuels) are excluded from the national GHG inventories. They are to be reported separately according to the IPCC's Greenhouse Gas Inventory Reporting Instructions (IPCC, 1995, p1.5). A review of national emission inventories revealed significant inconsistencies in current reporting practices, in particular with regard to emissions from international civil aviation (Det Norske Veritas, 1999). At the same time, there is an ongoing debate as to whether the international emissions should be allocated to individual countries or international bodies.

As long as the problems associated with the assessment and allocation of GHG emissions from international civil aviation persist, individual countries may have little interest in reducing emissions. Moreover, in contrast to the technological options that are possible in principle for stationary sources of pollutants, the potential for individual countries to apply technological solutions is generally more limited for mobile sectors. A technical fix that is relatively easy to implement—such as that for ozone depleting substances regulated by the Montreal Protocol—does not exist for GHG emissions from steadily growing civil aviation.

Taking into account these obstacles and the time that will most likely be required to integrate the aviation sector into a binding global climate regime, the question arises as to how the challenges ahead might be accommodated in the shorter term. The lack of effective policy for global environmental issues is an important aspect of the contemporary critique of globalization. One can argue that some of the phenomena embraced by the phrase 'globalization' are not new and are difficult to track empirically even for international trade and direct investment where economic integration is primarily taking place within and between the predominant economic unions like the EU and NAFTA (Kleinknecht and Wengel, 1998, p. 645). Nevertheless, civil aviation is a global industry and is of key importance for globalization in that it allows for rapid travel and goods movement across the globe. Moreover, its climate impacts are predominantly global in character.

In general, direct passenger and freight transport GHG emissions can be explained and estimated by these variables: transport activity (in passenger- or tonne-kilometres), the shares of the transport modes used, the energy intensities of the respective modes, and the types and volumes of fuels burnt by those modes during operation (Schipper et al, 2000, p. 10). The variable of the fuel used is of limited value for reducing aviation's GHG emissions as long as no fuels other than kerosene are available. Another important variable for aviation's impact on the climate is flight altitude, as already noted.

Tackling emissions from transport has often focused on technology forcing. In principle, it is imaginable that technological advances could result in zero GHG emissions from aviation. This would require use of other fuels than kerosene. So far, the focus has been on the use of hydrogen as a fuel in jet engines, but this would still result in radiative forcing from emissions of NO_x and water vapour at altitude (Lewis, Niedzwiecki, 1999, pp. 257-258). Aircraft that would result in emission of no GHGs could use hydrogen in fuel cells that drive electric motors, with the hydrogen produced from renewable primary energy sources. The water resulting from the chemical reaction in the fuel cell would have to be disposed of in a way that prevents the formation of contrails and cirrus clouds. Within the framework of a general conversion of primary energy use to renewables, and provided such aircraft are technically feasible, this could be the best long-term technical option.

Indeed Boeing is working on a such a technical concept for light aircraft. However, it is unclear whether aircraft of that kind will become technically feasible for civil aviation and at an acceptable price. Taking into account the development of the required new airframe and other aircraft components, the relatively long lead times of aircraft development, and the average economic lifetime of aircraft of around 30 years, significant contributions to reducing radiative forcing cannot be expected within 50 years. Stabilizing the climate and preparing for fossil fuel constraints cannot wait that long. Therefore, non-technical options need to be considered for the short and medium term. Even though technology necessarily plays an important role, it cannot be expected to provide the emission reductions needed for sectors that in the long term may display substantial growth in output. In such cases, policymaking needs to take a broader view as to how emissions can be reduced.

Demand has so far been the most important single factor driving increased fuel use and related carbon emissions from aviation. Rises in demand are expected to continue in the future in a business-as-usual scenario because of the potential savings in travel times offered by air travel. Average travel-time budgets have been found to be fairly constant over time and across different cultures (Schafer, Victor, 2000, p174-175). Thus, growth in overall travel is primarily dependent on increases in travel speed, prices for transport services, and available income. In many developed countries, car use no longer allows significantly increased travel speed and high-speed rail also offers limited potential for travelling faster. Therefore, aviation may have the greatest potential for growth in personal high speed, long distance travel.

Growth in demand for air travel is influenced by a variety of technological, economic, political, social, and psychological factors (Nielsen, 2001). Many of these are important only because of the advantages in travel time that air travel offers and its increased affordability by an ever-growing number of people. However, in dealing with growing demand, policy needs to address all relevant determinants, as it cannot be expected—short of major fuel price increases—that historic trends of increasing speed and affordability of air travel will be reversed.

Consequently, if emissions of GHGs and radiative forcing from civil aviation are to be reduced, and if energy constraints are to be effectively prepared for, the following options are available in the short and medium term:

- Reducing the frequency and average distance of air travel;
- Increasing the technical efficiency of aircraft in use;
- Increasing the operational efficiency of air traffic; and
- Optimizing cruise altitude to minimize the effects of emissions on the climate.

Deploying any of these options in isolation may result in partially counteracting or rebound effects (see Table 1).

Rebound effect of / On	Reduced Air Travel Frequency	Reduced Air Travel Distance	Increased Technical Efficiency	Increased Operational Efficiency	Optimized Cruise Altitude
Air Travel Frequency		+	+	+	ne
Air Travel Distance	+		+ +	+ +	ne
Technical Efficiency	-	-		ne	ne
Operational Efficiency	short term -	- -	ne		-
Optimized Altitude	ne	ne	ne	ne	

Table 1**.** *Likely rebound effects of potentials for reducing aviation's climate impact*

Notes: The effects of deploying the options in the columns on those in the rows are indicated by the abbreviations: (ne) no effect; (+) increase; (+ +) substantial increase; (-) decrease; (- -) substantial decrease.
Source: Pastowski (2003b, p. 183)

Reducing air travel frequency could induce longer air travel distances to the extent that air travel expenditures remain constant and demand concentrates on longer trips, and vice versa. Reductions in overall travel demand, either through reduced trip frequency or trip distance, may partly obviate the need for further achievements in technical and operational efficiency. However, development and penetration of more environmentally friendly aircraft technology may be delayed and airlines may face problems in maintaining high load factors in the short or medium run.

Increases in technical and operational efficiency that allow airlines to cut costs and hence ticket prices may activate latent air travel demand. Optimized (lower) cruise altitude may give rise to increased aerodynamic drag and hence higher fuel burn and more CO_2 emissions. With the exception of the negative effect of reduced air travel frequency on operational efficiency, which may disappear after adaptation of airlines to a decrease in the number of passengers, the rebound effects mentioned can be expected to be lasting. To keep rebound effects to a minimum, a balanced policy approach will be needed that combines all relevant options for reducing emissions in an optimum manner.

6 Actors, policies and instruments for mitigation

Political support for the aviation industry has played an important role in its success. Airlines that are state owned still serve as symbols of national economic success and power (Ragumaran, 1997, p.240). Such a role may be particularly important in some developing countries. However support still persists in developed countries, as illustrated by the way in which Swissair was perceived as the 'flying Swiss identity' (anon, 2001, p.30). This role of aviation—and indeed the government ownership of airlines—seems to be less appropriate given the rising adverse environmental effects of aviation.

Generally, environmental problems arise from activities performed by governments, industry, and consumers as depicted in Figure 12, which shows the main actors in the development of policies that affect the environment. Industry, consumers, and government are the main actors. Many consumers having an additional, and possibly contradictory role as voters. Many industries attempt to influence government through lobbying supported by financial contributions. Governments in turn provide infrastructure, information, and a regulatory climate that may or may not favour a particular industry group.

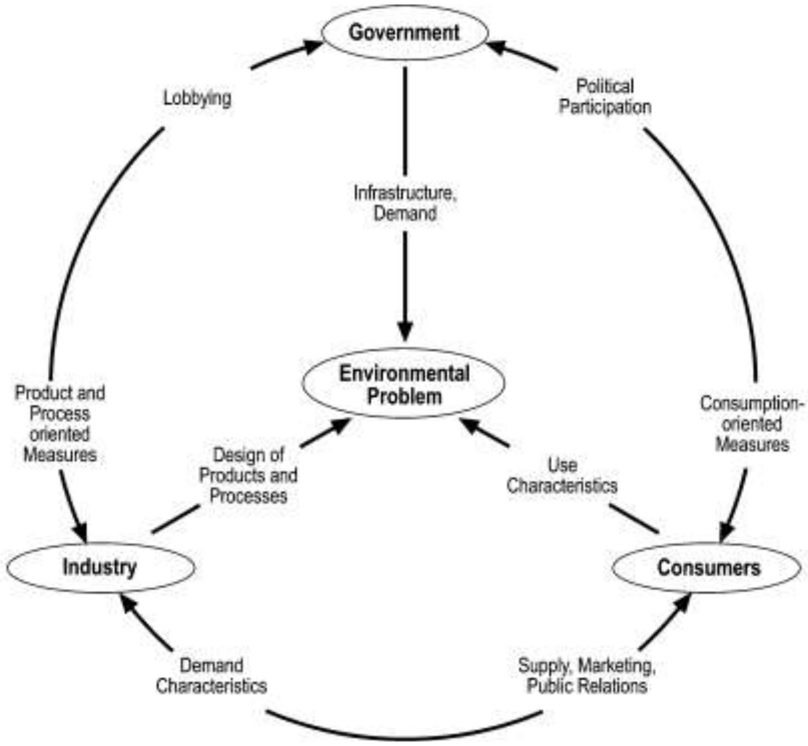

Figure 12**.** *Main Actors in the Causation of Environmental Problems and Environmental Policy*

Source: Pastowski (2003b, p. 185)

One area of environmental policy is focused on the supply of relevant infrastructure and government operations in general (e.g., procurement). Political action is predominantly directed at the interrelationships of industry and consumers on the one hand and the government on the other. Industry is subject to governmental policies relating to the design of goods and production processes. At the same time, governments are targeted by industry through related lobbying activities. Governments also address consumers via policies designed to render consumption more environmentally sound, while consumers influence government decision making through political participation of various kinds. Environmental NGOs have become an important element of political participation, the latter being expressed not only via a relationship with government but also via influence on production and consumption decisions beyond narrow product specifications and price. Additional pressure may come from capital markets as far as these factor environmental accountability and related risks of sectors and individual companies into investment decisions.

In the past, environmental policy often focused on measures and instruments implemented by governments that were aimed at industry. For the transport sector, it has become obvious that addressing transport industries alone will be insufficient if the volume and structure of demand are important contributors to environmental degradation (Pastowski, 2000 p. 359). Therefore, environmental policy necessarily needs to be broader with regard to the actors addressed and involved.

Environmental problems can be limited in terms of:

- the geographical spread of causation and impacts;
- the number of directly relevant actors determining environmental effects; and
- the number of nations and political levels that need to be involved in mitigating emissions.

Current environmental problems are more often transnational or global in character. This is particularly true of GHG emissions from civil aviation. In the past, aviation was primarily an environmental concern in the vicinity of airports, for local air pollution and noise. Because of its dynamics and influence on the anthropogenic greenhouse effect, civil aviation can be regarded as the prototype of a completely globalized sector. Thus, the tremendous growth in forecast demand poses a challenge for environmental policymaking that necessitates a political strategy that goes beyond national policy-making.

Policy-making for reducing GHG emissions from aviation starts from the ultimate objective of stabilizing the global climate. Limiting GHG emissions from aviation will contribute to this objective. Given the forecast growth in demand and the technological improvements to be expected, a business-as-usual development path could result in a permanently negative contribution from the aviation industry (subject to the impacts of energy constraints). Increases in fuel efficiency of aircraft have been substantial during the last decades, but they have not been sufficient to offset the effect of growing demand. Determining the level of emissions reductions required of civil aviation in order to stabilize global climate is a subject that requires serious discussion. Equity as well as economic efficiency are relevant considerations. This will all be subject to political decision-making and negotiations.

Table 2 lists the main actors and relationships regarding options for reducing aviation's impact on the climate. The directly relevant actors for reducing the GHG intensity of air traffic are the aircraft industry, which is important for introducing new technology, and the airlines, which have some influence on the technology used and a greater influence on operational practices. In addition, operational efficiency is influenced by airports and air traffic management and control. Activity is determined through decisions by travellers, the tourism industry, and shippers.

<table>
<tr><td>Overall Objective</td><td colspan="5">Stabilizing the Global Climate</td></tr>
<tr><td>Sectoral Objective</td><td colspan="5">Limiting GHG Emissions from Civil Aviation</td></tr>
<tr><td>Determinants/Options</td><td colspan="2">Capacity Unit Emissions</td><td>Aircraft Operation</td><td colspan="2">Demand for Aviation Services</td></tr>
<tr><td>Intermediate Determinants</td><td>Aircraft Technology</td><td>Modernity of Fleets</td><td>Efficiency of Air Traffic Operation</td><td>Frequency</td><td>Distance</td></tr>
<tr><td>Direct Actors Involved</td><td>Aircraft Industry</td><td>Airlines</td><td>Airports</td><td>Air Traffic Control</td><td>Traveller, Tourism Industry, Shipper</td></tr>
<tr><td rowspan="2">Political Actors
Governmental Bodies at Various Levels
International Organizations
Non-Governmental Organizations</td><td colspan="5">Actor-oriented Policies</td></tr>
<tr><td colspan="5">Sector-oriented Policies</td></tr>
</table>

Table 2**.** *Objectives, options, direct actors and climate policy in civil aviation*

Source: Pastowski (2003b, p. 186)

Political discussion often focuses on single policy instruments. Such a focus can be appropriate as long as single policy instruments implemented at the national level work well in solving the targetted environmental problems. However, a limited set of instruments most likely will prove insufficient in mitigating aviation's climate impact because of:

- the new and partly still preliminary evidence on aviation's climate impact;
- the relatively large number of actors involved;
- the varying economic dependency of countries and regions on aviation services;
- the significant variation in operational conditions within the aviation industry; and
- the need to take globally coordinated or harmonized measures.

To deal with these obstacles, the most suitable policy approach may be one that considers both the full range of options available for reducing aviation's climate impact and a broad range of policy instruments to be implemented at the various political levels. Only a full range of policy instruments could be able to cover the different political levels involved and account for the high level of coordination needed between national and regional approaches, on the one hand, and what are likely to be only moderately strict individual instruments implemented at the international level, on the other hand. Such an approach may also allow for more flexibility on the part of individual state and more local governments and hence help attain more ambitious emission reduction targets at the global scale. Moreover, single policy instruments often have significant rebound effects. A comprehensive policy package could help avoid undesired countervailing effects (ECMT, 1997, p. 117). An optimum package would combine policy instruments that are mutually reinforcing. Moreover, complementarity in terms of options used, actors influenced, and phasing would yield the biggest overall effect. Table 3 provides an assessment of strengths and weaknesses of several policy instruments.

In Table 3, the assumed strictness of individual policy instruments and the assessment of their effects reflect existing barriers to implementation. Together they can be regarded as an outcome of a political compromise. To the extent that reductions in GHG emissions give rise to cost reductions, this may result in rebound effects in form of induced demand. Some rebound effects on emission intensity may also occur in the form of higher fuel burn from a reduction in flight altitude. Table 3 also shows which instruments require which actors. The assessment of timing differentiates between the period required to introduce an instrument and that required to achieve the full effect. Regarding the geographical scope of implementation, political levels for implementation are suggested. The global level is the optimum level for environmental effectiveness and undistorted competition. However, policies may start at national or regional levels in a stepwise process of implementation designed to gain momentum.

Evidence about aviation's impact on the global climate is relatively new. Thus, public awareness campaigns may both influence decisions on demand and increase the acceptability of stricter measures. Hand in hand with this, a public consultation process on the future of aviation, similar to that initiated in the UK (DETR, 2000), may increase the public perception of the challenges ahead and foster a common understanding of measures and instruments available for policymaking. Voluntary agreements may be considered as a short term measure until economic instruments are implemented. Publicly financed research into aviation's climate impact is a necessary prerequisite for appropriate public awareness measures and related policies as well as for industry investment decisions on new technologies and aircraft. Refocusing of funding of research and development, with more emphasis on improved aircraft design in terms of lower fuel use and GHG emissions, is complementary to other policy instruments aimed at increased technical and operational efficiency.

Table 3. *Assessment of various instruments for climate policy in civil aviation*

	Main Effects		Influenced Direct Actors					Timing		Political Levels
Policy Instruments	Activity	Intensity	Aircraft I.	Airlines	Airports	ATM/C	Traveller	Introduc.	Effect *	
Information/Volunt. Action										
Public Awareness Campaigns	–	–					X	st	mt	n, r, g
Voluntary Agreements		–		X				st	mt	r, g
Research and Development										
Aviation's Climate Impact	–	– –	X	X		X	X	st	mt	n, r, g
Improved Aircraft Design	(+)	– –	X	X				st	mt, lt	n, r, g
Economic Instruments										
Phase out of Subsidies	–		X	X	X		X	st	st, mt	n, r, g
Kerosene Tax	– (+)	– –	X	X			X	mt	mt, lt	r, g
Emission Charge	– (+)	– –	X	X			X	mt	mt, lt	n, r
Trust Fund Charge		–	X	X				mt	mt, lt	g
Emissions Trading	– (+)	– –	X	X				mt	mt, lt	n, r, g
Regulation and Guidelines										
Privatizing Airlines/Airports	–			X	X			mt	st	n, r
SEA for Airport Capacity	–				X			mt	mt, lt	n, r
Optimization of Flight Altitude		– – (+)		X		X		st	st, mt	r, g
Emission Standard (NO_X)		–	X	X				mt	mt	g
Environmental Reporting		–	X	X			X	mt	mt, lt	r, g
Optimization of ATM/C	(+)	– –				X		mt	mt, lt	r

Notes: n, r, and g refer to national, regional, and global political levels; st, mt, and lt refer to short term, medium term, and long term phasing of application of the instruments; X means relevance of the instruments to the actors; –, and – – refer to degrees of negative effects on activity or intensity; (+) refers to rebound effects.
Source: Pastowski (2003b, p. 191)

Some progress has been made in the European Union regarding the abolishment of state aid to airlines and of duty-free sales on intra EU flights, but phasing out of environmentally perverse subsidies is not yet on the agenda. The most prominent tax exemptions are those for excise duties on fuels and, in many countries, for VAT on tickets for international travel. A wide definition of subsidies would imply a tax on aviation kerosene similar to excise duties imposed on other transport fuels. However, existing bilateral air services agreements preclude the introduction of such fuel taxes; they would need to be renegotiated. Fuel taxes would work primarily as an incentive for increasing fuel efficiency. Emission charges could be designed to cover all GHG emissions from aviation.

Ideally suited for implementation at the global level may be a trust fund charge with a low charge rate whose proceeds would be used to finance climate change mitigation measures inside and outside the aviation sector. Even with a low charge rate, and hence limited direct incentives for emission reduction, the overall effect could be significant (Leifert et al. 1997). Emissions trading is increasingly under discussion for the aviation sector. Emissions trading schemes for climate policy have mostly concerned CO_2 emissions. However, as with an emission charge, other important GHGs from aviation need to be included in emission trading. Otherwise, in an open trading regime the sector may become a net buyer of emission permits from other sectors resulting in an increase in total radiative forcing (Lee, Sausen, 2000, p. 2).

Regarding regulations and guidelines, privatization of airlines and airports may help separate governmental and commercial interests in relation to air traffic operation and airport capacity planning and avoid quasi-subsidies through capital holdings. In contrast to infrastructure planning for other modes of transport, there is currently no national/federal planning for airport capacity in most countries because no money from this source is spent on such projects. As a consequence, planning decisions can be uncoordinated with and between local authorities and in relation to growth in airport capacity.

Strategic Environmental Assessment (SEA) for transport infrastructure, currently being introduced within the European Union, may facilitate better coordination of airport capacity planning and hence eliminate excess capacity and supply-side-driven growth in demand. However, the European Union directive on SEA does not include airport capacity planning.

Concerning the influence of cruise altitude on radiative forcing, regulations requiring flying at somewhat lower altitudes than are currently usual could result in a substantial reduction in aviation’s effect on the climate.

ICAO’s engine emission standards were first introduced in 1980, and the latest standards adopted will be applicable to new engine designs after 2003 (ICAO, 1999b). However, stricter standards for new engine designs as well as minimum requirements for existing aircraft could be introduced.

Environmental reporting is essential for benchmarking of the environmental performance of airlines. Investors, tour operators, travellers, and shippers who may want to base their decisions on environmental considerations need comparable data on the emission characteristics of individual airlines. To date, environmental reporting is carried out on a voluntary basis and by only a few airlines. Moreover, data on fuel use and emissions are often generated using different methodologies and are therefore inconsistent (Pastowski, Koehn, forthcoming). Introducing mandatory environmental reporting under the umbrella of ICAO at the global level would be a solution. Existing voluntary reporting would greatly benefit from adoption of a unified methodology—that might be developed in an ICAO working group—for calculating and presenting the data on GHG emissions.

For historic and military reasons, air traffic management and control is often restricted and fragmented to an extent that precludes efficient air traffic operation. The technologies applied are often outdated and incompatible and lag behind the sophistication of modern aircraft. Regulations and internationally agreed guidelines—some already partly implemented—may foster more coherent regional systems of air traffic management and control as well as the application of latest technology. As well as more efficient air traffic operation, positive side effects from such efforts can be expected for safety of air traffic operation.

The instruments listed in Table 3 provide for a broad range of policy measures, many of which can be regarded as being mutually reinforcing and complementary. However, the economic instruments contain some redundancy, as evident in their identical patterns of effects. In particular, once a comprehensive emissions-trading regime is implemented, an emission charge may no longer be required. Even though some of the instruments discussed may be implemented at the national level, policies that address this highly globalized sector need to be sufficiently coordinated or harmonized. Additional policy instruments that are inherently international in character have been developed in the context of the Framework Convention on Climate Change and the Kyoto Protocol and could be adapted to the civil aviation industry. These instruments comprise international emissions trading, Joint Implementation (JI), and the Clean Development Mechanism (CDM). As well, direct international transfers of financial resources or technology could occur between countries that have committed themselves to quantitative emission reduction targets and those that have not adopted any such targets under the Kyoto Protocol (Bashmakov, Jepma 2001, pp. 424-430).

7 The civil aviation industry in North America and Europe and policy responses

There are important similarities and differences between Europe and North America that influence the volume and structure of demand for aviation services. They can be summarized as determinants that work via the demand side and those that shape the structure of the supply side independently of demand. On the demand side of civil aviation services, income per capita is an important determinant with higher incomes typically generating larger volumes of air travel. With regard to this factor, North America and Western Europe have more in common than there are differences between them.

Another feature important for demand for aviation services is geographic situation. Larger countries, those that are peripherally located, and those comprised of isolated islands can be expected to generate more air travel. Western Europe and North America are both large geographic regions, with North America's size allowing for substantially longer travel distances. However, the main difference is North America's relative homogeneity in terms of culture, language, legal system, and labour market, within which families spread across the whole continent, increasing demand for air travel. Even though citizens of member states of the European Union are allowed to settle in all other member states, for most of them this is not an option because of cultural barriers. Another aspect of the different cultures is the number of holidays that citizens have at their disposal, with North Americans being less well off in this regard. The number of holidays may influence how often people travel to distant places and which mode of transport they prefer. Having many holidays may strengthen preferences for exotic travel destinations. On the other hand, having fewer holidays may increase the preference for short travel times and the fastest mode of transport available.

On the supply side, North America has led in establishing markets for civil aviation services. This is particularly true for the liberalization of market access and the privatization of airlines. Airport capacity planning and construction as well as airlines themselves are still much more matters for governments in Western Europe than in North America. Government involvement often results in a predict-and-provide approach towards airport expansion plans and associated public investments that may discourage removal of aviation's tax exemptions. However, a similar philosophy towards growth in aviation services prevails in North America, with the difference that government interference in terms of ownership of airports and airlines is generally small. Moreover, liberalization of market access and the privatization of airlines have increased economic efficiency in the provision of air travel, thereby reducing the cost to passengers and contributing to growth in demand. The emergence of low cost carriers in Western Europe and North America can be regarded as a further step in the longer process of transforming air travel from a luxury into an everyday life service for a growing number of people in developed countries.

For short and medium distance travel, the use of aviation is influenced by the availability of alternative modes. For Western Europe, a dense railway network is available with a growing number of high-speed connections. The level of service of the high-speed trains is sometimes high enough to compete with aviation in terms of total travel time. For example, total travel times by high-speed rail can be comparable or shorter than by air between Frankfurt and Paris, and even between Brussels and London, if journey origins and destinations are located in central parts of those cities. Railway networks in North America are less dense and the railway system is usually operated with an emphasis on freight transport. Moreover, road conditions and regulations preclude high speed travel by car. Therefore, even for short and medium distances there is often a lack of alternatives to air in North America.

Thus, there are certain factors in North America that can explain why demand for civil aviation services on a per-capita basis is generally higher than for Western Europe. Some of those factors are beyond the scope of what can reasonably be influenced politically (e.g., geography); others could be changed in the long run (e.g., the extent of ground-based high speed connections).

With regard to policies designed to limit radiative forcing by civil aviation, on both sides of the Atlantic the matter has at best been only just put on the climate change agenda. Western Europe is somewhat ahead of North America on account of its more proactive role in the ongoing debates on climate change issue. However, in the context of the state of theoretical strategies and policy instruments noted in Sections 4 and 5, policy-making is in its infancy in both regions. The traditional predict-and-provide approach towards airport expansion plans is primarily targeted by local environmental groups. Governmental bodies at the various levels are reluctant to question growing demand for air travel for fear of loss of economic activity and voter disapproval of constraints on travel.

This means both that research into the climate impact of aviation needs to be strengthened and that its results require proper communication to the public. The UK's approach of initiating public debate on aviation, including its impact on the global climate, may be regarded as a potentially fruitful effort in this direction. As well, aviation-related funding of research and development requires some refocusing towards further advances in fuel efficiency of aircraft and air traffic operation even though this will most likely result in economic efficiency gains and hence lower ticket prices. In flight control, North America is much ahead of Europe where air traffic control is still fragmented to an extent that precludes efficient operation..

Beyond the foregoing, there is still much to do towards applying strategies for mitigation and environmental policy instruments. The latter would include abolishing the large subsidies to the sector and imposing excise duties on fuels that have become normal for many modes of transport in a growing number of countries. However, the current economic crisis of the aviation industry could retard any such development.

8 Conclusion

Even though at the time of writing the civil aviation industry is experiencing a significant drop in demand, it could well return to or near its historic growth trend because most of the causes of its current situation could disappear. Even if the long-term growth projections do not fully materialize for reasons of constraints in airport capacity in some regions of the world, insufficient fuel or other obstacles, civil aviation could take a growing share of global CO_2 emissions. Given the potentially significant additional contribution to radiative forcing from emissions of H_2O and NO_x at cruise altitudes, aviation's overall contribution to the greenhouse effect could become relatively substantial, enough to offset efforts for mitigation of GHG emissions in other economic sectors.

This logic reinforces the overriding importance of intensified research into the climate impact of civil aviation and options for mitigation of radiative forcing from air traffic. Parallel and complementary research could concern options for aviation in an era of energy constraints. Such research could allow well-grounded communication to the general public, appropriate business investment, and effective political decision making. In the meantime, the political discussion could focus on the challenges encountered by the traditional predict-and-provide approach towards airport expansion plans, which is where the growing demand for air travel seems to find its first limits to growth.

A long-term option for both insufficient supply of conventional fuel and for mitigation of its climate impacts would be forcing of aviation technology towards use of alternative fuels. As suggested in Section 5, hydrogen may be the most likely candidate, although only if produced from renewable resources and used in fuel-cell systems, and not perhaps for several decades. Present obstacles to such use of hydrogen include the unavailability of drive systems suitable for aviation and the high cost of hydrogen production from any source other than natural gas, which in North America is reaching its own production peak (Simmons, 2003), if not elsewhere (Gerling and Rempel, 2003). As well, transmission and storage of hydrogen are energy-intensive processes that appear to be unsuited to an era of energy constraint (see, for example, Brooks, 2002.)

Considered in the light of the need to avoid both climate change and a 'hard landing' in the event of rapidly increasing oil prices, the aviation industry's recent difficulties may be a blessing in disguise. They could dampen the expectation of long-term high rates of growth and prepare the industry for a leaner existence that will be more compatible with the realities of the unfolding 21st century.

Because of their overriding share in demand for aviation services and technological leadership in jet aircraft, North America and Western Europe have an obligation to take a leading role in finding answers to the challenges resulting from the success of the aviation industry.

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