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Greenhouse gas emissions from international aviation and allocation options

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1 Preface – background, objectives and contents

This report on greenhouse gas emissions from international aviation and allocation options is part of the outcome of a project funded by the Danish Environmental Protection Agency (DEPA). The steering group consisted of Lars Olsen Hasselager and Thorbjørn Fangel, both DEPA, and Stefan Krüger Nielsen, ECOtransport Consulting (external consultant).

The project was initiated to update the DEPA on ongoing developments in the field of air transport and environment. The background for starting up such a project is that aviation, due to the prospects for future growth in demand for air travel and freight volumes, may become a more significant source of emissions of greenhouse gases in the future.

Another reason for the DEPA to take up the subject is that the DEPA need an update on why the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) have not yet been able to agree upon a methodology to allocate emissions of greenhouse gases from international aviation between countries. Only emissions from domestic air transport are included in the national inventories on annual national greenhouse gas emissions reported by Parties to the UNFCCC while emissions associated with fuel used for international aviation activities are to be reported separately. Consequently, emissions from international aviation are not included under the so-called Kyoto Protocol that sets out targets for reductions of national emissions of greenhouse gases to be fulfilled by the period 2008-2012.

Article 2.2 of the Kyoto Protocol states that "*the Parties included in Annex I shall pursue limitation or reduction of emissions of greenhouse gases not controlled by the Montreal Protocol from international aviation and marine bunker fuels, working through the International Civil Aviation Organisation (ICAO) and the International Maritime Organisation (IMO), respectively*" [UNFCCC 1997]. As yet, the ICAO Assembly has not agreed upon new initiatives specifically aimed at reducing greenhouse gas emissions, but ICAOs Committee on Aviation Environmental Protection (CAEP) is investigating several options. Some of these options may have implications for the airlines' reporting requirements as well as the allocation issue.

For example, CAEP is currently discussing the possibility of negotiating agreements with the airline industry on a voluntary scheme for improving the fuel efficiency of airlines. Such a scheme may involve the need for airlines to engage in a reporting scheme for fuel consumption and emissions. CAEP is furthermore discussing the possibility of setting up an emissions trading scheme based on a system where airlines are allowed to buy emission quotas in other sectors included under the Kyoto Protocol. Such a framework may involve the setting of a cap for aviation emissions and allocation of emission permits to airlines and probably also the allocation of the emissions of CO_2 from international aviation to Parties as well as the need for airlines to engage in a reporting scheme for fuel consumption and emissions. Therefore, the discussion on data availability and requirements seems to be closely connected to the issues of allocation and control options. This explains why this report focuses broadly on all these issues.

One aim of the project is to describe the current status of the quality of the reporting by Parties to the UNFCCC of emissions from international aviation activities. The background for this is that the issue is scheduled for discussion at the 18th meeting of UNFCCCs Subsidiary Body for Scientific and Technological Advice (SBSTA). Another aim is to describe which methodologies for allocation of emissions from international aviation that are being discussed within the European Union (EU) and UNFCCC and elsewhere and to assess the data requirements and the data availability for the different options. A third aim is to give an updated description of recent developments within the UNFCCC, EU and ICAO relevant to future efforts to reduce emissions of greenhouse gases from international aviation. A final aim of the report is to give a brief description of some main aviation indicators and trends.

Besides the making of this report, this project has provided input to ongoing discussions within EUs Group of Climate Change Experts on Policies and Measures (PAM). During the Danish EU Presidency, the PAM group requested the Danish Presidency to prepare and circulate a questionnaire aiming at preparing EU Member States for discussions at the 18th meeting of SBSTA. The questionnaire should first of all help to the process of clarifying the quality of reporting of emissions from international aviation and marine activities by EU Member States to the UNFCCC. Another aim of the questionnaire is to start up initial discussions within the PAM group on longer-term preferences of EU Member States concerning possible solutions for allocating emissions from international aviation and marine activities to Parties as well as preferences for possible options to control emissions in the future.

Due to time constraints this report only briefly touches upon the issues raised in the questionnaire requested by the PAM group. This is because the process of defining the focus areas and specific questions dealt with in the questionnaire and the following period of time required by PAMs members to collect responses in the Capitals have been prolonged beyond the time schedule of this report.

The main input for making this report is a literature review of reports dealing with the questions of data quality and allocation options and relevant documents describing recent developments within the UNFCCC, EU and International Civil Aviation Organisation (ICAO) and its Committee on environmental Protection (CAEP) relevant to future efforts to reduce emissions of greenhouse gases from international aviation.

Chapter one summarises the contents of the project in Danish language.

Chapter two summarises the contents of the project in English language.

Chapter three outlines the scope of environmental problems connected to emissions of greenhouse gases from aviation and briefly describes some main aviation indicators and trends.

Chapter four gives a brief introduction to some main principles by which aviation greenhouse gas emissions can be reduced and continues by outlining different options for controlling emissions of greenhouse gases from international aviation.

Chapter five resumes background information on activities and developments within United Nations Framework Convention on Climate Change (UNFCCC), European Union (EU) and International Civil Aviation Organisation (ICAO) and its Committee on Environmental Protection (CAEP) concerning the political discussions on how to reduce the growth in emissions of greenhouse gases from aviation.

Chapter six contains information on emissions from international aviation and discusses the availability and quality of data as well as some recent efforts to improve data quality.

Chapter seven describes some selected aircraft emission inventories and reporting guidelines, focusing mainly on the European Corinair emission inventory guidelines, and discusses briefly how these can be used to improve the quality of data reported on emissions from international aviation.

Chapter eight describes recent airline reporting on average overall yearly fuel intensity and discusses why improved reporting may be needed if the international community agrees upon implementing control options such as voluntary agreements with airlines on future targets for improving their average fuel efficiency or an open emissions trading scheme allowing the airline industry to trade emissions permits with other sectors.

Chapter nine describes different methodologies for allocating emissions from international aviation to Parties and assesses the impact, in terms of carbon added to each country's inventory, of choosing each type of methodology as well as the data requirements and data availability for different allocation options. Furthermore, the chapter briefly discusses the data requirements of different control options that may be implemented at the global level. This latter solution could be part of a scheme where emissions from international aviation are not allocated to Parties leaving the responsibility for reducing emissions to the international community, i.e. for example implemented and administered through the International Civil Aviation Organisation (ICAO).

Chapter ten summarises the main conclusions of the report.

Appendixes A through K contain information on aviation fuel consumption and related emissions reported to the UNFCCC and the International Energy Agency (IEA) as well as information on air transport volumes in different geographical regions.

2 Sammenfatning

Dette kapitel indeholder en sammenfatning af indeværende rapport om emissionen af drivhusgasser fra den internationale luftfart og mulige allokeringsmodeller. Rapporten blev finansieret af Miljøstyrelsen. Projektets styregruppe bestod af Lars Olsen Hasselager og Thorbjørn Fangel fra Miljøstyrelsen og forfatteren til rapporten, Stefan Krüger Nielsen, ECOtransport (ekstern konsulent).

2.1 Baggrund

Formålet med dette projekt og den indeværende rapport er at opdatere Miljøstyrelsen om udviklingen i den internationale luftfarts udledning af drivhusgasser, og de igangværende diskussioner på internationalt niveau om hvordan disse emissioner kan reduceres i fremtiden. Emnet er relevant fordi den internationale luftfarts udledning af drivhusgasser forventes at vokse relativt hurtigt i de kommende årtier.

En anden årsag til at Miljøstyrelsen har ønsket at opstarte projektet er, at Miljøstyrelsen ønsker at få et overblik over de metodiske tvister der kan ligge til grund for at landene, der deltager i FNs internationale klimakonvention, endnu ikke har kunnet blive enige om en metode til at allokere udledningen af drivhusgasser fra den internationale luftfart mellem landene. Derfor er kun emissioner fra indenlands flytransport inkluderet i de nationale emissionsopgørelser som sendes til *United Nations Framework Convention on Climate Change* (UNFCCC), mens emissionerne fra den internationale flytransport rapporteres separat. Således er emissionerne fra den internationale luftfart ikke inkluderet i Kyoto protokollens målsætninger om reduktion af deltagerlandenes udledning af drivhusgasser frem mod perioden 2008-2012.

Landene, der deltager i FNs internationale klimakonvention, har diskuteret en række mulige metoder til at allokere emissionerne fra den internationale luftfart mellem landene i UNFCCCs *Subsidiary Body for Scientific and Technological Advice* (SBSTA). Indtil nu har landene dog ikke kunnet blive enige. Et af problemerne er, at lande med et relativt stort salg af jetbrændstof ikke finder det rimeligt, hvis emissionerne bliver allokeret til det land, hvor jetbrændstoffet sælges. Problemet er, at luftfartsselskaber der er indregistreret i et land, kan købe jetbrændstof i et andet land, flyve til et tredje land, og transportere passagerer og fragt som stammer fra en mængde andre lande. Det er således ikke indlysende, hvilket land der kan siges at være ansvarlig for emissionerne fra den internationale flytrafik.

Artikel 2.2 I Kyotoprotokollen indeholder en passus om at "*the Parties included in Annex I shall pursue limitation or reduction of emissions of greenhouse gases not controlled by the Montreal Protocol from international aviation and marine bunker fuels, working through the International Civil Aviation Organisation (ICAO) and the International Maritime Organisation (IMO), respectively*" [UNFCCC 1997]. Indtil nu har ICAOs *Assembly* ikke kunnet blive enige om at vedtage initiativer som specifikt er rettet mod at reducere luftfartens udledning af drivhusgasser. ICAOs *Committee on Aviation Environmental Protection* (CAEP) er dog i gang med at undersøge forskellige mulige reguleringsmuligheder. Nogle af de virkemidler som undersøges af CAEP kan have implikationer for fremtidige mulige allokeringsmodeller såvel som for luftfartsselskabernes mulige fremtidige forpligtigelser til at rapportere deres emissioner af drivhusgasser.

For eksempel undersøger CAEP for øjeblikket mulighederne for at indgå en frivillig aftale med luftfartsselskaberne om reduktion af deres energiintensitet, d.v.s. eksempelvis energiforbruget per tonkilometer, per passagerkilometer og per fagt-tonkilometer eller lignende. En sådan frivillig aftale vil sandsynligvis betyde, at luftfartsselskaberne fremover skal afrapportere deres energiforbrug. Ligeledes er CAEP for øjeblikket ved at undersøge mulighederne for at indføre et system for handel med CO_2 emissionskvoter, hvor det er hensigten, at luftfartsselskaberne skal kunne få mulighed for at købe kvoter i andre sektorer, som er inkluderet under Kyoto protokollen. Et sådant system for handel med emissionskvoter vil nødvendiggøre, at der fastsættes et absolut loft for luftfartsselskabernes emissioner. Når dette loft overskrides, skal luftfartsselskaberne købe en tilsvarende mængde emissionskvoter i andre sektorer. Endvidere vil det blive nødvendigt at finde en metode til at allokere rettighederne til at udlede CO_2 mellem de enkelte luftfartsselskaber, og sandsynligvis vil det også være nødvendigt at finde en metode til at allokere emissionerne fra international flytrafik mellem lande. Endelig er det nødvendigt at luftfartsselskaberne afrapporterer deres energiforbrug. Således er diskussionen om kvaliteten og tilgængeligheden af data for luftfartens energiforbrug og emissioner tæt forbundet med diskussionen om muligheder for at allokere emissionerne fra den internationale luftfart til lande samt diskussionen om muligheden for at implementere virkemidler til reduktion af luftfartens emissioner.

2.2 Projektets formål

Et formål med dette projekt er at beskrive status for kvaliteten af de data, der indrapporteres for emissioner fra den internationale luftfart i de emissionsopgørelser landene sender til UNFCCC. Dette emne er sat på dagsordenen til SBSTA 18. SBSTA har konstateret, at landenes afrapportering om emissioner fra den internationale luftfart er af svingende kvalitet, og ikke altid i overensstemmelse med de retningslinier for rapportering som er udstukket af FNs internationale klimapanel (IPCC) i rapporten "*Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*". Et af hovedproblemerne er, at mange lande har problemer med at vurdere, hvor stor en andel af jetbrændstoffet der bruges til indenlands og international luftfart. Denne opdeling er nødvendig, fordi emissionerne fra indenlands luftfart skal inkluderes i opgørelsen af de nationale emissioner, mens emissionerne fra international luftfart ikke skal inkluderes, men skal rapporteres separat under kategorien "*international bunkers*".

Et andet formål med projektet er at beskrive, hvilke metoder til allokering af emissionerne fra den internationale luftfart der diskuteres i international regi i EU, UNFCCC, ICAO og andre steder. Herunder diskuterer rapporten, hvilke data der er nødvendige for disse allokeringsmodeller, og vurderer, hvorvidt disse data er tilgængelige på nuværende tidspunkt, eller om det vil være nødvendigt at begynde at indsamle nye typer data.

Et tredje formål med projektet er at beskrive status for diskussionen i UNFCCC, EU og ICAO om muligheder for at implementere virkemidler til reduktion af luftfartens emissioner.

2.3 Luftfartens bidrag til globale klimaforandringer

I 1990 udledte vejtransporten ca. 75% af CO_2 udledningen fra transport på globalt plan, mens luftfarten stod for 12%, international skibsfart 7% og de resterende 6% kom fra banetransport og indenlands søfart [IPCC 1999]. I 1999 udledte luftfarten ca. 3% af de totale CO_2 emissioner relateret til afbrændingen af fossile brændsler [IEA 2001]. Lidt over halvdelen af luftfartens brændstof bruges på internationale ruter.

Luftfartens bidrag til globale klimaforandringer er beskrevet af IPCC i rapporten "*Aviation and the Global Atmosphere*" [IPCC 1999]. Denne rapport blev bestilt af den internationale organisation for civil luftfart (ICAO) og landene som har underskrevet Montreal Protokollen (*Montreal Protocol on Substances that Deplete the Ozone Layer*). IPCC rapporten konkluderer, at emissioner fra flymotorer i store højder antages at bidrage til en ændring af atmosfærens sammensætningen gennem en ændring af "*the concentration of atmospheric greenhouse gases, including carbon dioxide (CO_2), oxone (O_3) and methane (CH_4); trigger formation of condensation trails (contrails); and may increase cirrus cloudiness – all of which contribute to climate change*" [IPCC 1999, s. 3].

Ifølge IPCC antyder den nuværende viden om luftfartens bidrag til globale klimaændringer, at luftfartens samlede klimaeffekt kan være 2-4 gange højere end klimabidraget fra flyenes CO_2 emissioner. Der er dog stor usikkerhed omkring dette estimat, fordi den nuværende viden, om de atmosfæriske processer der følger af emissioner fra flymotorer i store højder, er relativt usikker. En af de største ubekendte faktorer er den mulige klimaeffekt af flyenes udledning af vanddamp, som antages at kunne bidrage til skabelsen af længerevarende skyformationer i store højder.

2.4 Luftfartens vækst

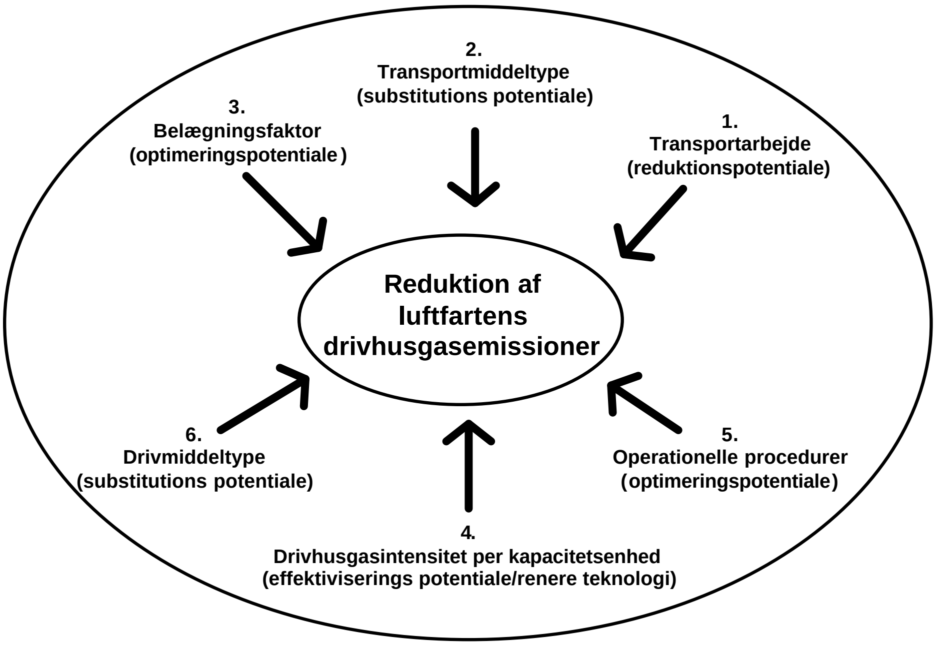
I perioden mellem 1960 og 1998 20-dobledes passagertransporten med fly, målt i passagerkilometer. Samtidig er der dog sket en gradvis reduktion af luftfartsselskabernes energiforbrug per passagerkilometer, primært som følge af teknologisk udvikling og forbedret passagerbelægning. Disse forbedringer har dog ikke kunnet opveje væksten i transportomfanget. Denne udvikling kan eksemplificeres ved nogle udviklingstræk for de amerikanske luftfartsselskaber i perioden 1973-1997. I denne periode reducerede de amerikanske luftfartsselskaber deres energiforbrug per tonkilometer med 55%, men antallet af tonkilometer voksede 280%, således at det samlede forbrug af jetbrændstof steg 70%. I de næste årtier forventer IPCC, at flytrafikken, målt i passagerkilometer, vil vokse med 5% per år, mens forbruget af jetbrændstof forventes at vokse med 3% om året [IPCC 1999, s. 5 og s. 329].

På globalt plan repræsenterer passagerer og deres bagage 70% af den samlede vægt, som transporteres af luftfartsselskaberne, mens flyfragt udgør de resterende 30%. Flyfragten vokser i øjeblikket hurtigere end passagertransporten. Hovedparten af den globale flytrafik foregår i og imellem

Nordamerika, Europa og Asien. Omkring 29% af det samlede antal passagerkilometer på globalt plan genereres på indenrigs ruter i Nordamerika. En gennemsnitlig europæer flyver ca. 1200 kilometer om året, mens en gennemsnitlig amerikaner flyver omkring 3400 kilometer per år. Til sammenligning flyver folk i de fleste udviklingslande gennemsnitligt mindre end 100 kilometer per år. Dette eksemplificerer ikke blot, at der er tale om en fordelingsmæssig problemstilling, men understreger også det kæmpemæssige potentiale for vækst i luftfarten i fremtiden, hvis folk i udviklingslandene efterhånden begynder at tilnærme deres livsstil til den vestlige.

2.5 Muligheder for at reducere luftfartens drivhusgasemissioner

Som illustreret i Figur 1 er der en række forskellige muligheder for at reducere flytrafikkens drivhusgasemissioner.



Figur 1: Muligheder for at reducere luftfartens drivhusgasemissioner.

Først og fremmest vil en reduktion af transportarbejdet med fly (d.v.s. antallet af passagerkilometer, fragt-tonkilometer eller tonkilometer) reducere antallet af flyafgange, og dermed emissionen af drivhusgasser (under forudsætning af at belægningsfaktoren i flyene holdes konstant). Andre muligheder er at substituere brugen af fly med alternative, og mindre drivhusgasintensive transportformer, såsom tog, busser eller biler og at forøge flyenes belægningsfaktor eller at substituere fossilt jetbrændstof med mindre drivhusgasintensive brændstoffer, som eventuelt kan være baseret på vedvarende energikilder. Ligeledes kan man reducere energiintensiteten, eller drivhusgasintensiteten, per kapacitetsenhed, dvs. emissionen per sædekilometer og per tilgængelig fragtkapacitet. Eksempler på dette kan være at benytte mere energieffektive motortyper, at sætte flere sæder i flyene eller at benytte større fly. Ligeledes kan man reducere emissionerne fra hver enkelt flyvetur ved at optimere flyenes operationelle procedurer, eksempelvis ved at flyve mere direkte ruter og ved at undgå for meget ventetid i og over lufthavnene. Mere vidtgående eksempler på hvordan man kan optimere de operationelle procedurer, med henblik på at reducere flyenes drivhusgasbidrag, er valg af lavere flyvehastighed og højde samt eventuelt at undlade at flyve i de mest følsomme områder i atmosfæren. Det skal understreges, at de i Figur 1 illustrerede teoretiske muligheder for at reducere luftfartens emission af drivhusgasser i høj grad er afhængige af hinanden, og til en vis grad modsatrettede, d.v.s. at når man forbedrer en parameter, kan det forværre andre parametre.

2.6 Muligheder for at regulere luftfartens drivhusgasemissioner

De teoretiske muligheder for at reducere luftfartens drivhusgasemissioner beskrevet i afsnit 2.5 kunne i princippet fremmes ved introduktion af forskellige virkemidler. Luftfarten er dog indtil videre ikke underlagt international miljøregulering, som er specifikt rettet mod at reducere drivhusgasemissionerne. ICAO har eksempelvis indtil nu primært fokuseret på at fastsætte standarder for flyenes støjprofil og sundhedsskadelige emissioner i lufthavnenes umiddelbare nærhed. Der har dog igennem de senere år været lagt øget pres på ICAOs generalforsamling, særligt fra de europæiske lande og EU Kommissionen, for at få indført nye typer regulering som kan bidrage til at reducere væksten i luftfartens emissioner. På den seneste generalforsamling i ICAO blev det således vedtaget at igangsætte undersøgelser af flere forskellige muligheder. ICAOs miljøkomite, CAEP, undersøger herunder muligheden for på kort sigt at indgå frivillige aftaler med flyselskaberne om forbedring af deres energieffektivitet, og udgiver snart en rapport om mulighederne for at forbedre energieffektiviteten bl.a. gennem forskellige forbedringer af flyselskabernes operationelle procedurer. Samtidig undersøger CAEP muligheden for, på længere sigt, at indføre markedsbaserede virkemidler såsom et system for handel med CO_2 kvoter eller en afgift på jetbrændstof (jetbrændstof er i øjeblikket fritaget for afgifter og sælges derfor langt billigere end eksempelvis diesel til biler).

I en status rapport udgivet i 2001 konstaterer CAEP, at "…*voluntary measures alone could not achieve an ambitious emission reduction target. They would have to be used in conjunction with other measures. In addition, these voluntary measures allow industry to enhance its ability to undertake activities related to "capacity building". They are primarily looked at as transitional measures. A key issue is the need to ensure that any such action would be to the advantage of the participants if market-based or other regulatory measures were imposed at a later date*" [CAEP 2001n]. Flytrafikkens kraftige vækst er hovedårsagen til, at en frivillig aftale med flyindustrien ikke anses for værende tilstrækkelig, men som nævnt i citatet fra CAEP rapporten kan en frivillig aftale eventuelt bidrage til at strømline flyselskabernes rapportering af deres energiforbrug. En forbedring af datamaterialet for flyselskabernes energiforbrug vil sandsynligvis være nødvendig, hvis det på et senere tidspunkt besluttes at indføre markedsbaserede virkemidler såsom et system for handel med CO_2 kvoter eller en afgift på jetbrændstof.

I en undersøgelse af den mulige virkning af en række markedsbaserede virkemidler har CAEP indtil videre vurderet, at et system for handel med CO_2 kvoter, hvor luftfartsselskaberne gives mulighed for at købe udledningskvoter i andre sektorer, er en billigere løsning end for eksempel afgifter på brændstof eller emissioner [CAEP 2001n]. Denne vurdering bygger på antagelsen om, at det vil være dyrere at reducere luftfartens CO_2 emissioner end at foretage tilsvarende reduktioner i andre sektorer. Handel med CO_2 kvoter synes dog at være en relativt langsigtet løsning, fordi det vil tage tid at designe og vedtage et handelssystem for luftfarten. Nogle af hoveddiskussionspunkterne er her fastsættelsen af en grænse for, hvor meget CO_2 luftfarten må udlede, fordeling af udledningsrettigheder mellem de enkelte luftfartsselskaber og fastsættelsen af en metode til at allokere emissionerne fra international luftfart mellem lande. Herudover er der det problem, at CAEP indtil videre kun ser på CO_2. Eftersom luftfartens emissioner af NOx og vanddamp i store højder kan være en større bidragyder til de globale klimaforandringer end luftfartens CO_2 udledninger, foreslår eksempelvis den engelske Royal Commission on Environmental Pollution, at et handelssystem for emissionskvoter også skal inkludere disse gasser [Royal Commission on Environmental Pollution 2002]. I så tilfælde skal luftfarten købe væsentligt flere CO_2 udledningskvoter i andre sektorer end hidtil antaget i CAEPs vurderinger.

Endelig skal det nævnes, at EU Kommissionen igennem flere år har undersøgt muligheden for at introducere markedsbaserede virkemidler til reduktion af luftfartens udledning af drivhusgasser i Europa, men indtil videre har EU landene ikke implementeret sådanne virkemidler.

2.7 Kvaliteten af landenes rapportering af emissioner fra international luftfart til UNFCCC

Der er gennemført nogle få studier, som sammenligner de metoder landene anvender til at indsamle data om luftfartens energiforbrug, såvel som de metoder der benyttes til at estimere de relaterede emissioner[1]. Disse studier viser, at der er en del problemer forbundet med at estimere emissionerne fra international luftfart. Et af de primære problemer er forbundet med at opdele luftfartens energiforbrug på national og international transport [IEA 2001] [Velzen 1999] [UNFCCC 1999b og 1999f]. Desuden er der for øjeblikket kun 12 af de 32 Annex I lande, som rapporterer deres CO_2 emissioner fra indenlands luftfart for hele perioden 1990-1999 til UNFCCC, mens 16 lande rapporterer CO_2 emissioner fra international luftfart i perioden. Færre lande rapporterer de øvrige emissioner (N_2O, CH_4, NMVOC, SO_2, CO og NO_x) fra luftfart for hele perioden 1990-1999 [UNFCCC 2002c].

UNFCCCs sekretariat har bedt CAEP om at undersøge muligheden for at forbedre kvaliteten og sammenligneligheden af de data for luftfartens energiforbrug og emissioner, som landene rapporterer til UNFCCC [UNFCCC 2002a]. CAEPs Styregruppe besluttede på et møde i september 2002 at bede ICAOs sekretariat om at arrangere et "*scoping meeting*", i et samarbejde med UNFCCCs sekretariat og rapportørerne fra nogle af CAEPs arbejdsgrupper, såvel som eksperter som arbejder med emissionsopgørelser [CAEP 2002a]. Dette initiativ kan desværre ikke beskrives nærmere her, da mødet først kommer til at foregå efter deadline for denne rapport.

Ligeledes er Eurostat og det internationale energi agentur (IEA) ved at forberede fælles retningslinier for deres årlige energistatistikker, med henblik på at hjælpe medlemslandenes statistikbureauer med vejledning i hvorledes rapporteringen bør foregå. Eurostat organiserer også workshops for medarbejdere fra landenes statistikbureauer med henblik på at diskutere problemer med dataindsamling og rapportering.

Et nyligt initiativ fra *European Civil Aviation Conference* (ECAC) kan også tænkes at komme til at bidrage til at forbedre kvaliteten og sammenligneligheden af rapporteringen fra de lande, som deltager I ECAC. ECAC udgav i marts måned 2002 nogle retningslinier for, hvorledes landene

[1] Se for eksempel [Olivier 1999], [UNFCCC 1999f] og [UNFCCC 2000b].

bør estimere og rapportere luftfartens emissioner [ECAC 2002 a og 2002b]. I denne publikation opfordrer ECAC medlemslandene til at benytte den detaljerede Corinair metode til at estimere luftfartens emissioner. Brug af denne metode kan blandt andet forbedre landenes mulighed for at adskille energiforbruget til indenlands og udenrigs luftfart.

Et andet europæisk initiativ, rettet mod at forbedre kvaliteten og sammenligneligheden af de data der rapporteres for luftfartens energiforbrug af de europæiske lande, er blevet startet op i et samarbejde mellem EU's Miljøagentur, Eurocontrol og Eurostat [Eurostat 2002] [Lock 2002]. I denne sammenhæng er der blevet udviklet en database til beregning af energiforbruget fra alle flyvninger fra europæiske lande, med brug af flyrutedata fra Eurocontrol kombineret med data for flyenes energiforbrug og emissioner fra den detaljerede Corinair model. Dette initiativ åbner mulighed for at sammenligne disse database beregninger med de data der rapporteres af landene til UNFCCC. Dette initiativ kan desværre ikke beskrives nærmere her, da rapporten først publiceres efter deadline for denne rapport.

Eurostat financierer også specifikke projekter rettet mod at ensrette de data for energiforbrug som EUs medlemsstater rapporterer til Eurostat med de data som indrapporteres for CO_2 emissioner til UNFCCC. Dette arbejde vil også inkludere brændstofforbrug til international luftfart. Projekterne vil tage udgangspunkt i landenes rapporteringer for årene 1990, 1995 og 2000, med henblik på at identificere og forklare forskelle.

Ud over behovet for at forbedre metodegrundlaget til at estimere hvor stor en andel af energiforbruget og emissionerne der kan tilskrives henholdsvis indenrigs og udenrigs luftfart, er der for EU et andet særligt problem: Siden EU har ratificeret Kyoto protokollen opstår spørgsmålet om EU i sin samlede opgørelse af EU's emissioner skal indregne international luftfart indenfor EU som indenrigs eller udenrigs luftfart. Hidtil har EU lagt totalerne fra landenes udenrigsluftfart sammen. Hvis EU fremover skal til at regne international flytrafik indenfor EU med under EU's nationale energiforbrug, er der brug for nye data. Det ovenfor beskrevne initiativ fra EU's Miljøagentur, Eurocontrol og Eurostat, til opbygning af en database, kan i givet fald bruges til at generere sådanne data.

Et yderligere problem for EUs emissionsopgørelse er, hvorvidt de lande som har oversøiske territorier, inkluderer emissioner fra flytrafik til disse destinationer i deres nationale emissionsopgørelser, eller om disse emissioner rapporteres under udenrigs flytrafik. Ifølge IPCC/UNFCCCs retningslinier bør sådanne oversøiske territorier sandsynligvis inkluderes i landenes nationale emissionsopgørelser, hvilket mange lande ikke gør for øjeblikket.

2.8 Brugen af modeller til beregning af flytrafikkens emissioner

Blandt de lande som rapporterer emissioner til UNFCCC, bruges forskellige metoder med varierende detaljeringsgrad til at beregne flytrafikkens emissioner. Det i afsnit 2.7 beskrevne initiativ fra European Civil Aviation Conference (ECAC) er rettet mod at opmuntre europæiske lande som deltager i ECAC til fremover at benytte den detaljerede corinair metode eller lignende detaljerede metoder. Efterhånden som landene begynder at følge disse retningslinier burde sammenligneligheden og kvaliteten af de data landene rapporterer øges.

Det i afsnit 2.7 beskrevne initiativ fra EU's Miljøagentur, Eurocontrol og Eurostat til opbygning af en database kan, udover at beregne emissioner fra international flytrafik indenfor EU, også benyttes til sammenligning med landenes rapporteringer til UNFCCC.

I øjeblikket er det kun Annex I lande, som rapporterer emissioner fra luftfart til UNFCCC, men omkring en tredjedel af CO_2 emissionerne fra international flytrafik stammer fra flybrændstof solgt i andre lande. En stor andel af det flybrændstof som sælges udenfor Annex I landene, bruges sandsynligvis af luftfartsselskaber fra Annex I lande, eller bruges af luftfartsselskaber som transporterer passagerer og gods, som kommer fra Annex I lande. I tilfælde af at ICAOs generalforsamling skulle beslutte sig for eksempelvis at etablere et system, hvor luftfartsselskaberne kan handle med CO_2 kvoter, vil det være nødvendigt at opbygge en præcis rapportering af flyselskabernes brændstofforbrug og emissioner. For øjeblikket rapporterer flyselskaberne ikke disse data. Herunder kunne det være nyttigt at få opbygget en model til beregning af de globale emissioner fra flytrafik. Der findes et par modeller til beregning af de globale emissioner, men kun for året 1992. Disse modeller er desuden mindre detaljerede end eksempelvis den detaljerede corinair metode i deres opdeling af flyflåden og i deres brug af index for emissioner. Desuden er modellernes databaser over flyafgange ikke så detaljerede som eksempelvis Eurocontrols data.

CAEP har nedsat en arbejdsgruppe "Alternative Emissions Methodology Task group" som har til formål at bidrage til en bedre forståelse for emissioner i flyenes cruise højde. EU Kommissionen finansierer også et lignende projekt, kaldet NEPAIR. Indtil nu er begge projekter rettet mod at etablere metoder til certificering af emissioner fra flymotorer ved cruise. Baggrunden er, at ICAOs "*Emissions Databank*" kun indeholder certificerede data for emissioner fra flymotorer i LTO (landing and take off) fasen [NEPAIR 2002].

2.9 Luftfartsselskabernes rapportering af brændstofforbrug

CAEP synes for øjeblikket at hælde mod, som første step, at lave en frivillig aftale med luftfartsselskaberne om reduktion af CO_2-udledningen per passagerkilometer eller per tonkilometer, og som andet step, at lave et system for handel med CO_2 kvoter, hvor flyselskaberne kan købe udledningsrettigheder i andre sektorer. Begge disse initiativer vil kræve bedre afrapportering af data fra flyselskaberne. Desuden kræver to af de i næste afsnit beskrevne allokeringsmodeller bedre rapportering af data fra flyselskaberne.

Mange luftfartsselskaber udgiver miljøregnskaber, eller rapporterer på anden vis deres brændstofforbrug og emissioner, men selskaberne benytter forskellige metoder til afrapporteringen. Eksempelvis benytter flyselskaberne forskellige metoder til at rapportere deres energiintensitet, d.v.s. eksempelvis deres energiforbrug per passagerkilometer, per fragt-tonkilometer og per tonkilometer. Et eksempel på forskellene er, at nogle selskaber tillægger hele brændstofforbruget til passagertransporten, mens andre fordeler brændstofforbruget ligeligt mellem passagerer og fragt i forhold til deres vægt. Endnu andre selskaber benytter mere sofistikerede metoder til at fordele brændstoffet mellem passagerer og fragt, eksempelvis ud fra en betragtning om at et ton passagerer og bagage fylder mere i flyene end et ton fragt, fordi passagererne skal have sæder, mellemgange, frit rum omkring sig samt mad, toiletter og anden forplejning, o.s.v. Fordelingen af brændstofforbrug og emissioner mellem passagerer og fragt er således ikke standardiseret flyselskaberne imellem.

I USA er alle luftfartsselskaber af en vis størrelse ved lov forpligtiget til at rapportere en lang række operationelle og finansielle data til Trafikministeriet (den såkaldte "Form 41 arrangement"). Derfor har myndighederne i USA rådighed over en meget omfattende database med detaljerede oplysninger om blandt andet luftfartsselskabernes brændstofforbrug. Oplysningerne i denne database kunne eksempelvis bruges til at lave et indeks for de enkelte flyselskabers energiintensitet. Sådanne data bliver ikke rapporteret og indsamlet systematisk fra eksempelvis europæiske og asiatiske luftfartsselskaber, men de fleste luftafartsselskaber må formodes at have sådanne data til rådighed, eksempelvis til brug for diverse interne økonomiske analyser.

Et interessant spørgsmål i denne sammenhæng er, hvorvidt det eventuelt kunne være muligt at etablere en eller anden form for global rapporteringsforpligtigelse for alle luftfartsselskaber i stil med den amerikanske "Form 41" ordning. ICAOs miljøkomite, CAEP, er for øjeblikket i gang med at undersøge mulighederne for at etablere en frivillig aftale med luftfartsselskaberne om reduktion af deres specifikke energiforbrug. En sådan aftale kunne måske komme til at involvere en global afrapportering af de enkelte luftfartsselskabers energiforbrug. Endvidere undersøger CAEP muligheden for, på længere sigt, at etablere et globalt system, hvor luftfartsselskaberne kan handle CO_2 kvoter med andre sektorer. Under et sådant system er det sandsynligt, at det vil være nødvendigt at fastsætte en grænse for, hvor meget CO_2 luftfarten maksimalt må udlede, samt at finde en model til fordeling af rettighederne til at udlede CO_2 mellem de enkelte selskaber, og endelig vil det være nødvendigt at luftfartsselskaberne begynder at rapportere deres energiforbrug. Både frivillige aftaler og handel med CO_2 kvoter ser således ud til at kræve en eller anden form for rapportering af luftfartsselskabernes energiforbrug og emissioner.

Selvom luftfartsselskabernes energiforbrug kan beregnes ved brug af "bottom-up" modellering, eksempelvis ved brug af den detaljerede corinair metode, vil det sandsynligvis være nødvendigt at indsamle faktiske energiforbrugsdata fra selskaberne, da modellerne ikke kan beregne luftfartsselskabernes energiforbrug helt præcist. Som beskrevet i afsnit 2.8 findes der heller ikke for øjeblikket en model til beregning af luftfartsselskaberne globale energiforbrug. Desuden indeholder modellerne ikke oplysninger om flyenes passager- og fragtbelægning. Belægningen bliver relevant hvis luftfartsselskaberne eksempelvis indgår frivillige aftaler om at reducere deres energiforbrug per transporteret passager- og fragt enhed. Som beskrevet i næste afsnit er belægningen ydermere relevant for nogle af de mere sofistikerede metoder til allokering af emissioner fra den internationale luftfart til lande. Det er dog, netop på grund af det relativt store databehov, ikke umiddelbart så sandsynligt at landene bestemmer sig for at benytte nogle af disse mere sofistikerede modeller til allokering.

2.10 Allokering af emissioner fra international luftfart

Landene som indgår i FNs klimakonvention har endnu ikke været i stand til at bleve enige om en metode til at allokere emissionerne fra international luftfart mellem lande. Disse emissioner er derfor ikke inkluderet i landenes nationale emissionsopgørelser som rapporteres til UNFCCC, men rapporteres separat under kategorien ”*international bunkers*”, i øvrigt sammen med emissioner fra den internationale skibstrafik, som heller ikke er inkluderet i landenes opgørelser af de nationale emissioner.

SBSTA har overvejet følgende muligheder for at allokere emissionerne fra den internationale luftfart [UNFCCC 1996a]:

1. Ingen allokering
2. Allokering i forhold til størrelsen af landenes nationale emissioner
3. Allokering til det land hvor flybrændstoffet sælges
4. Allokering til det land hvor luftfartsselskaberne er indregistreret
5. Allokering til det land hvorfra flyet letter eller lander. Alternativt kan emissionerne deles mellem afgangsland og ankomstland
6. Allokering til det land hvorfra passagererne eller fragten afgår. Alternativt kan emissionerne deles mellem afgangsland og ankomstland
7. Allokering til det land hvorfra passagererne og fragten stammer
8. Allokering til de lande over hvis territorium emissionerne foregår

På SBSTAs fjerde møde i 1996 besluttedes det, at metode 1, 3, 4, 5 og 6 skal være basis for det videre arbejde med at vurdere, hvilken metode der er mest hensigtmæssig. For metode 1s (ingen allokering) vedkommende lægges ansvaret for at reducere den internationale luftfarts emissioner over på det internationale samfund. Metode 2, 7 og 8 blev fravalgt af SBSTA af forskellige årsager. Hovedårsagen til fravalget af metode 2 er, at den ikke anses for at være retfærdig, fordi emissionerne ikke bliver allokeret i forhold til landenes luftfartsaktiviteter. Problemet med metode 7 er, at den fordrer data om herkomsten af passagerer og fragt, som ikke er offentligt tilgængelige. Metode 8 blev fravalgt, fordi den kun inkluderer allokering af emissioner over landenes territorier, hvorfor den del af emissionerne som foregår over internationale havområder ikke bliver allokeret.

I 1999 meddelte EU, i en erklæring til SBSTA, at allokering af emissioner fra international luftfart bør træde i kraft i Kyoto protokollens ”*second commitment period*”. Baseret på de ovennævnte konklusioner fra SBSTA 4, foreslog EU en såkaldt ”*twin-track approach*” (model I og II). Model I går på at emissionerne fra international luftfart ikke skal allokeres til lande, og at ansvaret for at reducere emissionerne overlades til det internationale samfund repræsenteret ved ICAO. EU vil dog kun overveje model 1 (ingen allokering) videre, hvis ICAO viser fremskridt, i overensstemmelse med de reduktionsmål der udstikkes af Kyotoprotokollen. Model II går på at inkludere emissionerne fra international luftfart i de nationale emissionsopgørelser. EU foreslår herunder, at SBSTA skal sammenligne og diskutere metode 3, 4, 5 og 6 med henblik på at nå frem til en beslutning om en model i 2005. Hvis emissionerne fra international flytrafik skal allokeres til lande tilbagestår spørgsmålet om hvorvidt det vil være muligt for landene at blive enige om en allokeringsmetode i 2005.

ICAO satser for øjeblikket på at undersøge mulighederne for, på længere sigt, at oprette et system for handel med CO_2 kvoter, hvor luftfartsselskaberne får mulighed for at købe kvoter i andre sektorer. Det er for nylig blevet understreget af den engelske Royal Commission on Environmental Pollution, at hvis et sådant handelssystem bliver implementeret, er det nødvendigt at inkludere emissionerne fra international luftfart i landenes emissionsopgørelser, for at undgå dobbelt-tælling af reduktionerne af emissionerne [Royal Commission on Environmental Pollution 2002]. Derfor er det muligt, at det også vil være nødvendigt at allokere emissionerne fra international luftfart, selvom ansvaret for at reducere emissionerne overlades til ICAO (i tilfælde af at ICAO vælger at vedtage et system for handel med CO_2 kvoter).

SBSTA og EU Kommissionen påpeger, at en given metode til allokering skal være i overensstemmelse med "forureneren betaler" princippet. Problemet er, at når det drejer sig om den internationale luftfart, er det ikke ligetil at definere, hvem der kan betegnes som værende "forureneren". Ydermere er der det problem, at man i vurderingen af de enkelte metoder må tage højde for, om de nødvendige data er til rådighed.

Metode 3 (allokering til det land hvor flybrændstoffet sælges) vil være den nemmeste måde at allokere emissionerne fra den internationale luftfart, fordi statistikker for salget af brændstof er tilgængelige. Denne metode ligner den metode som benyttes for vejtransporten, hvor de enkelte lande inkluderer emissioner fra benzin og diesel som sælges i landet, selvom en del af brændstoffet sælges til brug i køretøjer, som er indregistreret i andre lande. Endvidere viser en sammenligning af metode 3 med metode 5 (allokering til det land hvorfra flyet letter eller lander) og metode 6 (allokering til det land hvorfra passagererne eller fragten afgår), at der i praksis, for de fleste lande, ikke vil være den store forskel på, hvilken af disse tre modeller man vælger. Hovedproblemet med statistikken for salget af flybrændstof er, at mange lande har svært ved at opdele salget på indenrigs- og udenrigs flytrafik, men denne opdeling synes ikke længere at være nødvendig, hvis hele luftfartens brændstofforbrug skal allokeres til det land, hvor brændstoffet sælges. Et problem med metode 3 er dog, at metoden ikke kan tage hensyn til, at flyene kan tanke ekstra brændstof, i de lande hvor brændstoffet sælges billigst. Lande som sælger flybrændstoffet billigt vil således få tilskrevet flere emissioner ved brug af metode 3 end ved brug af eksempelvis metode 5 og metode 6, som benytter sig af modelberegninger for flyenes energiforbrug, og derfor i princippet vil tillægge turen fra a til b det samme energiforbrug som turen fra b til a. Selvom metode 5 og metode 6 på denne vis tager bedre højde for problemet med tankning af ekstra brændstof, er de mere besværlige, fordi de kræver, at landene bruger komplicerede bottom-up modeller til at beregne flyenes brændstofforbrug. Metode 6 er yderligere mere besværlig end metode 5, fordi den kræver at modellerne også inkluderer data om passagerer og fragt. Metode 3, 5 og 6 fører alle til, at lande med mange luftfartsaktiviteter tildeles en stor andel af flyenes emissioner. Dette gælder for eksempel også de lande, som huser store transitlufthavne, og det kan betragtes som unfair overfor disse lande at de skal tildeles emissioner for denne transittrafik.

Metode 4 (allokering til det land hvor luftfartsselskaberne er indregistreret) besværliggøres af, at der for øjeblikket ikke foretages en samlet indrapportering af flyselskabernes energiforbrug på globalt plan, men det må antages, at sådanne data relativt nemt vil kunne indsamles fra flyselskaberne. Hovedproblemet med metode 4 synes at være, at metoden ikke nødvendigvis altid er i overensstemmelse med "forureneren betaler" princippet. På flyvninger mellem det land hvor luftfartsselskaberne er indregistreret og andre lande, bliver både ud- og hjemrejse tilskrevet det land hvor selskabet er indregistreret. Desuden kan luftfartsselskaberne flyve mellem destinationer i tredielande, og derfor på nogle flyvninger principielt slet ikke lande i det land hvor selskabet er indregistreret. En fordel ved metode 4 er dog, som det ser ud i dag, at en større andel af emissionerne fra international luftfart vil blive tildelt Annex I landene, end det er tilfældet i metode 3, 5 og 6, idet en trediedel af det brændstof der bruges til international luftfart, sælges i ikke-Annex I lande. En stor del af dette brændstof må formodes at blive brugt til at transportere passagerer og fragt med herkomst i Annex I lande. Metode 4 synes således at være en retfærdig løsning for ikke-Annex I landene.

Endelig skal det nævnes, at metode 7 (allokering til det land hvorfra passagererne og fragten stammer) sandsynligvis er den løsning, som er bedst på linie med "forureneren betaler" princippet. Denne løsning ville sandsynligvis også være den mest favorable for ikke-Annex I landene, såvel som for lande der huser store transitlufthavne, men metode 7 blev fravalgt af SBSTA på grund af metodens substantielle databehov.

De beskrevne fordele og ulemper ved de 8 allokeringsmodeller er opsummeret i nedenstående tabel:

Model	Fordele	Ulemper
1	Ansvaret for at reducere luftfartens CO_2 emissioner overlades til ICAO. Hvis ICAO indfører regulering gælder den globalt. Det kan være en fordel at gå gennem ICAO for at opnå ensartet lovgivning globalt, og fordi enkelte lande ofte ikke kan gøre noget ved problemet alene.	Luftfartens emissioner allokeres ikke til lande og giver dermed ikke landene incitament til at reducere disse. ICAO har indtil nu ikke fået vedtaget initiativer til at reducere CO_2-udledningen. EU-Kommissionen ønsker at gå videre med allokering til lande fordi ICAO endnu ikke har vist betydelige fremskridt.
2	Til denne model er det kun nødvendigt at have data for landenes totale emissioner.	Luftfartens emissioner fordeles ikke i.f.t. landenes luftfartsaktiviteter. Løsningen er således ikke på linie med forureneren betaler princippet og blev derfor forkastet af SBSTA i 1996.
3	Nem måde at allokere emissionerne fra den internationale luftfart, fordi statistikker for salget af brændstof er tilgængelige. Ligner metode for vejtransporten.	Tager ikke højde for tankering. Lande som har store transitlufthavne vil blive tildelt emissioner for transittrafikken. Metoden tager ikke højde for passagerernes og fragtens nationalitet og er således ikke helt på linie med forureneren betaler princippet.
4	Metoden besværliggøres af, at der for øjeblikket ikke foretages en samlet indrapportering af flyselskabernes energiforbrug på globalt plan, men det må antages, at sådanne data relativt nemt vil kunne indsamles fra flyselskaberne. Falder godt i tråd med frivillige aftaler og handel med CO_2 kvoter. Metode 4 synes at være en mere retfærdig løsning for ikke-Annex I landene end model 3, 5 og 6.	Hovedproblemet med metode 4 synes at være, at metoden ikke nødvendigvis altid er i overensstemmelse med "forureneren betaler" princippet. Dels fordi metoden ikke tager højde for passagerernes og fragtens nationalitet og dels fordi flyselskaberne kan flyve mellem tredielande.

5	Tager, til forskel fra model 3, højde for tankering.	Kræver at landene bruger komplicerede bottom-up modeller til at beregne flyenes brændstofforbrug og emissioner. Lande som har store transitlufthavne vil blive tildelt emissioner for transittrafikken. Metoden tager ikke højde for passagerernes og fragtens nationalitet og er således ikke helt på linie med forureneren betaler princippet.
6	Tager, til forskel fra model 3, højde for tankering.	Kræver at landene bruger komplicerede bottom-up modeller til at beregne flyenes brændstofforbrug og emissioner. Er ydermere mere datatung end model 5, fordi den også kræver data om passagerer og fragt. Lande som har store transitlufthavne vil blive tildelt emissioner for transittrafikken. Metoden tager ikke højde for passagerernes og fragtens nationalitet og er således ikke helt på linie med forureneren betaler princippet.
7	Metode 7 er sandsynligvis den løsning, som er bedst på linie med "forureneren betaler" princippet. Denne løsning ville sandsynligvis også være den mest favorable for ikke-Annex I landene, såvel som for lande der huser store transitlufthavne.	Problemet med metode 7 er, at den, udover at kræve samme modelberegninger som metode 5 og 6, yderligere kræver kobling til data om herkomsten af passagerer og fragt, som ikke er offentligt tilgængelige. Modellen blev derfor forkastet af SBSTA i 1996 som værende for datatung.
8		Metode 8 blev fravalgt af SBSTA i 1996., fordi den kun inkluderer allokering af emissioner over landenes territorier, hvorfor den del af emissionerne som foregår over internationale havområder ikke bliver allokeret.

Tabel 1: Opsummering af fordele og ulemper ved de 8 allokeringsmodeller beskrevet i teksten herover.

3 Summary

This chapter gives a summary of the main findings of this report discussing greenhouse gas emissions from international aviation and allocation options. This report is part of the outcome of a project funded by the Danish Environmental Protection Agency (DEPA). The steering group consisted of Lars Olsen Hasselager and Thorbjørn Fangel, both DEPA, and the author of the report, Stefan Krüger Nielsen, ECOtransport Consulting (external consultant).

3.1 Background

The project was initiated to update the DEPA on ongoing developments in the field of air transport and environment. The background for starting up such a project is that aviation, due to the prospects for future growth in demand for air travel and freight volumes, may become a more significant source of emissions of greenhouse gases in the future.

Another reason for the DEPA to take up the subject is that the DEPA need an update on why the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) have not yet been able to agree upon a methodology to allocate emissions of greenhouse gases from international aviation between countries. Only emissions from domestic air transport are included in the national inventories on annual national greenhouse gas emissions reported by Parties to the UNFCCC while emissions associated with fuel used for international aviation activities are to be reported separately. Consequently, emissions from international aviation are not included under the so-called Kyoto Protocol that sets out targets for reductions of national emissions of greenhouse gases to be fulfilled by the period 2008-2012.

Parties to the UNFCCC and the UNFCCC Subsidiary Body for Scientific and Technological Advice (SBSTA) have been discussing different possibilities for allocating emissions from international aviation to Parties, but so far no agreement has been reached on this subject. A main problem seems to be that if emissions are allocated to the country where the fuel is sold some Parties that have large sales of fuel for transit passengers will have to bear a larger burden than countries where there are no large hub airports. The basic problem seems to be that an airline registered in one country can carry passengers and freight originating from another country to a third country.

Article 2.2 of the Kyoto Protocol states that "*the Parties included in Annex I shall pursue limitation or reduction of emissions of greenhouse gases not controlled by the Montreal Protocol from international aviation and marine bunker fuels, working through the International Civil Aviation Organisation (ICAO) and the International Maritime Organisation (IMO), respectively*" [UNFCCC 1997]. As yet, the ICAO Assembly has not agreed upon new initiatives specifically aimed at reducing greenhouse gas emissions, but ICAOs Committee on Aviation Environmental Protection (CAEP) is investigating several options. Some of these options may have implications for the airlines' reporting requirements as well as the allocation issue.

For example, CAEP is currently discussing the possibility of negotiating with the airline industry on options to set up a voluntary scheme for improving the fuel efficiency of airlines. Such a scheme may involve the need for airlines to engage in a reporting scheme for fuel consumption and emissions. CAEP is furthermore discussing the possibility of setting up an emissions trading scheme based on a system where airlines are allowed to buy emission quotas in other sectors included under the Kyoto Protocol. Such a framework may involve the setting of a cap for aviation emissions and allocation of emission permits to airlines and probably also the allocation of the emissions of CO_2 from international aviation to Parties as well as the need for airlines to engage in a reporting scheme for fuel consumption and emissions. Therefore, the discussion on data availability and requirements seems to be closely connected to the issues of options for allocation and control. This explains why this report focuses broadly on all these issues.

3.2 Project objectives

One aim of this project is to describe the current status of the quality of the reporting by Parties to the UNFCCC of emissions from international aviation activities. The background for this is that the issue is scheduled for discussion at the 18th meeting of UNFCCCs Subsidiary Body for Scientific and Technological Advice (SBSTA). SBSTA has noticed that the reporting by Parties to the UNFCCC on fuel consumption and emissions from international aviation are currently not always consistent with the methodological guidelines set out by the Intergovernmental Panel on Climate Change (IPCC) in its "*Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*". Especially Parties to the Climate Convention are having difficulties in separating fuel consumption and related emissions from domestic and international aviation. This distinction is necessary because emissions from international aviation are not to be included in the national emission inventories of Parties, but are to be reported separately.

Another aim of this project is to describe which methodologies for allocation of emissions from international aviation to Parties that are being discussed within the European Union (EU) and UNFCCC and elsewhere and to assess the data requirements and the data availability for the different allocation options.

A third aim of this project is to give an updated description of recent developments within the UNFCCC, EU and ICAO relevant to future efforts aiming towards reducing emissions of greenhouse gases from international aviation.

3.3 The environmental impact of aviation

Air transport, being the fastest growing transportation mode, is currently a much smaller energy consumer than road transport, but may become a relatively large source in the future if the sector continues to grow at current rates. In 1990, road transport emitted around 75% of the CO_2 emissions from transport activities, while around 12% was attributable to air transport and 7% to international shipping and around 6% to rail and inland waterways [IPCC

1999]. Air transport is currently estimated to emit approximately 3% of the total CO_2 emissions associated with combustion of fossil fuels [IEA 2001].

Aviation's contribution to climate change has been described by the IPCC in a comprehensive special assessment report "*Aviation and the Global Atmosphere*", requested by the International Civil Aviation Organisation (ICAO) and the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer [IPCC 1999]. The IPCC report concluded that aircraft engine emissions at high altitudes are considered to change the atmospheric composition by altering the "*concentration of atmospheric greenhouse gases, including carbon dioxide (CO_2), oxone (O_3) and methane (CH_4); trigger formation of condensation trails (contrails); and may increase cirrus cloudiness – all of which contribute to climate change*" [IPCC 1999, p. 3].

According to the IPCC, the current knowledge about commercial civil air transport's overall contribution to climate change suggests that the total positive radiative forcing (warming) effect might be 2-4 times higher than that of CO_2 emissions from aircraft alone. However, there is a high degree of uncertainty connected to this estimate, because the current knowledge about some of the atmospheric processes induced by high altitude aircraft engine emissions is relatively weak. Among the major uncertainties is the potential of persistent contrail formations to trigger the formation of cirrus clouds.

3.4 Aviation indicators and trends

In the period between 1960 and 1998 passenger air travel, measured in revenue passenger kilometres[2], has grown more than 20-fold. At the same time the fuel efficiency of the aircraft fleet has been substantially improved, mainly as a consequence of the use of more fuel efficient aircraft combined with an improvement of the average load factor. However, still these technical and operational improvements are overridden by volume growth. For example, in the period 1973-1997, the American air carriers reduced their fuel consumption per revenue tonne kilometres[3] by 55%, but the amount of revenue tonne kilometres carried increased by a factor of 3,8 resulting in an increase in fuel consumption of a factor 1,7. In the next decades air traffic, measured in revenue passenger kilometres, and fuel consumption is estimated by the IPCC to grow by 5 percent and 3 percent per year respectively [IPCC 1999, p. 5 and p. 329]

On a global scale passengers and their baggage accounts for 70% of the revenue tonne kilometres transported by commercial airlines while freight accounts for the residual 30%. The amount of freight transported in aircraft grows stronger than passenger transport. The major flows of passengers and freight are transported between North America, Europe and Asia and within North America. 29% of the World's passenger transport by air is generated on domestic routes within North America. Average European and American citizens travel around 1200 and 3400 kilometres per year in aircraft

[2] A revenue passenger kilometre is a measure for the amount of passenger air travel that is calculated by multiplying the number of revenue passengers (passengers that pay at least a certain percentage of the normal fare) to the distance flown in kilometres.

[3] A revenue tonne kilometre is a measure for the amount of tonnes being transported that is calculated by multiplying the weight of the revenue passengers and the revenue freight transported to the distance flown in kilometres.

respectively while people living in developing countries generally travel less than 100 kilometres. This does not only have implications for distributional concerns, but also exemplifies the growth potential represented by developing countries that may be on their way towards adapting Western consumption patterns.

3.5 Options for reducing aviation greenhouse gas emissions

In principle, there are several ways the GHG emissions from aviation could be reduced, see Figure 1.

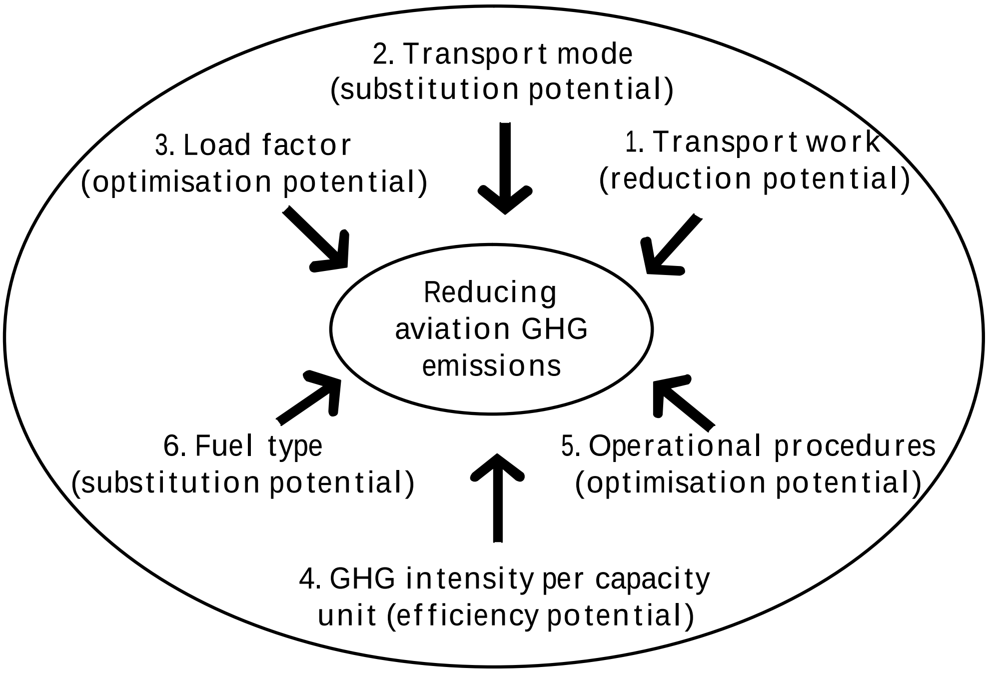


Figure 1:Examples of options for reducing greenhouse gas (GHG) emissions from commercial civil air transport. Source: [Nielsen 2001].

First of all, a reduction of the growth in commercial civil air transport could be part of a strategy for reducing emissions. Such a strategy would benefit from people adapting their lifestyles towards fewer holiday and business trips and towards travelling less by air, for example by choosing less remote destinations as well as by choosing to travel in transportation modes that are less greenhouse gas intensive than aircraft. Furthermore, the aerospace industry could produce aircraft that are less greenhouse gas intensive and the airlines could optimise load factors and operational procedures and scrap or re-engine their oldest and most fuel intensive aircraft. The improvement of operational procedures could, for example, involve investments in more efficient air transport management systems based on satellite navigation to allow the aircraft to choose more direct routings, thereby saving fuel. Another strategy would be to operate the aircraft at lower speeds and altitude. On the longer term it may be possible to substitute current fossil jet fuel by more environmentally benign fuels, based for example on renewable sources of energy.

It should be noted that the theoretical options for reducing the emissions of greenhouse gases from commercial civil air transport described in Figure 1 are to a large extent interdependent, and therefore not fully separable and addable, and furthermore to some extent counteractive.

3.6 Possible government incentives and control options for reducing GHG emissions from aviation

In principle, most of the options for reducing aviation GHG emissions described in section 3.5 could be promoted by different types of government incentives and control options.

The commercial civil air transport industry has until now not been subject to international regulations aimed specifically at reducing aircraft greenhouse gas emissions. Rather, standards issued by the International Civil Aviation Organisation (ICAO) set limits for aircraft noise and engine emissions in and near airports. However, the industry may soon be facing new environmental policies that can to some extent contribute to reduce the GHG intensity as well as the growth in passenger air travel.

ICAOs Committee for Environmental Protection (CAEP) is currently in the process of studying how a voluntary scheme for reducing the fuel intensity of airlines could be set up [CAEP 2002a]. This initiative is likely to be implemented within a relatively short timeframe because the industry itself seems to acknowledge the need for such a voluntary scheme. However, in a recent status report CAEP acknowledge "…*voluntary measures alone could not achieve an ambitious emission reduction target. They would have to be used in conjunction with other measures. In addition, these voluntary measures allow industry to enhance its ability to undertake activities related to "capacity building". They are primarily looked at as transitional measures. A key issue is the need to ensure that any such action would be to the advantage of the participants if market-based or other regulatory measures were imposed at a later date*" [CAEP 2001n]. The main reason why voluntary measures are not considered sufficient is that the growth in aviation is expected to override the technical and operational improvements that could be part of a voluntary emission reduction scheme. However, as noted by CAEP in the citation above, if carefully designed, a voluntary scheme could be used to streamline airline environmental reporting, potentially improving the data material that may also have to be available if other market-based measures, such as a kerosene tax or an emissions trading scheme, are implemented at a later date.

In its assessment of a range of market-based measures CAEP recently concluded that an "open emissions trading scheme" allowing the commercial civil air transport industry to buy emission quotas in other energy consuming sectors would be a better and cheaper solution than for example a tax on emissions or fuel [Wickrama 2001] [CAEP 2000a and 2000b]. This is because it appears that less costly reductions are possible in other sectors (than aviation) because the aviation sector faces higher abatement costs, and hence the potential savings from trading with other sectors would be substantial. However, CAEP considers emissions trading a long-term solution because the design of an emissions trading regime would have to be agreed upon before trading can begin. Some of the key issues here are the setting of a cap for aviation emissions and the distribution of emission permits between airlines (i.e. grandfathering, based on past or current use, or auctioning through a bidding process) and possibly also the allocation of CO_2 emissions to Parties to the Climate Convention.

Another important issue for the design of an emissions trading scheme for aviation is whether the scheme should only consider CO_2 or if emissions of NOx and water vapour at cruise altitude should be included. The last mentioned solution would mean that the aviation industry would have to buy more GHG emission permits than the before mentioned solution. For example, the UK Royal Commission on Environmental Pollution states in a recent report that an aviation emissions trading scheme ought to take into account that the total radiative forcing of aviation is about three times that of the carbon dioxide emitted [Royal Commission on Environmental Pollution 2002].

In Europe, the European Commission has been investigating the possibility of introducing European market-based control options for reducing GHG emissions from aviation, but until now, the European Community has not yet implemented any such measures.

3.7 Availability and quality of the reporting by Parties to the UNFCCC on emissions from international aviation

A few studies have been conducted aimed at describing the methods used to collect data and estimate and report emissions from aviation bunker fuels[4]. These studies report that aviation emissions are complicated to estimate because the statistical basis is relatively weak. Especially the distinction between fuel used for domestic and international purposes is difficult [IEA 2001] [Velzen 1999] [UNFCCC 1999b and 1999f]. Another problem is the separation of fuel consumed by military aircraft from fuel consumed by civil aircraft. According to the UNFCCC guidelines Parties should report fuel consumption for military aviation under the Source/sink category 1A5, “Other” while this is included under domestic aviation under IEA reporting guidelines [IEA 2001].

Of the 32 Annex I Parties to the UNFCCC, 12 Parties report to the UNFCCC their CO_2 emissions from domestic aviation in all the years from 1990-1999 while 16 Parties report CO_2 emissions from international aviation in the period. Fewer Parties report the other emissions species from aviation for the whole period 1990-1999 [UNFCCC 2002c]. Thus, currently there seems to be an inadequate geographical coverage of the data reported to the UNFCCC by Annex I Parties.

The UNFCCC Secretariat has requested CAEP to explore opportunities to examine and improve the quality of data reporting and comparability of aviation bunker fuel data [UNFCCC 2002a]. CAEPs Steering Group Meeting in September 2002 agreed that the ICAO Secretariat should take the necessary steps to organize a “scoping meeting”, involving the UNFCCC Secretariat, the rapporteurs of some of CAEPs working groups and experts on emissions inventory and data reporting [CAEP 2002a]. This initiative may bring new insights of relevance on the topic, but the deadline of work lies beyond the deadline of this report, and the initiative is therefore not described further here.

Eurostat and the International Energy Agency are preparing a joint manual on annual energy statistics to help Member States’ statistical authorities in filling in the energy statistics questionnaires. Eurostat also organises training

[4] See for instance [Olivier 1999], [UNFCCC 1999f] and [UNFCCC 2000b].

workshops for officials from these authorities to discuss problems in data collection and reporting.

In a recent ECAC initiative European countries that participate in ECAC are encouraged to begin using the Detailed Corinair Methodology for calculating aircraft emissions. This may improve the ability of European countries to separate better emissions for international air transport from emissions for domestic air transport [ECAC 2002a and 2002b].

Another recent European initiative has been launched in a co-operation between the European Environment Agency, Eurocontrol and Eurostat to improve the data availability involving the use of a database supplied by Eurocontrol on actual flights performed in Europe and the use of the detailed Corinair emission calculation methodology. This effort may offer the opportunity to compare the data reported to the UNFCCC by European Parties to ECAC to the data calculated by EEA, Eurocontrol and Eurostat. At the time of writing this report the final results of the work has not yet been published [Eurostat 2002] [Lock 2002].

Eurostat finances specific projects in the Member States that aim at eliminating differences in energy data reported to Eurostat and those used for the calculation of CO_2 emissions reported to the UNFCCC. This work will also improve reporting of fuel consumption for international aviation. The projects will examine the energy data used in the submissions for the years 1990, 1995 and 2000, identifying and explaining the differences. The projects furthermore aim at establishing a procedure at national level that will eliminate diversions of different reporting mechanisms in the future and also aim at providing the updated energy data in the form of annual questionnaires for the period 1990-2000.

Besides the need to improve the methodologies for separating emissions from international aviation from emissions from domestic aviation there is another related question that is applicable to the reporting of aviation emissions in the European Union: Since the European Union has ratified the Kyoto Protocol the question arises whether the EU inventory should merely represent the sum of national inventories or if international intra-EU flights should be regarded as “domestic” in the EU inventory. If it is decided that the EU inventory should include international intra-EU flights as domestic these emissions have to be separated from the emissions reported as international by EU Member States. The emission calculation work currently under way in the co-operation between the European Environment Agency, Eurostat and Eurocontrol may be used to produce the data needed for that process.

Another problem that may remain in Europe is whether countries that have overseas territories should include flights to these areas in their national inventories or if these emissions should be reported as domestic emissions. According to the IPCC/UNFCCC reporting guidelines, administered territories should be included in national inventories, but for many countries they are not at present.

3.8 Availability and quality of inventory models

Currently Parties to the UNFCCC can use different methodologies of varying detail in their reporting of aviation emissions to the UNFCCC. A recent ECAC initiative aims at encouraging European countries that participate in

ECAC to begin using the Detailed Corinair Methodology for calculating aircraft emissions [ECAC 2002a and 2002b]. This may increase comparability and accuracy in the reporting from these countries to the UNFCCC.

Another recent initiative from the European Commission, Eurostat and EUROCONTROL, the so-called TRENDS project, may also improve the data material and may also give the European countries the possibility to crosscheck their reporting to the UNFCCC to the data from Eurostat. The TRENDS initiative also opens the possibility of calculating fuel use and emissions separately for intra-EU flights. Such data may be needed for the EU emission inventory submitted to the UNFCCC [Eurostat 2002] [Lock 2002].

In the current situation only Annex I countries report emissions from aviation to the UNFCCC, but around one third of the CO_2 emissions from international aviation bunkers in 1999 relate to fuel sold in non-Annex I countries that have not yet agreed to reduction targets under the Climate Convention. Much of the fuel sold in non-Annex I countries may be consumed by airlines registered in Annex I countries or may be consumed by airlines transporting passengers and goods originating from Annex I countries. In case CAEP/ICAO intends to set up an emissions trading scheme the development of a yearly updated global inventory may be useful for calculating the total emissions from aviation, and more exact figures than those available today may also be needed to set up the system. A few global inventories have been conducted, but only for the year 1992, and these inventories are neither as detailed as for example the detailed CORINAIR methodology in their use of aircraft categories and emission indexes and neither do they contain accurate data on flights actually performed by all airlines globally.

A working group “Alternative Emissions Methodology Task group” has been set down by CAEP aiming at providing a better understanding of cruise emissions from aviation. Similarly, the European Commission is currently funding a programme in this area called “NEPAIR”. At this time, both projects are seeking to establish methodologies, but not standards, that could be used for certification of aircraft engine cruise emissions, that may be ready by 2003. Currently, the ICAO Emissions Databank only contains certificated data for Landing and Take Off (LTO) emissions but these new initiatives may in the future lead to recommendations for the development of standards for engine emissions at cruise [NEPAIR 2002].

3.9 Availability and quality of airline data

The airlines that currently report their fuel intensity in environmental reports do not use a common standard. The fuel intensity estimates reported by different airlines are not directly comparable because of the differences in reporting methodologies. One example is that some airlines subtract a part of the fuel consumption which is attributable to freight transport in passenger aircraft, whereas others include this use in the estimate for the specific fuel use per revenue passenger kilometre. The division of fuel use between passengers and freight is not straightforward.

In the United States all airlines of a certain size are required by law to report their operating statistics to the Department of Transportation (the so-called “Form 41” arrangement). Therefore, in the United States, a comprehensive database exists with data for the fuel consumption of airlines and their aircraft spanning back several decades. This type of data can be used to make comparisons between airlines and for indexing their fuel efficiency. Such data are currently not being systematically reported to the same detail to governments, ICAO or elsewhere by airlines in other countries, although most airlines almost certainly gather such data for internal purposes.

One interesting question is whether it would be possible to establish some sort of global reporting requirement for all the World's airlines in line with the US "Form 41" establishment. Since ICAO and CAEP are currently investigating possibilities for setting up voluntary agreements with airlines on reducing their specific emissions of CO_2 that process might involve setting up a scheme for airline reporting of fuel consumption and emissions. Furthermore, ICAO and CAEP are currently investigating the possibility to set up a global system for emissions trading. Such a system may come to involve the setting of an emission cap and the allocation of certain emission quotas to airlines and may also involve new reporting requirements for airlines.

Even though airline fuel consumption could be estimated using bottom-up modelling, for example using the Corinair-model, actual fuel consumption data from airlines may be needed because airlines might not be likely to accept being accredited for modelled fuel consumption data. At least at present, the models that have been constructed to calculate emissions from air traffic on a global scale do not contain a comprehensive database on flights actually being performed and furthermore relies on calculating fuel consumption and emissions by using less detailed aircraft categories than those used in the detailed CORINAIR methodology. Furthermore, all the models constructed to date are disadvantaged by not containing detailed information on the actual passenger loads and freight loads transported by the aircraft. These loads may become relevant for example in the case that airlines should become required to reduce their emissions per passenger kilometre and per freight tonne kilometre in a voluntary scheme. Detailed data on the passenger and freight loads may also become necessary for some of the more sophisticated models for allocating emissions from international aviation to Parties. However, these sophisticated models of allocation currently do not seem to be the most likely to be chosen if Parties to the Climate Convention should agree upon implementing an allocation option.

3.10 Allocation of emissions from international aviation

Parties to the UN Climate Convention have not yet been able to agree upon a methodology for allocating emissions from international aviation to Parties. Therefore, these emissions are not included in the national emission inventories that are to be reported to the UNFCCC by Annex I countries, but are reported separately under international bunkers in conjunction with emissions from international marine transport.

SBSTA has considered the following options for allocating emissions from international aviation [UNFCCC 1996a]:

1. No allocation
2. Allocation in proportion to national emissions of Parties
3. Allocation to the country where the fuel is sold
4. Allocation to the nationality of airlines

5. Allocation to the country of destination or departure of aircraft. Alternatively, the emissions related to the journey of an aircraft could be shared by the country of departure and the country of arrival
6. Allocation to Parties according to the country of departure or destination of passenger or cargo. Alternatively, the emissions related to the journey of passengers or cargo could be shared by the country of departure and the country of arrival
7. Allocation to the country of origin of passengers or owner of cargo
8. Allocation according to emissions generated within each party's national space

In 1996 SBSTA 4 concluded that options 1, 3, 4, 5 and 6 should be the basis for the further work and that with respect to option 1 (non-allocation) the responsibilities of the international community to address issues related to international bunker fuels should be recognised. Options 2, 7 and 8 were discarded by SBSTA for different reasons. The main reason for discarding option 2 is lack of equity because emissions are not allocated in proportion to the amount of aviation activities performed by each Party. The problem with option 7 is that the data needed on the origin of passengers and freight simply is not generally publicly available. Finally, option 8 was discarded because of its inadequate global coverage since all emissions above international waters are not allocated to Parties under this option.

By 1999, in a statement to SBSTA, the European Community stated that any decision on the inclusion of emissions from international bunker fuels in the national inventories of Parties (i.e. on allocation) should enter into force during the second commitment period. Based on the conclusions of SBSTA 4, the EU proposed a twin-track approach (main options I and II). Option I is not to allocate emissions from international aviation in the national inventories of Parties as in the current situation. Limitation or reduction of emissions from international aviation would be under the general responsibility of the international community to be pursued through ICAO. The EU may consider option 1 (no allocation) further, if ICAO makes demonstrable progress, taking into account the overall emission reduction target of the Kyoto Protocol. Option II is to include emissions from international aviation in the national inventory of the Parties. With regard to the allocation options (options 3, 4, 5, and 6), EU propose that SBSTA should compare and discuss these with a view to being in a position to reach agreement on one option by 2005. The remaining question seems to be whether it may be possible to reach an agreement on the allocation issue before 2005.

Furthermore, recent developments suggest that ICAO may be heading towards investigating further the potential use of an open emissions trading scheme for aviation, allowing the aviation industry to buy emission permits in other sectors. It has recently been pointed out by the UK Royal Commission on Environmental Pollution that if an emissions trading scheme is implemented, emissions from international aviation would have to be included in national greenhouse gas inventories of Parties to avoid double-counting of emission reductions attained in other sectors [Royal Commission on Environmental Pollution 2002]. Therefore, on the longer term, it seems that emissions from international aviation may have to be allocated to Parties also in the case where emissions reduction is pursued through ICAO.

SBSTA and the European Commission seem to agree that any allocation option chosen should be consistent with the 'polluter pays' principle and therefore should be equitable. The problem is that, in the case of international aviation activities, it is not always clear who should be considered as the ‘polluter’. Furthermore there is the problem that it should be possible to ensure the availability and accuracy of the data required for allocating emissions. Option 3, allocation to the Party where the fuel is sold, seems to be the easiest way to allocate emissions from aviation because the data are to a wide extent already available. Furthermore, a comparison of options 3, 5 and 6 show that, for most countries, the different methodologies used for each option do not produce radically different results. The main problem with the data reported by Parties to the UNFCCC on fuel consumed for international aviation, is that Member States are having difficulties in separating fuel consumed for domestic and international purposes. The separation of fuel sales into domestic and international does not seem to be necessary if emissions from international aviation are to be included in national totals according to where the fuel is sold. However, option 3 does not take into account that aircraft can tanker extra fuel for a given trip. Some countries that sell aviation fuel at relatively low prices may therefore be disfavoured by option 3 as compared to options 4 (allocation to the nationality of airlines), 5 (allocation to the country of destination or departure of aircraft) and 6 (allocation to Parties according to the country of departure or destination of passenger or cargo). Option 5 may solve the tankering problem but would require that Parties use bottom-up models to calculate fuel consumption. Option 6 is disfavoured by the fact that it would require even more complicated models and data details than option 5. Options 3, 5 and 6 disfavours countries with a high level of aviation activities (for example countries that house large international hub airports) and this can cause equity considerations in cases where a large portion of the passengers and the freight is transported through the country in transit. Option 4 is disfavoured by the fact that countries do not currently gather data on the fuel consumption of national airlines. However, such data may be relatively easy to collect. The main disadvantage of option 4 seems to be that it does not necessarily always apply the ‘polluter pays’ principle because countries with large national airlines would be held responsible for a large proportion of global aviation emissions, even if many of the flights does not depart or arrive within the country itself. However, option 4 may involve that a higher share of the emissions from international aviation will be allocated to Annex I countries than what is the case for options 3, 5 and 6. From an equity point of view option 4 could be considered more equitable for non-Annex I countries due to the fact that much of the fuel sold for international aviation in these countries may actually relate to air travel performed by people living in Annex I countries. Finally it should be mentioned that option 7 (allocation to the country of origin of passengers or owner of cargo) is probably the option which is most in line with the “polluter pays” principle and would most likely be favourable to non-Annex I countries and to countries that house large international hub airports, but this option has been discarded by SBSTA due to its substantial data requirements.

4 Aviation indicators and trends

A growing concern over emissions of greenhouse gases into the atmosphere has led governments to sign agreements on future reduction schemes [UNFCCC 1997]. Currently, the emissions from international air traffic are not included in these international commitments, but an increasing political focus on the sector internationally suggests that they might be in the future. In this respect it becomes relevant to assess the possible role of commercial civil air transport in a future greenhouse gas (GHG) reduction scheme.

4.1 Aviation's contribution to climate change

Air transport, being the fastest growing transportation mode, is currently a much smaller energy consumer than road transport, but may become a relatively large source in the future if the sector continues to grow at current rates. In 1990, road transport emitted around 75% of the CO_2 emissions from transport activities, while around 12% was attributable to air transport and 7% to international shipping and around 6% to rail and inland waterways [IPCC 1999]. Air transport is currently estimated to emit approximately 3% of the total CO_2 emissions associated with combustion of fossil fuels [IEA 2001]. According to the IEA, little more than half of the CO_2 emissions from air transport are related to international aviation, the rest being consumed in domestic aviation activities [IEA 2001]. However, it should be mentioned, that the distinction between domestic and international fuel consumption is relatively uncertain [Velzen 2000].

Aviation's contribution to climate change has been described by the IPCC in a comprehensive special assessment report "*Aviation and the Global Atmosphere*", requested by the International Civil Aviation Organisation (ICAO) and the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer [IPCC 1999].

The above mentioned IPCC report concluded that aircraft engine emissions at high altitudes are considered to change the atmospheric composition by altering the "*concentration of atmospheric greenhouse gases, including carbon dioxide (CO_2), oxone (O_3) and methane (CH_4); trigger formation of condensation trails (contrails); and may increase cirrus cloudiness – all of which contribute to climate change*" [IPCC 1999, p. 3]. Furthermore, according to the IPCC, the current knowledge about commercial civil air transport's overall contribution to climate change suggests that the total positive radiative forcing (warming) effect might be 2-4 times higher than that of CO_2 emissions from aircraft alone. This is because emissions of water vapour and NOx act as greenhouse gases when emitted at cruising altitude (it should be noted that emissions of CO_2 do not contribute more to climate change when emitted at high altitude than when emitted at ground level). However, there is a high degree of uncertainty connected to this estimate, because the current knowledge about some of the atmospheric processes induced by high altitude aircraft engine emissions is relatively weak. Among the major uncertainties is the potential of persistent contrail formations to trigger the formation of cirrus clouds. The best estimate from the IPCC on the radiative forcing resulting from emissions from subsonic aircraft in 1992 is that they contribute with about 3,5% of the total radiative forcing caused by anthropogenic activities [IPCC 1999, pp 3-10].

4.2 Demand growth and technical/operational improvements

Passenger air travel, measured in revenue passenger kilometres[5] (RPKs), has grown continuously from year to year since 1960 except for two years, namely 1991 and 2001. In 1991, the war in the Persian Gulf pressed up the oil price leading to a general downturn in the economy and to some extent scared travellers from flying through fears of hijackings. Likewise, in 2001, the September 11 terrorist attack on World Trade Centre in New York lead to a decrease in the global demand for air traffic as compared to 2000. From 1960 to 1998 the number of RPKs increased more than 20-fold from around 131 billions to around 2888 billions, corresponding around 44 RPKs per capita globally in 1960 and almost 500 RPKs per capita in 1998 [Nielsen 2001]. Figure 2 illustrates the growth in the seat capacity of the World's scheduled airlines since the early days of commercial civil aviation.

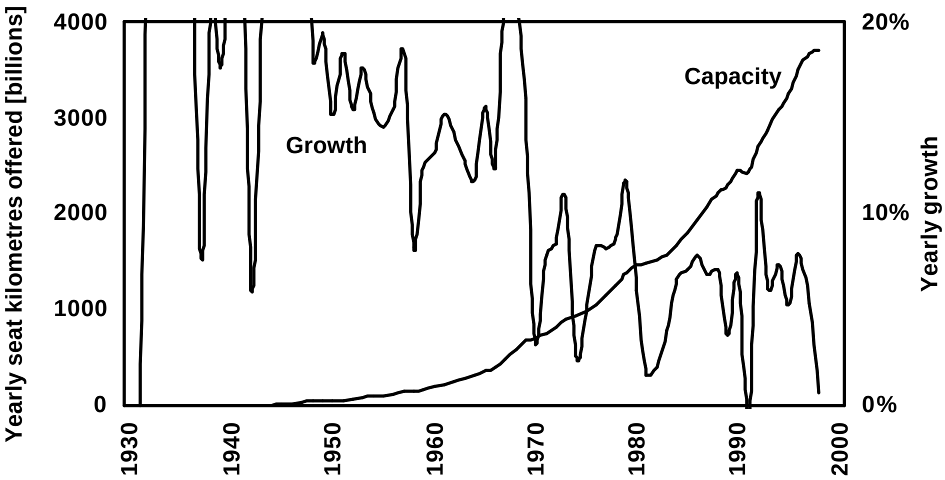


Figure 2: Seat capacity of the world's scheduled airlines (excluding the former Soviet Union). Source for data: ICAO Statistics taken from [DTI 1999].

While the demand for air travel and airfreight has grown in the last decades the fuel intensity of the aircraft fleet has been substantially reduced, mainly as a consequence of the use of less fuel intensive aircraft combined with an increase in the average load factor. However, these technical and operational improvements have not been substantial enough to reduce the total fuel use. Efficiency gains are overridden by volume growth.

This can be exemplified by an analysis of some overall developments for the American air carriers in the period 1973-1997, see Figure 3. Within that period the amount of revenue passenger kilometres (RPKs) and revenue freight tonne kilometres (RFTKs) grew by factors of 3,6 and 4,6 respectively, leading to an increase in the total amount of revenue tonne kilometres (RTKs) by a factor of 3,8. At the same time the specific average fuel consumption per revenue tonne kilometre was reduced by some 55% leading

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[5] A revenue passenger kilometre is a measure for the amount of passenger air travel that is calculated by multiplying the number of revenue passengers (passengers that pay at least a certain percentage of the normal fare) to the distance flown in kilometres.

to an overall increase in fuel consumption by a factor of 1,7. Freight transport and passenger transport have grown at average yearly rates of around 6,5% and 5,4% since 1973. While the yearly growth rate in passenger air travel has slowed down in the second half of the period freight transport has grown faster in these later years than in the first half, see Figure 3.

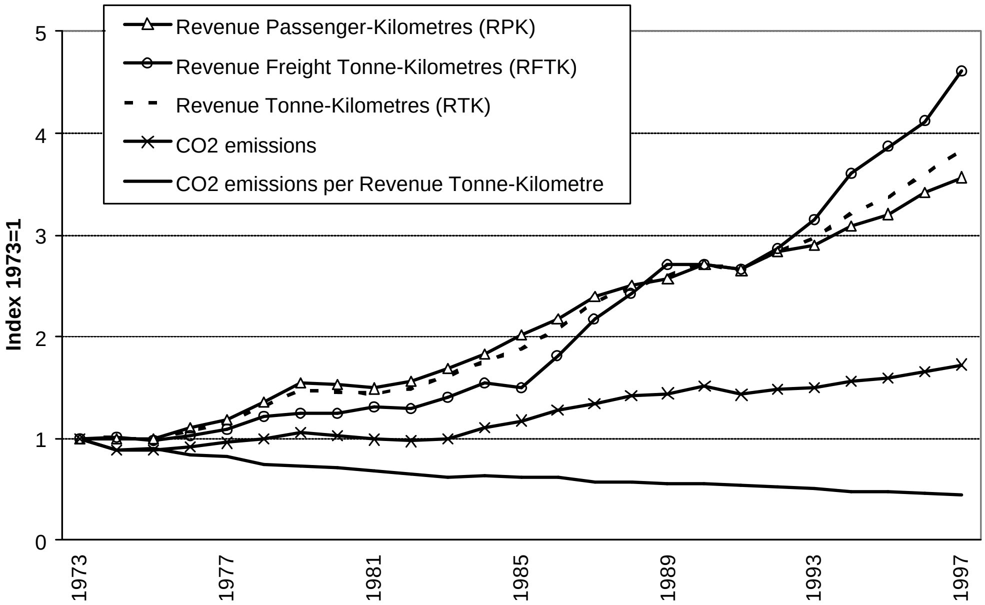

Figure 3: Some main developments for the US air carriers 1973-1997. Source: [Davis 1995 and 1999]

In the next decades, aviation fuel consumption is expected by the Intergovernmental Panel on Climate Change (IPCC) to continue growing. The IPCC describes and compares several long-term scenarios for global air traffic demand and associated fuel use and emissions until the middle of this century. These scenarios consider different combinations of developments in the demand for passenger air travel and airfreight and the specific fuel consumption and associated emissions of NOx. In the scenarios the demand for air traffic, measured in Revenue Passenger Kilometres (RPK), is assumed to grow by between 360 percent and 2140 percent by 2050 as compared to 1990 leading to increases in fuel consumption of between 160 and 1600 percent and increases in emissions of NOx of between 160 and 810 percent. A central IPCC estimate for the next fifteen years projects air traffic and fuel use to grow by 5 percent and 3 percent per year respectively [IPCC 1999, p. 5 and p. 329]. It should be noted that these scenario calculations were presented prior to the 11 September 2001 terrorist attacks on World Trade Centre in New York. However, even though the magnitude seems uncertain, aviation's future contribution to climate change seems likely to grow in the next decades.

4.3 The significance of airfreight

On a global scale air freight accounts for some 30% of the weight transported by commercial airlines while passengers and their baggage accounts for the residual 70% (see Appendix H) [Nielsen 2001]. Therefore, the contribution of freight transport to the overall environmental load of air transport should not be neglected. In the last decade freight transport by air has grown stronger than passenger transport and the importance of airfreight is therefore growing. The tendency is exemplified by the main developments for the US air carriers illustrated in Figure 3. Some airfreight is carried in dedicated freighter aircraft, but the major share is carried as belly-hold in passenger aircraft. On short- to medium distance passenger flights freight typically only accounts for a rather insignificant share of the weight transported, but on long-distance flights freight often account for more than 40% of the revenue weight [Nielsen 2001].

4.4 Distributional issues and prospects for growth

Figure 4 illustrates, in overall terms, the flows of passengers and freight within and between World regions. Most of the freight tonne kilometres (a freight tonne kilometre describes transport of one tonne of freight over one kilometre) are transported between North America, Europe and Asia and within North America. We note that the passenger traffic within North America alone represents around 29% of the revenue passenger kilometres performed by scheduled airlines on a global scale.

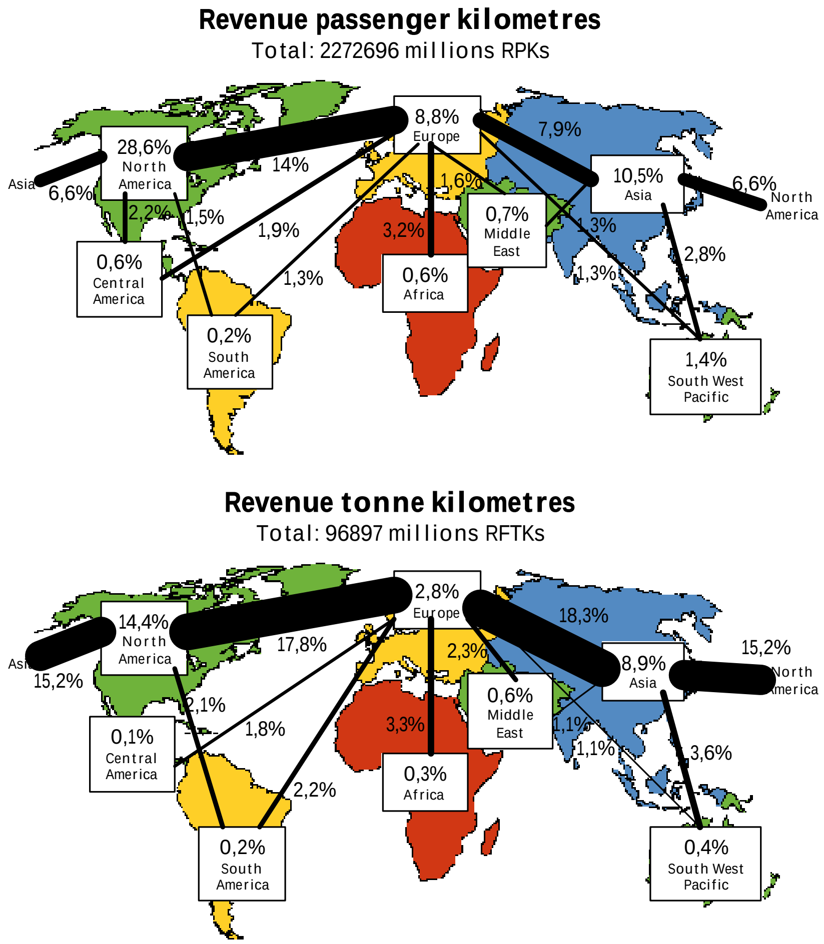

Figure 4: Major Traffic flows between regions of the world 1999. Scheduled services performed by IATA member airlines. Source: [IATA 2000].

People living in highly industrialised countries generate the bulk of passenger air travel and airfreight. In some industrialised countries people travel several thousand kilometres per year on average while people living in developing countries generally fly less than 100 kilometres per year, and in some countries less than 10 kilometres per year. For example, globally, people travel less than 500 kilometres by air per year on average, but average European and

American citizens travel around 1200 and 3400 kilometres per year respectively. This does not only have implications for distributional concerns, but also exemplifies the growth potential represented by developing countries that may be on their way towards adapting Western consumption patterns. For example, if people currently living in China and India begin flying as much per capita each year as Europeans currently do on average, they would alone generate almost as much air traffic per year as is currently generated globally.

4.5 Determinants of air transport growth

Some important economic, physical, social and political determinants of passenger air travel growth are illustrated in the diagram in Figure 5. The circle in Figure 5 illustrates the size of passenger air travel demand. The arrows pointing out from the circle represents elements that currently seems to drive passenger air travel growth, while the arrows pointing towards the circle centre are meant to represent current and potential impeders. Note that many of the current drivers could become impeders in the future, i.e. the current drivers are not necessarily per se going to continue increasing the demand for air travel in the future.

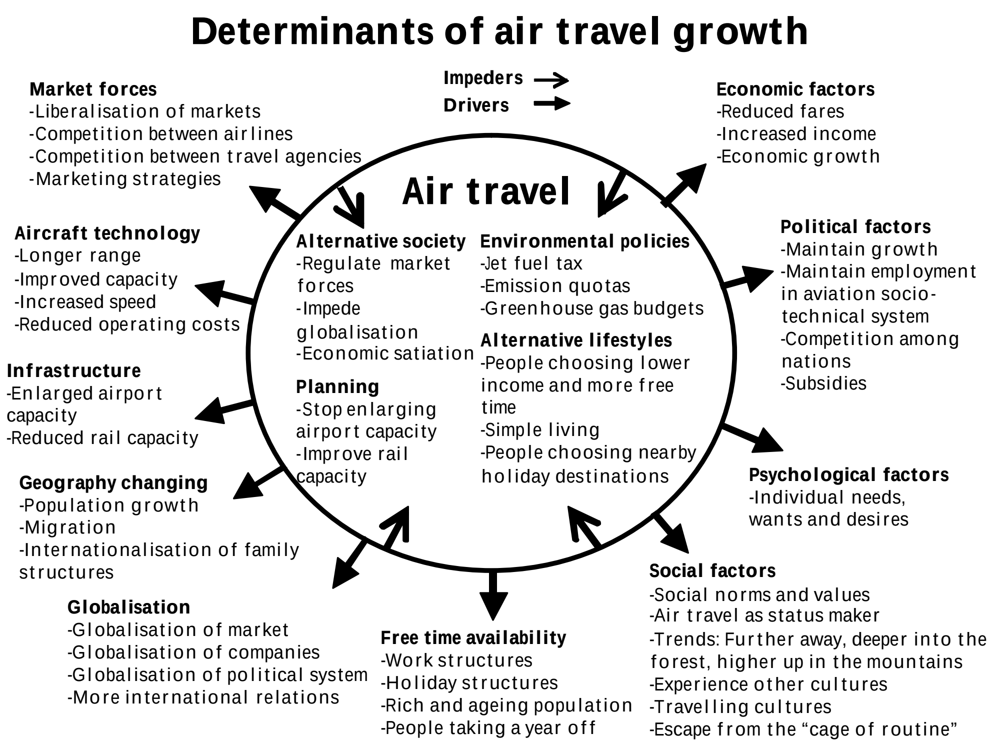

Figure 5: Some main determinants of air travel growth. Source: [Nielsen 2001].

Air transport growth is furthered by constantly enlarging the physical capacity of commercial civil air transport’s socio-technical system and by improving its productivity while cutting real costs. Improved airline productivity brings reduced real airfares, and increasing income allows a higher number of people to fly. Economic growth in general as well as globalisation of economies, companies, markets, political systems and personal relations leads to the drive for travelling more often and over longer distances. Increasing migration, marriages across national borders and population growth are further aspects.

People are basically restricted from air travel by financial and time constraints as well as technology and geography. Financial constraints are mainly connected to airfares and personal incomes. Technology is an important constraint in the sense that aircraft speed, range and capacity limit the distance people are able to fly within the time available. Geographical characteristics also play an important part in the sense that the earth is a limited geographical area, and unless space-flight becomes available for a broad part of the population, there seems to be upper limits as to how far each person might want to travel in a year. Current impeders to passenger air travel growth are congested airports and airspace. In the future new environmental policies might emerge, and on the longer term a reduction or a saturation of world economic- and population growth could reduce air travel growth.

Figure 5 illustrates in broad terms that there are numerous driving forces generating air transport growth. It is beyond the scope of this report to give an in depth description of all these drivers. However, Figure 5 is intended to illustrate the broad range of factors that influences the demand for air travel to emphasize that potential policies aimed at reducing the future growth in air transport could, in principle, be directed towards changing any of these driving forces.

5 Possibilities for reducing aviation GHG emissions

This chapter briefly describes some main possibilities for reducing aviation greenhouse gas emissions. Furthermore some possible future government options for implementing incentives that can help controlling aviation greenhouse gas emissions are listed. The options for reducing greenhouse gas emissions mentioned in section 5.1 and the list of possible control measures given in section 5.2 do not represent all possibilities, but merely mentions the options found in the literature reviewed in the process of writing this report. It is not the intention of this report to suggest which reduction options are the biggest and which measures that would be most effective or politically and legally feasible. The intention is merely to indicate some main possibilities that may be taken into consideration in a future scheme for reducing emissions of greenhouse gases from aviation.

5.1 Potentials for reducing aviation GHG emissions

A reduction of the growth in commercial civil air transport could be part of a strategy for reducing the global emissions of greenhouse gases in the future. Such a strategy would benefit from people adapting their lifestyles towards fewer holiday and business trips and towards travelling less by air, for example by choosing less remote destinations as well as by choosing to travel in transportation modes that are less greenhouse gas intensive than aircraft. Furthermore, the aerospace industry could produce aircraft that are less greenhouse gas intensive and the airlines could optimise operational procedures and scrap or re-engine their oldest and most fuel intensive aircraft. Figure 6 exemplifies some main principles by which greenhouse gas emissions of civil air traffic can be reduced.

1. A reduction of the transport work, or transport volume, measured as tonne-kilometres (which represents the total weight of the revenue freight tonne kilometres (RFTKs)[6] and the revenue passenger kilometres (RPKs)[7]), leads directly to less aircraft movements (if the load factor is kept constant) and hence to reduced GHG emission.

2. A shift to transport modes with lower GHG intensity than aircraft will reduce the emissions per amount of transport work performed, and can reduce the overall GHG emission (if the transport work and the load factors are kept constant). An example is a switch of passengers

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[6] A revenue freight tonne kilometre is a term describing when one tonne of revenue freight is transported one kilometre.

[7] A passenger kilometre is a term describing when a passenger is transported one kilometre. The term “revenue passenger kilometres” refers to the distance travelled by revenue passengers. For some airlines only passengers that have paid a certain percentage of the normal fare are counted as revenue passengers. Examples of non-revenue passengers are the pilots and crew onboard as well as other passengers travelling for free.

or goods from aircraft to railway, the latter being generally less GHG intensive than aircraft [Roos et. al. 1997] [IPCC 1996e and 1999].

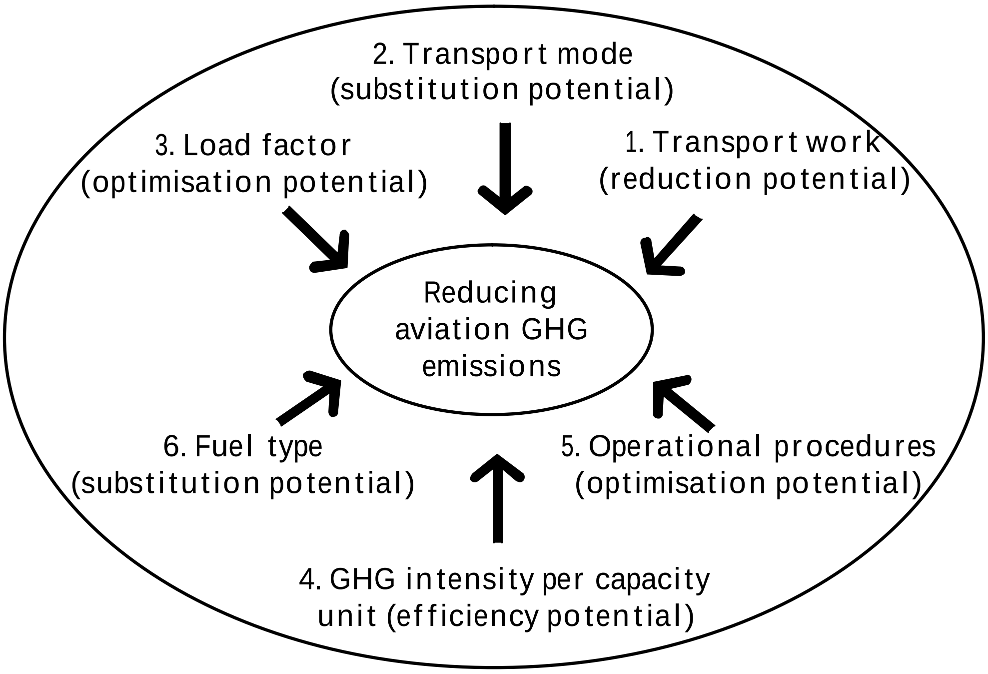

Figure 6:Examples of options for reducing greenhouse gas (GHG) emissions from commercial civil air transport. Source: [Nielsen 2001].

3. Increasing the load factor (the passenger load factor and the freight load factor) involves better use of the aircraft capacity. This will reduce the necessary vehicle kilometres and hence the GHG emissions per unit of transport work performed [Daggett et. al 1999]. For example, the average passenger load factor of the World's scheduled airlines has been improved from around 50 percent in the early 1970s to around 70 percent in the late 1990s [Mortimer 1994a and 1994b] [ICAO 1998f].

4. A reduction of the energy intensity per seat or per freight capacity unit of aircraft directly reduces the emissions of CO_2 (if the transport work, the fuel type and the load factor are kept constant). This involves the development of more fuel-efficient types of aircraft. Examples are the development of more fuel-efficient engine types [IPCC 1999] [Birch 2000] [ACARE 2002] or new fuselage shapes offering larger capacity per weight unit or lower air resistance [Cranfield College of Aeronautics 2000a]. However, there is a trade-off between aircraft engine fuel-efficiency improvements and emissions of NOx that act as a greenhouse gas precursor when emitted at high altitudes [IPCC 1999]. A strategy to reduce the greenhouse gas intensity therefore has to take this into account. Another possibility for reducing the greenhouse gas intensity of aircraft may be to design aircraft for cruising at lower speeds and altitude [Barrett 1994] [Dings et. al. 2000b].

5. By improving the operational procedures the flow of air traffic can be optimised, thereby reducing the GHG emissions for a given trip. One example is that stacking and queuing in and above airports could be

reduced leading the aircraft to consume less fuel for take-off and landing [Lufthansa 1999]. Another example is that aircraft could be allowed to fly more direct routings. Many routes are today longer than the shortest great circle distances because of restrictions in the use of airspace[8] [ACARE 2002] and regulations on how far away from airports twin-engine aircraft are allowed to operate when passing over the great oceans [Air International 2000]. A third example is that the choice of routings could be optimised as to avoid flying at altitudes and latitudes where aircraft emissions are considered to contribute most to global warming [Lee 2000]. Such a strategy could for example take into account that the layers in the atmosphere that are considered most sensitive to aircraft emissions are situated at lower altitude near the Poles than at latitudes nearer to the Equator.

6. Choosing a fuel with lower GHG emissions per available energy unit than the fossil jet fuel that is currently being used can reduce the emissions per distance travelled. An example could be a switch from fossil kerosene fuel to jet fuel produced from biomass or to liquid hydrogen produced on the basis of renewable energy sources [Brewer 1991] [Pohl 1995a]. However, there is uncertainty as to whether for example hydrogen is a less GHG intensive fuel than fossil kerosene when combusted at high altitude, primarily because the combustion of hydrogen leads to higher emissions of water vapour than combustion of kerosene [Marquart et. al. 2001].

It should be noted that the theoretical options for reducing the emissions of greenhouse gases from commercial civil air transport described in Figure 6 are to a large extent interdependent, and therefore not fully separable and addable, and furthermore to some extent counteractive. Most of the options exemplified in Figure 6 could be promoted by different types of government incentives and control options, as discussed further in section 5.2.

5.2 Possible government incentives and control options

The commercial civil air transport industry has until now not been subject to international regulations aimed specifically at reducing aircraft greenhouse gas emissions. Rather, standards issued by ICAO set limits for aircraft noise and engine emissions in and near airports [ICAO 1993a and 1998f]. However, the industry may soon be facing new environmental policies that can to some extent contribute to reduce the GHG intensity as well as the growth in passenger air travel. Some of the most commonly suggested policies are listed below:

- Economic means that reduce the demand for passenger air travel and airfreight and/or increase the airlines' incentive to reduce their emissions, i.e. a jet fuel tax, a passenger tax, landing charges, an

[8] One example of an initiative that may bring about improvements in operational procedures and reduction of the distances flown between city-pairs is the European Single Sky initiative.

emission tax[9], environmental charges[10] and/or emission trading schemes[11] for commercial civil air transport.

– Voluntary agreements[12] between governments and the aviation industry, i.e. certain reduction targets to be met by the commercial civil air transport industry such as targets for the future improvement of airlines' average fuel efficiency and targets for aircraft producer's improvement of the fuel-efficiency of next-generation aircraft.

– Regulatory means for improving aircraft technologies and operational procedures, i.e. in-flight emission standards for new aircraft, speed limits, performance standard incentives[13], "old for new" aircraft scrapping schemes[14] and/or banning operation with the oldest aircraft[15] and implementation of new technologies for improving the flow of traffic and optimising flight routings (such as for example satellite based navigation).

– Regulatory means for reducing the demand for commercial civil air transport, i.e. personal passenger air travel emission quotas limiting individual mobility patterns as well as promotion of railway infrastructure and restrictions to expanding airport capacity[16].

– Cancelling direct and indirect subsidies for the commercial civil air transport sector. That is, direct subsidies for producers of aircraft and engines and for airlines and airports as well as indirect subsidies such

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[9] See for instance Bleijenberg et. al. [1998] for a discussion of the environmental effects of taxes on tickets, landings and emissions.

[10] See for instance Wit et. Al [2002] for a discussion on environmental charges.

[11] E.g. the possibility for the commercial civil air transport industry to trade emission quotas either in a "closed" system within the industry or in an "open" system including trade with other industries. See for instance Wickrama [2001], [Pulles 2000] and Hewitt and Foley [2000] for a discussion of how an emission trading system could function and what the possible effects may be for commercial civil air transport.

[12] A voluntary agreement on average aircraft fuel-efficiency may be one part of a solution in line with what has been agreed between the European Community and the car industry [CEC 1997b], see for instance CEC [1999a].

[13] See for instance Wit et. Al. [2002] for a discussion on a revenue neutral scheme where aircraft performing better than a certain "performance standard" receive money while aircraft performing worse than the standard are to pay. The concept could be designed to be revenue neutral so that the sum of payments and revenues equals zero.

[14] "Old for new" scrapping schemes is a measure that has been suggested by representatives of British Airways. The suggestion is to let airframe producers buy back and scrap old fuel intensive aircraft each time they sell a new aircraft. Such a scheme could potentially secure earlier scrapping of old aircraft than what would else happen [Muddle et. al. 2000] [Cooper 2000].

[15] Such bans exist, but are primarily aimed at prohibiting the use of the noisiest aircraft [ICAO 2001d]. So-called Chapter 2 aircraft can be hush-kitted to apply to the Chapter 3 noise standard but in some cases this even increases the fuel intensity [IPCC 1999].

[16] NGOs seem to mainly to focus on three aspects of the need to reduce the expansion of airport capacity namely on reducing the total number of flights and reducing the use of the oldest and most noisy aircraft and on banning night flights [FoE 2000b] [Mulcahy 2001].

as the commercial civil air transport industry's exemption from paying VAT and kerosene tax and its allowance to maintain duty free sales[17].

- Cancelling indirect subsidies to business travellers, i.e. the ability of companies to deduct their travel expenses against taxes and the ability of frequent business fliers to use airmiles earned through frequent flier programmes for private trips.

- Support for research into and development of more environmentally benign aircraft technologies and new improved air traffic management systems.

- Institutional measures, e.g. the necessity of creating new institutions that can promote lifestyle changes or the need of creating a supranational organisation that can implement and police for example global agreements on GHG reductions or economic measures such as a global jet fuel tax.

- Behavioural measures, e.g. information campaigns that aim at enlightening the public on commercial civil air transport's possible impact on climate change as well as on giving information on possibilities for changing lifestyle in more appropriate directions.

- Other policies aimed at changing the driving forces behind transport growth through adapting policies in economics, labour, etc. towards transport patterns in appropriate directions. Some examples could be to aim policies at impeding globalisation or at reducing economic growth rates.

In line with what is suggested by Figure 5 and Figure 6, the implementation of any of these policies may likely slow down the growth in aviation's environmental load. Sections 5.2.1 and 5.2.2 look a bit further into two of the main types of measures often being proposed, namely voluntary agreements and economic measures.

5.2.1 A further look at voluntary measures

As mentioned in section 5.2 voluntary agreements between governments and the aviation industry, i.e. certain reduction targets to be met by the commercial civil air transport industry, are often mentioned as one possible future incentive that could be part of a scheme for reducing emissions of greenhouse gases from aviation. Voluntary agreements could be designed to set out targets for the future improvement of airlines' average fuel efficiency and targets for aircraft producer's improvement of the fuel-efficiency of next-generation aircraft. The latter, an agreement with aircraft producers, would be in line with what has been agreed upon between the European Community and European automobile manufacturers [CEC 1997]. However, this section looks into the first option mentioned, i.e. the possibility of setting up a voluntary scheme with airlines.

[17] See for instance FoE [1998] and Lipinski [2000] for a discussion of the magnitude of government subsidies to commercial civil air transport.

A number of airlines around the World have already voluntarily committed to certain goals for reducing their fuel intensity in the future [IATA 2002] [Nielsen 2001]. For example, Lufthansa's passenger airline aims at reducing the specific fuel consumption per revenue passenger kilometre by 35% in 2012 as compared to 1991. This goal acquires that Lufthansa reduces its specific fuel consumption by around 18 percent between 1999 and 2012 [Lufthansa 2000b]. British Airways has similarly committed to reduce the specific fuel consumption per passenger kilometre by 30% in 2010 as compared to 1990, corresponding a reduction of some 16% as compared to the 1999-level [British Airways 1999a and 1999b]. Furthermore, in 1998, the Scheduled Airlines Association of Japan, that represents ten Japanese airlines, has committed to the target of reducing the emissions of CO_2 per available seat kilometre (ASK) by 10% in 2010 as compared to 1990 [All Nippon Airways 1999, p. 5]. Likewise, the airlines that are members of the International Air Transport Association (IATA) are planning to reduce their specific fuel consumption per RPK by 10% in 2010 as compared to 2000 [Dobbie 2001]. These targets may reflect the magnitude of the fuel efficiency improvements that can be expected due to voluntary measures in the next decade. It should be noted, as also mentioned in Sections 3.4 and 4.2, that these efficiency gains are generally expected by far to be overridden by demand growth.

In Europe, the reduction of the fuel intensity due to the introduction of new aircraft may become relatively modest in the next decade, because many airlines have already recently carried through some major fleet renewal programmes. The current average age of the European aircraft fleet is estimated at 9 years. The European aeronautical industry does not expect to exceed annual reductions in the specific fuel consumption of more than 1.1% per RPK on the average until 2012. Only a part of that reduction is expected due to introduction of new aircraft, while some may come from improved load factors and operating procedures [AEA and AECMA 1999]. In the US, airlines generally operate older fleets, suggesting that, in principle, the potential for improving fuel-efficiency may be higher than in Europe [Nielsen 2001].

As described above, airlines around the World have committed to different voluntary goals for improving their fuel efficiency. However, studies of airline environmental reporting reveal that the goals vary significantly from airline to airline [Nielsen 2001] [IATA 2002]. First of all, airlines have several different ways of measuring fuel efficiency. Some airlines measure their efficiency towards capacity (e.g. available seat kilometres, available freight-tonne kilometres or available tonne-kilometres) whereas others measure efficiency towards productivity (e.g. revenue passenger kilometres, revenue freight-tonne kilometres and revenue tonne kilometres). It is generally acknowledged that these differences in reporting make it difficult to compare the fuel efficiency of different airlines as well as their respective efficiency goals [Nielsen 2001] [IATA 2002]. The problems connected to benchmarking airline fuel efficiency are explained further in sections 9.3 and 9.3.2.

The International Civil Aviation Organisation's (ICAO) Committee for Environmental Protection (CAEP) is currently in the process of studying how a voluntary scheme for reducing the fuel intensity of airlines could be set up [CAEP 2002a]. However, in a status report from its fifth meeting (CAEP5) CAEP acknowledges, "…v*oluntary measures alone could not achieve an ambitious emission reduction target. They would have to be used in conjunction* *with other measures. In addition, these voluntary measures allow industry to enhance its ability to undertake activities related to "capacity building". They are primarily looked at as transitional measures. A key issue is the need to ensure that any such action would be to the advantage of the participants if market-based or other regulatory measures were imposed at a later date"* [CAEP 2001n]. The main reason why voluntary measures are not considered sufficient is that the growth in aviation is expected to override the technical and operational improvements that could be part of a voluntary emission reduction scheme. However, as noted by CAEP in the citation above, if carefully designed, a voluntary scheme could be used to streamline airline environmental reporting, potentially improving the data material that may also have to be available if other market-based measures, such as a kerosene tax or an emissions trading scheme, are implemented at a later date.

5.2.2 A further look at fuel taxation and other economic measures

Several academic studies have been undertaken in recent years to assess the likely impact of jet fuel taxation implemented either at a regional or global scale[18]. These studies investigate to what extent a kerosene tax will raise airfares thereby reducing consumers' access to air transport and changing their preferences towards other modes of consumption and to what extent a jet fuel tax will give the aircraft producers and airlines increased incentive to develop and introduce more fuel-efficient aircraft in the future.

The future demand reduction due to introduction of a jet fuel tax can by its nature not be foreseen. The impact will to a large extent depend on economic growth, rise in real income and improvements in airline productivity reducing real airfares as well as consumer preferences for air travel over other modes of consumption. These determinants therefore have to be forecasted to give a reasonable estimate of the possible effect of a future kerosene tax.

Studies assessing the likely future demand impact of a kerosene tax generally use a methodology based on projecting the future demand growth in a so-called "business as usual" forecast. "Business as usual" forecasts are most often based on assumptions on future economic growth and income rise as well as increasing airline productivity reducing real airfares. Studies furthermore use demand elasticity estimates indicating how consumers might react to the airfare increases. Note that the studies base their projections on statistical analysis of historical time-series data. Different studies use varying assumptions on these key parameters [Nielsen 2001].

As a rule of thumb, most studies conclude that the environmental effectiveness of a kerosene tax will be rather small unless a quite substantial tax rate is applied [Nielsen 2001]. The main reason for this is that studies assume that, in a business as usual scenario, economic growth and income rise will continue at current rates leading to a tripling of global demand for air travel and freight within a twenty-year time period. Some studies even forecast higher growth rates [Barrett 1996] [OECD 1997].

One study suggests, that at a projected future "business as usual" growth rate of 3% in CO_2 emissions from commercial civil air transport, a kerosene tax of

[18] See for example [Barrett, M. 1996], [OECD 1997], [NEI 1997], [CAEP 1997], [Resource Analysis 1998], [Bleijenberg et. al 1998], [Brockhagen and Lienemeyer 1999], [DIW 1999], [Pulles 2000], [Wickrama 2001] and [Olsthoorn 2001].

some 80-130US¢/kg may be needed to stabilise global emissions at current level [Bleijenberg et. al 1998]. Another study calculates that to reduce fuel use by 5% in 2010 as compared to 1990 a tax rate of around 180 US¢/kg might be needed [Pulles 2000b] [Wickrama 2001]. A main explanation for the difference between these two studies is that the first mentioned study has higher expectations for fuel-efficiency improvement, anticipating that so-called propfan engines will be introduced throughout all size categories of the fleet in the future and that lower operating speeds will be deployed. This assumption has been criticised by various sources for not taking adequately into account the costs barriers connected to operating at lower speeds [Dings 2000b, Annex VIII, pp.1-6] and the technological barriers to meeting airworthiness [Wickrama 2001, p. 57]. Thus, the lower estimates given by Bleijenberg et. al [1998] for the level of kerosene tax needed to stabilise the CO_2 emissions from commercial civil air transport (80-130 US¢/kg) may be too low if such radically improved technologies do not emerge. Other studies anticipate that even higher tax levels than the 180 US¢/kg suggested by Wickrama [2001] would be needed to stabilise CO_2 emissions at current level [DIW 1999] [Olsthoorn, X. 2001].

For comparison, EU minimum fuel tax for road diesel fuel is around 30 US¢/kg, but some countries levy higher taxes, up to 87 US¢/kg in the United Kingdom [Nielsen 2001].

As can be seen from Figure 7 jet fuel constitutes a major component in airlines' operating costs. The actual fuel price is fluctuating, following crude oil spot prices. In the period from the early 1970s, before the 1973 oil crisis, and until the second oil price shock in 1979 the real jet fuel price rose by a factor of five. Following the second oil crisis in 1979 the fuel costs peaked at around 30% of the total airline operating costs [Jenkins 1999] and above 50% of the direct operating costs [Dings et. al. 2000b]. Throughout the 1980s the real fuel price plummeted (except for a short peak in 1990 due to the Iraqi war in the Gulf) and fuel costs reached a historical low of 12% of the total airline operating costs in 1998. This left the real kerosene price at 18 US¢ per kilogram, which is comparable to the pre-1973 level when measured in constant 2000$. In 2000, the jet fuel price peaked again above 30 US¢ per kilogram, see Figure 7.

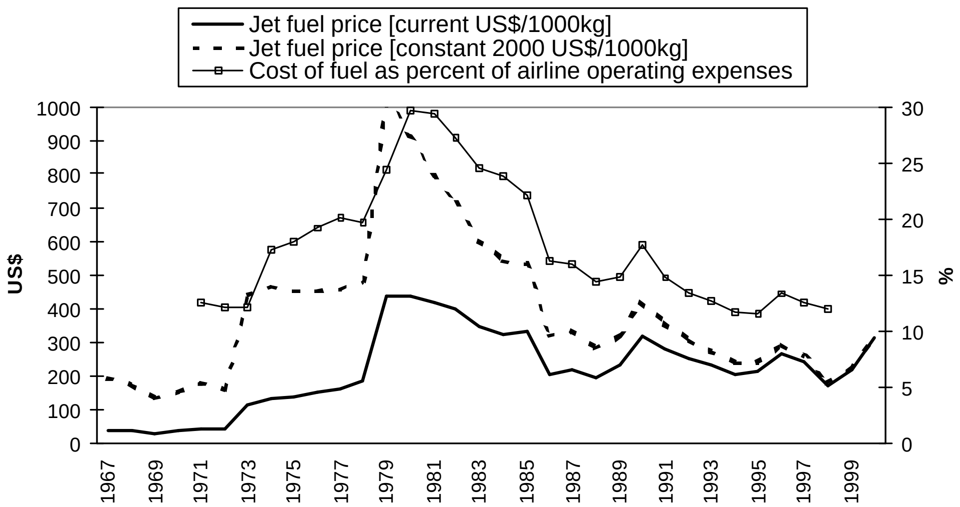

Figure 7: Jet fuel price development 1967-2000 in current and constant 2000$ and jet fuel costs as percent of total airline operating expenses.
Yearly averages have been used except for 2000 using the average for January to August. Current price has been converted into constant 2000 US$ using the US

consumer price index. Data sources: Fuel costs from [Jenkins 1999] except for jet fuel cost data for 1999 and 2000 that are taken from [Air Transport Association 2000a].

Thus, a tax on jet fuel corresponding the EU minimum fuel tax for road diesel (30 US¢/kg) would correspond to a doubling of the jet fuel price in 2000. Similarly, a jet fuel tax of 87 US¢/kg, corresponding the tax on road diesel in the United Kingdom, would roughly quadruple the airlines' fuel costs, again as compared to the fuel price in August 2000. The tax needed to stabilise aviation CO_2 emissions at the current level may be around 180 US¢/kg leading to something like a seven-doubling of the August 2000 fuel price level [Nielsen 2001].

In its assessment of a range of market-based measures CAEP recently concluded that an "open emissions trading scheme" allowing the commercial civil air transport industry to buy emission quotas in other energy consuming sectors would be a better and cheaper solution than for example a tax on emissions or fuel [Wickrama 2001] [CAEP 2000a and 2000b]. This is because it appears that less costly reductions are possible in other sectors (than aviation) because the aviation sector faces higher abatement costs, and hence the potential savings from trading with other sectors would be substantial [Seidel and Rossell 2001].

However, CAEP considers emissions trading a long-term solution because the design of an emissions trading regime would have to be agreed upon before trading can begin. Some of the key issues here are the setting of a cap for aviation emissions and the distribution of emission permits between airlines (i.e. grandfathering, based on past or current use, or auctioning through a bidding process) [Hewitt 2000] and possibly also the allocation of CO_2 emissions to Parties to the Climate Convention.

Another important issue for the design of an emissions trading scheme for aviation is whether the scheme should only consider CO_2 or if emissions of NOx and water vapour at cruise altitude should be included. The last mentioned solution would mean that the aviation industry would have to buy more GHG emission permits than the before mentioned solution. For example, the UK Royal Commission on Environmental Pollution states in a recent report that an aviation emissions trading scheme ought to take into account that the total radiative forcing of aviation is about three times that of the carbon dioxide emitted [Royal Commission on Environmental Pollution 2002]. Yet another important issue raised by the UK Royal Commission on Environmental Pollution is that emissions from international aviation would have to be included in national greenhouse gas inventories of the Parties to the Kyoto Protocol. If this is not the case there is a risk that, if the aviation industry supports for example either renewable energy (such as wind turbines) or energy efficiency (such as energy efficient combined heat and power plants) to offset its own growth in emissions, the resulting emission savings could be double-counted as part of the host nation's commitments and no net emission reduction result.

In Europe, the European Commission has been investigating the possibility of introducing European control options. Some recent studies have been commissioned by the European Commission assessing aspects such as environmental effectiveness, legal feasibility and competition effects of different economic measures such as kerosene taxation [Resource Analysis 1998], performance standard incentives [Wit 2002] and environmental charges [Wit 2002] to be lifted on aircraft operating within European Union airspace. The scale of the economic incentives explored in these studies is generally quite low as compared to the global fuel tax of 180 US¢/kg that may be needed to stabilise global aviation CO_2 emissions. For example, a recent study operates with values of 30 EURO/tonne of CO_2 and 3,6 EURO/kg of NOx to be implemented within European Union airspace. 30 EURO/tonne of CO_2 corresponds 0,095 EURO/kg of jet fuel. In the study such an incentive is expected to reduce European aviation CO_2 emissions by around 9% in 2010 over a business as usual scenario, and around half of the reduction is expected from less demand increase while the other half may appear due to enhanced technical and operational measures implemented by airlines in response to the incentive (as compared to what could otherwise be expected in a business as usual scenario). It should be mentioned that the studies on the possible impact of European control options that are mentioned here do not necessarily reflect the view of the European Commission, and, until now, the European Community has not implemented such measures.

6 Some recent policy developments

The commercial civil air transport sector has until now not been subject to international regulations aimed specifically at reducing greenhouse gas (GHG) emissions from aircraft engines. Rather, standards issued by the International Civil Aviation Organisation (ICAO) set limits for aircraft noise and engine emissions in and near airports throughout the so-called landing and take-off (LTO) cycle [ICAO 1993a and 1998f]. However, some recent developments within the United Nations Framework Convention on Climate Change (UNFCCC), the European Union (EU) and ICAO indicate that aviation GHG emissions may be subject to new regulation in the near future. These recent developments within the UNFCCC, the EU and ICAO are briefly summarised in this chapter.

6.1 UNFCCC developments

Following recent international commitments to reduce global GHG emissions, the aviation sector has come under increasing pressure to reduce energy use and GHGs. In Article 2, Paragraph 2 to the 1997 "*Kyoto Protocol to the United Nations Framework Convention on Climate Change*", it is stated that "*The Parties included in Annex I shall pursue limitation or reduction of emissions of greenhouse gases not controlled by the Montreal Protocol from aviation and marine bunker fuels, working through the International Civil Aviation Organization and the International Maritime Organization, respectively*" [UNFCCC 1997, article 2b]. ICAO has therefore agreed upon a working programme in this area, see section 6.3.

UNFCCC and its Subsidiary Body for Scientific and Technological Advice (SBSTA) have been discussing different possibilities for allocating emissions from international aviation to Parties, but so far no agreement has been reached on this subject. A main problem seems to be that if emissions are allocated to the country where the fuel is sold some Parties that have large sales of fuel for transit passengers will have to bear a larger burden than countries where there are no large hub airports. The basic problem seems to be that an airline registered in one country can carry passengers and freight originating from another country to a third country.

The allocation issue is currently not scheduled for discussion at SBSTA 18. However, United Nations Framework Convention on Climate Change's (UNFCCC) Subsidiary Body for Scientific and Technological Advice (SBSTA) has noted that the quality of reporting by Annex I Parties on bunker fuel emissions needs to be improved. At its 16th session in June 2002 SBSTA "*recalled its invitation, at its fifteenth session, to International Civil Aviation Organization (ICAO) and International Maritime Organisation (IMO), in consultation with the secretariat, to explore opportunities for examining and improving the quality of data reporting and comparability under the relevant provisions of the Convention and the Kyoto Protocol, and under ICAO and IMO. Noting the relevant provisions of the Convention and of the Kyoto Protocol, in particular its Article 2, paragraph 2, it decided to consider the methodological aspects related to the reporting of emissions based upon fuel sold to ships and* *aircraft engaged in international transport at its eighteenth session. It invited ICAO and IMO to report on their activities in this regard at that session"* [UNFCCC 2002a]. Therefore, currently a main priority of UNFCCC seems to be to find ways to improve the quality of reporting by Annex I Parties on bunker fuel emissions, and this subject is currently scheduled for discussion at SBSTA 18 [UNFCCC 2002a].

6.2 EU developments

In recent years, the European Commission has pushed for international agreements for introducing measures to reduce the environmental impact of commercial civil air transport. Most notably, in a December 1999 Communication, *"Air Transport and the Environment - Towards meeting the Challenges of Sustainable Development"*, the European Commission describes a list of measures that might be taken into consideration. The Commission proposes more stringent international standards and rules to reduce aircraft engine emissions and noise and for improving air traffic management efficiency. These should be accompanied by market incentives such as aviation charges, emission trading, voluntary agreements and research and development into new and more efficient aircraft technologies [CEC 1999a]. The main objectives of the Commission's December 1999 Communication were updated and re-iterated in a December 2000 Communication, "*Community objectives for the 33rd Assembly in the International Civil Aviation Organisation (ICAO) and ICAO Council decisions prior to this Assembly in the field of environmental protection"* [CEC 2000d].

Furthermore, in a Communication on "*Taxation of Aircraft Fuel*" issued March 2000, the European Commission states that the European Union member states, in co-operation with the Commission, should intensify their work within the ICAO framework for the introduction of taxation on aviation fuel and other instruments with similar effects on the global level [CEC 2000a]. Besides focusing on a global jet fuel tax, some European countries as well as the European Commission and the European Parliament have been discussing the possibility of introducing a jet fuel tax in Europe. This is also discussed in the above-mentioned Communication. One idea is to allow EU Member States to tax domestic and intra-EU flights [CEC 2000a].

6.3 ICAO developments

In September/October 2001 ICAOs 33rd Assembly adopted resolution A33-7 "*Consolidated statement of continuing ICAO policies and practices related to environmental protection"* The resolution consists of an introductory text and a number of Appendices concerning different aspects relating to the environmental impact of aviation. For example, the resolution introduces a new *"balanced approach"* to noise management and a guidance on *"land-use planning and management*". Of main relevance to this report the resolution also contains a new working programme concerning greenhouse gas emissions aiming at improving the understanding of their impact and of investigating possible means of limitation.

In Appendix H *"Environmental impact of civil aviation on the atmosphere*" to resolution A33-7 the ICAO Assembly Requests the ICAO Council:

a) *"to continue to co-operate closely with the IPCC and other organizations involved in the definition of aviation's contribution to environmental problems in the atmosphere, and with organizations involved in policy-making in this field, notably with the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC);*

b) *to continue to study policy options to limit or reduce the environmental impact of aircraft engine emissions and to develop concrete proposals and provide advice as soon as possible to the Conference of the Parties of the UNFCCC, placing special emphasis on the use of technical solutions while continuing its consideration of market-based measures, and taking into account potential implications for developing as well as developed countries; and*

c) *to promote the use of operational measures as a means of limiting or reducing the environmental impact of aircraft engine emissions [ICAO 2001a]".*

Furthermore, in Appendix I *"Market-based measures regarding aircraft engine emissions"*, to resolution A33-7 the ICAO Assembly

1. *"Requests the (ICAO) Council to develop guidance for States on the application of market-based measures aimed at reducing or limiting the environmental impact of aircraft engine emissions, particularly with respect to mitigating the impact of aviation on climate change; and to develop concrete proposals and provide advice as soon as possible to the Conference of the Parties to the UNFCCC;*

2. *Encourages States and the Council, taking into account the interests of all parties concerned, to evaluate the costs and benefits of the various measures with the goal of addressing aircraft engine emissions in the most cost-effective manner and to adopt actions consistent with the framework outlined below, with States striving to take action in a consistent manner to both domestic and international aviation emissions:*

   a) Voluntary measures

      1. *Encourages short term action by States and other parties involved to limit or reduce international aviation emissions, in particular through voluntary measures; and*

      2. *Urges the Council to facilitate actions by developing guidelines (e.g., for quantifying, monitoring and verifying emission reductions or actions) for such measures, including a template voluntary agreement, as appropriate, and to work to ensure that those taking early action would benefit from such actions and would not subsequently be penalized for so doing;*

   b) Emission-related levies

      1. *Recognizes the continuing validity of Council's Resolution of 9 December 1996 regarding emission-related levies;*

      2. *Urges States to follow the current guidance contained therein;*

3. *Urges States to refrain from unilateral action to introduce emission-related levies inconsistent with the current guidance; and*

4. *Urges the Council to carry out further studies and develop further guidance on the subject;*

c) Emissions trading

1. *Endorses the development of an open emissions trading system for international aviation; and*

2. *Requests the (ICAO) Council to develop as a matter of priority the guidelines for open emissions trading for international aviation focussing on establishing the structural and legal basis for aviation's participation in an open trading system, and including key elements such as reporting, monitoring, and compliance, while providing flexibility to the maximum extent possible consistent with the UNFCCC processs [ICAO 2001a]."*

Thus, ICAOs Committee on Aviation Environmental Protection (CAEP) is investigating these issues further. One of the main findings of CAEPs studies until now is that voluntary measures alone cannot achieve an ambitious emission reduction target, but would have to be used in conjunction with other measures. ICAO is about to publish a circular describing "*Operational opportunities to minimise fuel use and reduce emissions*". Furthermore, CAEP is currently examining a template for a voluntary programme for reducing CO_2 emissions from aviation [CAEP 2002a]. These currently unpublished efforts unfortunately cannot be described further within this report.

Another main finding of CAEPs work until now is that, among the market-based options considered, an open emission trading system would likely be the most efficient and effective measure to meet Kyoto Protocol targets [Pulles 2000b]. On this background CAEP has recently decided upon requesting from a consultant a further investigation of how an emission trading system could work [CAEP 2002a]. At the current time of writing these efforts are at an early stage of the process and therefore unfortunately cannot be described further within this report.

6.4 The position of environmental NGOs and industry

Recently, a network of NGOs around the World formed the International Coalition for Sustainable Aviation (ICSA) that has been granted the role of observer within CAEP. Likewise, the aviation industry, represented by the International Air Transport Association (IATA) and the International Coordinating Council of Aerospace Industries Associations (ICCAIA) has observer status within CAEP. The views of the environmental NGOs and the industry towards the use of market-based measures to reduce the emissions of greenhouse gases from aviation can be seen from Boxes 1 and 2 below.

One main disagreement between the environmental NGOs and the industry is whether the total emissions of CO_2 from the commercial civil air transport sector should be allowed to grow or if they should be reduced in accordance to the goals set up in the Kyoto Protocol, as suggested by the NGOs. The industry seems to prefer voluntary agreements for improving the fuel efficiency and an open CO_2 emission-trading scheme that will allow the industry to buy emission permits in other sectors [IATA/ICCAIA 2001]. The environmental NGOs seem to prefer a tax that considers all types of emissions in all phases of flight. If no agreement can be reached the NGOs furthermore urge the UNFCCC to take over ICAOs obligation to introduce measures that can contribute to reduce emissions from commercial civil air transport [T&E/ICSA 2001]. Note that the statements in Boxes 1 and 2 were made at CAEPs fifth meeting (CAEP 5), before ICAOs 33rd Assembly.

Box 1: The position of the International Coalition for Sustainable Aviation (ICSA) towards market-based options to limit or reduce emissions.

– CAEP has mainly been focusing on possibilities to reduce emissions of CO_2. ICSA therefore suggests that ICAO and CAEP should urgently develop a strategy that addresses all greenhouse gas emissions.

– Voluntary agreements are not considered sufficient to respond to the provisions laid out for commercial civil air transport in the Kyoto Protocol and ICAO is therefore urged not to develop this concept further.

– ICAO is furthermore urged to establish a CO_2 target that is consistent with the Kyoto Protocol and aiming at a reduction of 5% in the period 2008-2012 as compared to 1990 levels.

– ICAO should introduce an emission charge (on both the LTO and the cruise cycle) by its 34th Assembly at the latest. If the charge is not adequate for achieving the 5% reduction target, it should be supplemented by an emission-trading scheme that would begin no later than 2008.

– ICAO should establish a NO_x cruise standard and a market-based mechanism to control all emissions during the cruise phase, including potentially weighing CO_2 emissions to fully reflect the total radiative forcing.

– If no appropriate solutions are decided by at the next ICAO Assembly, COP7 of the UNFCCC should decide on a workplan and immediate implementation plan, by COP8 at the latest.

Source: [T&E/ICSA 2001].

As can be seen from Box 2 the commercial civil air transport industry hopes to avoid taxes, and proposes instead the adoption of voluntary agreements for future emission reductions. Such proposals are brought forward by for example, the Association of European Airlines [AEA 2000b] and the European Association of Aerospace Industries [AEA and AECMA 1999], the British Air Transport Association [British Air Transport Association 2000] and the International Air Transport Association [ATAG 2000] [Dobbie 1999 and 2001] [IATA 2000a, 2000b and 2000c]. Some airlines have similarly adopted future efficiency targets, which are to be met mainly by continually buying new and more efficient aircraft [Lufthansa 1999] [All Nippon Airways 1999].

To sum up, in general the position of the commercial civil air transport industry is that technical measures to mitigate the emissions of greenhouse

Box 2: The position of the International Air Transport Association (IATA) and the International Coordinating Council of Aerospace Industries Associations (ICCAIA) towards market-based options to limit or reduce emissions.

– Compared to environmental charges or taxes the combined use of open emissions trading and voluntary mechanisms is likely to be more conducive to the development of a sustainable commercial civil air transport sector. A CO_2-related charge is likely to be less economically efficient than an open emission trading scheme and the industry would have to carry an unacceptable cost burden and severe demand reductions, for relatively little environmental benefit.

– Emissions trading is likely to provide the most promising and cost-effective option for maximising the contribution of commercial civil air transport to the reduction of global CO_2 emissions. ICAO should therefore investigate further the key issues concerning the design and implementation of an open emissions trading system, such as the reporting of emissions, the establishment and distribution of emissions caps and permits and the monitoring, verification and enforcement of the system.

– Voluntary mechanisms could help to establish the basis for future emission abatement at lower costs than market-based options. IATA member airlines have adopted a fuel efficiency goal that aim at improving the fuel efficiency by 10 percent over the next ten years. This goal could serve as a basis for a voluntary mechanism. IATA is also prepared to agree upon fuel efficiency goals to be delivered from improvements in CNS/ATM systems.

Source: [IATA/ICCAIA 2001]

gases would be preferable from measures that are aimed at reducing demand, and among the market-based measures the industry seems to prefer an open emissions trading system.

7 CO_2 Emissions from international aviation

This chapter is intended to give an overview of CO_2 emissions from domestic and international aviation activities. Section 7.1 describes some international conventions under which the Parties are obliged to report emissions from aviation activities. The convention of main concern for this project is United Nations Framework Convention on Climate Change (UNFCCC) under which emissions from domestic aviation are to be included in national totals whereas emissions from international aviation are not to be included in national totals but should be reported separately. Sections 7.1.2 and 7.1.2.1 describes in brief the main principles of the reporting guidelines for aviation under UNFCCC. Section 7.2 continues by describing the emissions of CO_2 reported by Parties to the UNFCCC. The UNFCCC data are supplemented by data from the International Energy Agency (IEA). The main reasons for also looking at IEA data are that the reporting by Annex I Parties to the UNFCCC of CO_2 emissions from domestic and international aviation is rather incomplete and furthermore that non-Annex I countries have not yet started reporting these emissions. The IEA have collected data on fuel sold for domestic and international aviation for decades and hold such data spanning back to 1971. Section 7.3 describes in brief some of the problems related to the data on emissions from domestic and international aviation reported by Parties to the UNFCCC.

7.1 International conventions and reporting obligations

This section gives a brief summary of the main reporting obligations for emissions from air transport.

7.1.1 UNECE Long Range Transboundary Air Pollution Convention

The Convention on Long Range Transboundary Air Pollution (LRTAP) was adopted in Geneva in 1979 and aims at preventing acid rain and photochemical smog. Several protocols are in force, dealing with different emissions. These Protocols are: The Helsinki Sulphur Protocol (1985), the Sofia NOx Protocol (1988), the Geneva VOC Protocol (1991), the Oslo Sulphur Protocol (1994) and the Aarhus Protocols on Heavy Metal and on Persistent Organic Pollutants (POPs). Parties are required to submit annual national emissions of SO_2, NO_x, NMVOC, CH_4, CO and NH_3 and various heavy metals and POPs to UNECE (United Nations Economic Commission for Europe). Concerning aviation, UNECE request only data for emissions from the Landing and Take Off (LTO) phase of the flight for all other emissions species than CO_2. Only emissions of CO_2 are to be reported for the entire LTO and cruise phase [CORINAIR 2001]. This is different from the reporting requirements of the UNFCCC where Parties should report emissions through all stages of the flight, not only LTO emissions.

7.1.2 United Nations Framework Convention on Climate Change

United Nations Framework Convention on Climate Change aims at stabilising atmospheric greenhouse gas concentrations at a safe level within an acceptable time frame. All Parties to the Convention shall report national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol. Parties are required to report CO_2, CH_4, N_2O, PFCs, HFCs and SF6 and should also provide information on emissions of CO, NOx and NMVOCs and are encouraged to provide information on emissions of SO_2. Concerning aviation, unlike UNECE, UNFCCC requests reporting of emissions for the entire LTO and cruise phase [IPCC 2000].

7.1.2.1 IPCC reporting guidelines

UNFCCC requires Parties to use the *“Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories”* [IPCC 1996b, 1996c, 1996d]. IPCC has developed reporting guidelines that are described in the guidance document "*Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*" [IPCC 2000].

According to the IPCC guidelines, generally national inventories should include greenhouse gas emissions and removals taking place within national (including administered) territories and offshore areas over which the country has jurisdiction. Thus, emissions from domestic air transport are to be included in national inventories. However, emissions based upon fuel sold to aircraft engaged in international transport should not be included in national totals but reported separately under international bunker emissions [IPCC 2000]. The main methodological problem related to this reporting is that national energy statistics often contain inaccurate estimates of the split between fuel sold for domestic and international activities [Velzen 2000] [Olivier 1999].

According to the current IPCC definition, civil aviation includes emissions from all civil commercial use of airplanes (international and domestic) consisting of scheduled and charter traffic for passengers and freight, including air taxiing, as well as general aviation (e.g. agricultural airplanes, private jets or helicopters). IPCC methods can also be used to estimate emissions from military aviation, but these emissions should be reported under the IPCC category ’Other‘. Stationary combustion and ground transport at airports are to be included in other appropriate categories [IPCC 2000].

The IPPC definition of the split between domestic and international flights can be seen from Table 1. These definitions should be applied irrespective of the nationality of the carrier.

The IPCC guidelines note that fuel use data distinguished between domestic and international aviation may be obtained in different ways. What is feasible will depend on national circumstances, but some data sources (e.g. energy statistics or surveys) will give more accurate results than others. The following data sources should be evaluated:

1. Bottom-up data can be obtained from surveys of airline companies for fuel used, or estimates from aircraft movement data and standard tables of fuel consumed or both.

2. Top-down data can be obtained from national energy statistics or surveys of:
   • Airports for data covering the delivery of aviation kerosene and aviation gasoline
   • Fuel suppliers (quantity of aviation fuel delivered)
   • Refineries (production of aviation fuels), to be corrected for import and export
3. Fuel consumption factors for aircraft (fuel used per LTO and per nautical mile cruised) can be used for estimates and may be obtained from the airline companies.

	Domestic	**International**
Depart and arrive in same country	Yes	No
Depart from one country and arrive in another	No	Yes
Depart in one country, stop in the same country without dropping or picking up any passengers or freight, then depart again to arrive in another country	No	Yes
Depart in one country, stop in the same country and drop and pick up passengers or freight, then depart finally arriving in another country	Domestic stage	International stage
Depart in one country, stop in the same country, only pick up more passengers or freight and then depart finally arriving in another country	No	Yes
Departs in one country with a destination in another country, and makes an intermediate stop in the destination country where no passengers or cargo are loaded.	No	Both segments

Table 1: IPCC distinction between domestic and international flights [IPCC 2000]

Aircraft emit carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), as well as carbon monoxide (CO), non-methane volatile organic compounds (NMVOCs), sulfur dioxide (SO_2), particulate matter (PM) and nitrogen oxides (NOx). The IPCC methodology focuses on estimating the direct greenhouse gases CO_2, CH_4 and N_2O.

The IPCC guidelines for calculating aircraft emissions operate with three methods of varying accuracy, detail and complexity (this is in line with the CORINAIR and ANCAT/EMCAL reporting guidelines used by some EU Member States as discussed further in sections 8.1 and 8.2). These methodologies are dubbed Tier 1, Tier 2a and Tier 2b.

The simple Tier 1 method is based on an aggregate figure of fuel consumption for civil aviation multiplied by average emissions factors. For Tier 1 emission inventories only data on fuel consumption are needed. Emissions are estimated on the basis of the quantities of fuel consumed and average emission factors based on fleet average values, based on the assumption that 10% of the fuel is used in the LTO (landing/take off) phase of the flight.

In the Tier 2 methods emissions are separated into emissions below and above 3000 feet (914 m) to harmonise the methodology with other methods (such as the CORINAIR Methodology, see section 8.1). This distinction is made to increase the accuracy of the estimates as emission factors and fuel use factors vary between phases of the flight. In the Tier 2 methods the emission estimates are furthermore based on actual composition of the aircraft fleet and movement data. Tier 2a uses more aggregate aircraft data than Tier 2b, Tier 2a corresponding the CORINAIR Simple Methodology (see section 8.1) while Tier 2b resembles the CORINAIR Detailed Methodology (see section 8.1), but is less detailed in the number of aircraft categories and emission factors. Similar to the CORINAIR and ANCAT/EMCAL guidelines (see sections 8.1 and 8.2) the IPCC guidelines allow Parties to use national approaches if they are well documented and have been peer reviewed. A more detailed description of guidelines for estimating emission inventories is given in section 8.1 describing the CORINAIR guidelines.

7.1.3 Other reporting obligations

The European Community has adopted a monitoring mechanism on CO_2 and other greenhouse gas emissions. Member States shall report to the Commission their national inventory data on emissions and removal by sinks of the six Kyoto Greenhouse gases on an annual basis. Inventories are established in accordance with the methodologies accepted by IPCC and agreed upon by the Conference of Parties [CORINAIR 2001].

7.2 Aviation greenhouse gas emissions

This section gives a brief overview of different data sources for aviation greenhouse gas emissions. Section 7.2.1 presents the data on emissions from domestic and international aviation reported by Annex I Parties to the UNFCCC. Sections 7.2.2 and 7.2.3 presents data that are currently reported to the IEA for Annex 1 and Annex 2 countries using them as a basis for giving an overview of global aviation emissions. Section 7.2.2 describes CO_2 emissions from domestic and international aviation while section 7.2.3 focuses on CO_2 emissions from international aviation. Section 7.2.4 compares the data on CO_2 emissions from international aviation bunkers reported to the IEA and UNFCCC by Annex I countries.

7.2.1 Emissions from domestic and international aviation reported by Annex I Parties to the UNFCCC

This section briefly describes the data reported in 2001 from those Annex I countries that have used the Common Reporting Format (CRF). Appendix K to this report contains the full reporting on emissions of the three greenhouse gases CO_2, CH_4, N_2O, as well as the three indirect greenhouse gases CO, NO_x and NMVOCs and for SO_2 for the years 1990-1999. The data shown in Appendix K are published in a Working Paper that was recently submitted to ICAO by the UNFCCC Secretariat [UNFCCC 2002c]. The UNFCCC Working Paper illustrates that, in the 2001 reporting, of the 32 Annex I Parties, 12 Parties report CO_2 emissions from domestic aviation in all the years from 1990-1999 while 16 Parties report CO_2 emissions from international aviation in all the years from 1990-1999. Fewer Parties report the other emissions species from aviation for the whole period 1990-1999. Thus, currently there seems to be an inadequate geographical coverage of the data reported to the UNFCCC by Annex I Parties.

7.2.2 Global CO2 emissions from domestic and international aviation – IEA data

To give a brief overview of global CO_2 emissions from domestic and international aviation activities we use the statistics provided by the International Energy Agency (IEA). We note that statistics on emissions from international aviation bunkers are known to be relatively weak, especially in the distinction between fuel used for domestic and international purposes [UNFCCC 1999f] [Olivier 1999] [Velzen 2000]. For example, the IEA notes that some countries (in both Annex I and non-Annex I countries) have incorrectly defined international bunkers as fuel used abroad by their own aircraft or have included international bunkers in their national totals [IEA 2001, p. I.4]. Furthermore, the IEA uses another definition of domestic aviation including the military use of aviation fuels, which, under the UNFCCC guidelines, are to be reported under the Source/sink category 1A5, "Other" [IEA 2001, p. I.5]. Furthermore, the IEA data on CO_2 emissions from aviation may be based on other units for calculating emissions from fuels than those used by individual Parties in their reporting to the UNFCCC [IEA 2001, p. I.6]. Therefore, the IEA data shown for emissions from domestic and international aviation in this section should be used with care, especially in comparisons to UNFCCC data.

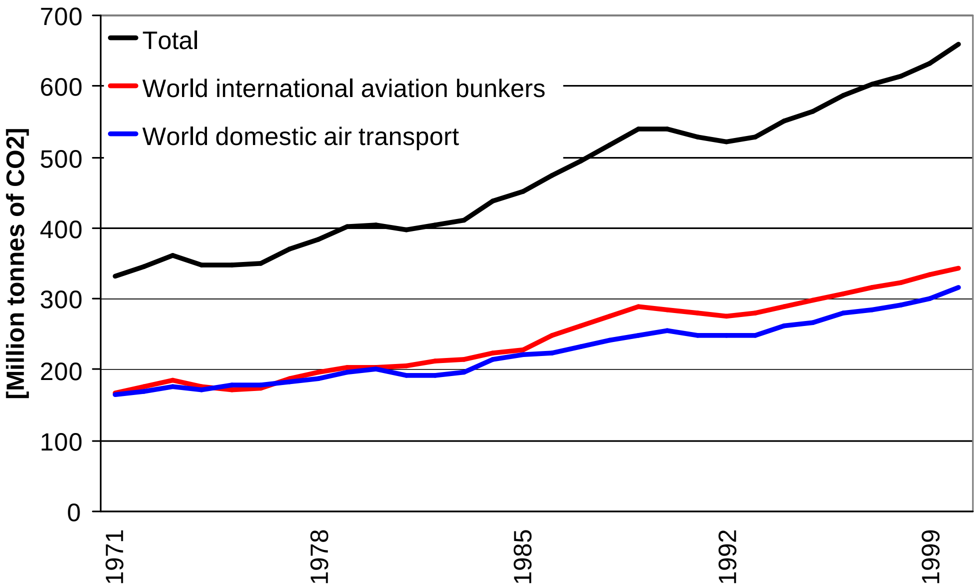

Figure 8: Global CO2 emissions from domestic and international aviation 1971-1999. Source: [IEA 2002].

Figure 8 illustrates the growth in global emissions of CO_2 from domestic and international aviation based on data reported by countries to the IEA. According to these data aviation emitted around 635 million tonnes of CO_2 in 1999, corresponding about 3% of the 22.148 million tonnes of CO_2 emitted from fuel combustion globally in 1999 [IEA 2001]. In 1999, domestic aviation emit around 300 million tonnes while international aviation emit around 335 million tonnes. In the period between 1971 and 2000 global CO_2 emissions from aviation activities approximately doubled thereby growing faster than the total emissions of CO_2 from fuel combustion that grew by 50% in the period [IEA 2002].

Figure 9 illustrates that the top 20 emitters of CO_2 represent around 82% of the CO_2 emissions from domestic and international aviation activities. The United States alone represents 39% of CO_2 emissions and is by far the biggest consumer.

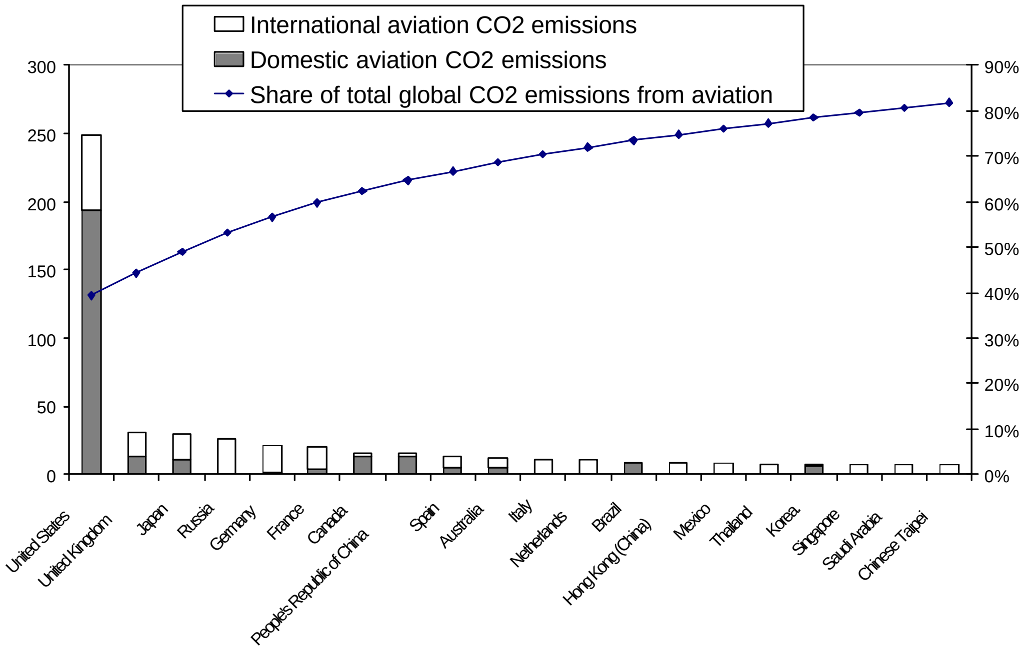

Figure 9: Top 20 emitters of CO2 emissions from domestic and international aviation 1999. Source: [IEA 2002].

Figure 10 illustrates the top 20 per capita emitters of CO_2 from domestic and international aviation activities. In terms of CO_2 per capita a range of smaller countries are major sellers of aviation fuel.

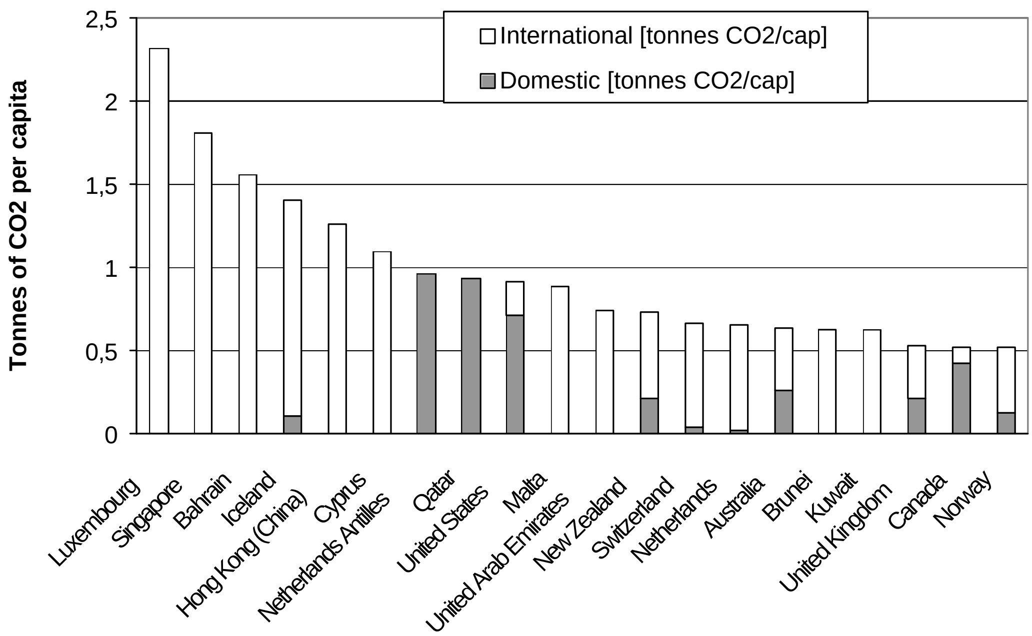

Figure 10: Top 20 per capita emitters of CO2 from domestic and international aviation 1999. Source: [IEA 2002].

It should be noted that the IEA data described in this section merely illustrates where the fuel used for domestic and international aviation is sold. The data do not show which nationalities are using the aviation services. Because of the truly international nature of aviation, airlines registered in one country can lift fuel from another country while transporting passengers and freight originating from a third country.

7.2.3 CO_2 emissions from international aviation bunkers for Annex I and Annex II countries – IEA data

Figure 11 plots data for the emissions of CO_2 from international aviation bunkers in 1971 and 1999 as collected by the IEA. Figure 11 suggests that CO_2 emissions from fuel sold for international aviation activities have doubled in the period. In 1971 non-OECD countries reported the main part of the CO_2 emissions from international aviation bunkers, whereas in 1999 the OECD countries represent the major part. Furthermore, as it is explained in the later chapter that discusses the allocation issue, the major share of the fuel sold for international air transport in non-OECD countries may most likely be attributable to passenger air travel performed by people living in OECD countries. Thus, Figure 11 merely illustrates where the fuel used for international aviation is sold, it does not show which nationalities that uses these services.

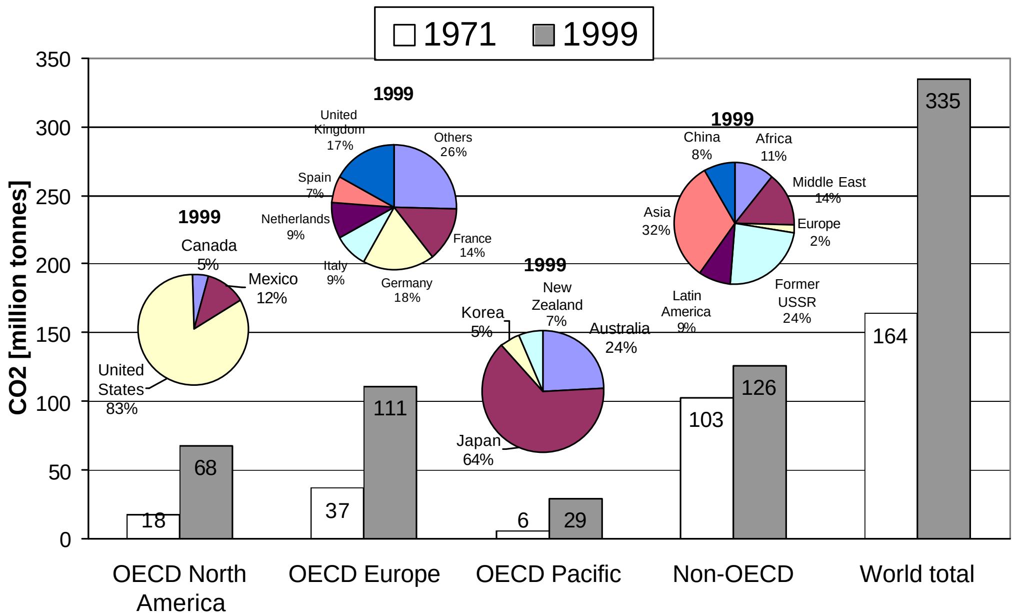

Figure 11: IEA data on CO_2 emissions from international aviation bunkers 1971 and 1999. Source: [IEA 2001].

Statistics on emissions from international aviation bunkers are known to be relatively weak, especially in the distinction between fuel used for domestic and international purposes [Velzen 1999]. Therefore, the data shown for emissions from international aviation bunkers in this section should be used with care.

In 1999, according to the IEA statistics, the global emissions of CO_2 from fuel combustion add up to around 22.148 million tonnes excluding emissions from international aviation and marine bunkers. Emissions of CO_2 from international aviation bunkers equal 335 million tonnes and international marine bunkers equal 423 million tonnes, or about 1,5% and 1,9% of the total respectively.

Note that the figures discussed in this section do not include CO_2 emissions from fuel consumed for domestic aviation. In some of the large industrialised

OECD countries rather large shares of the jet fuel is sold for domestic purposes (see Table 17, Appendix G) and the related CO_2 emissions are thereby already included in national reduction targets for greenhouse gases under the Climate Convention. Some examples of countries in which domestic air transport represents a rather significant share of the total air transport activities are summarised in Table 3 (in section 7.2.4).

Note also, that little less than one third of the CO_2 emissions from international aviation bunkers in 1999 relate to fuel sold in non-annex I countries that have not yet agreed to emission reduction targets under the Climate Convention. Furthermore, Annex I Parties that have not yet decided upon rectifying the Kyoto Protocol represent a rather significant share of the jet fuel sold (for domestic and international purposes) in Annex I countries[19].

Figure 12 illustrates that around 80% of the total CO_2 emissions from international aviation bunkers are emitted by the 25 countries that have the largest sales of jet kerosene for international purposes. The United States is by far the biggest consumer.

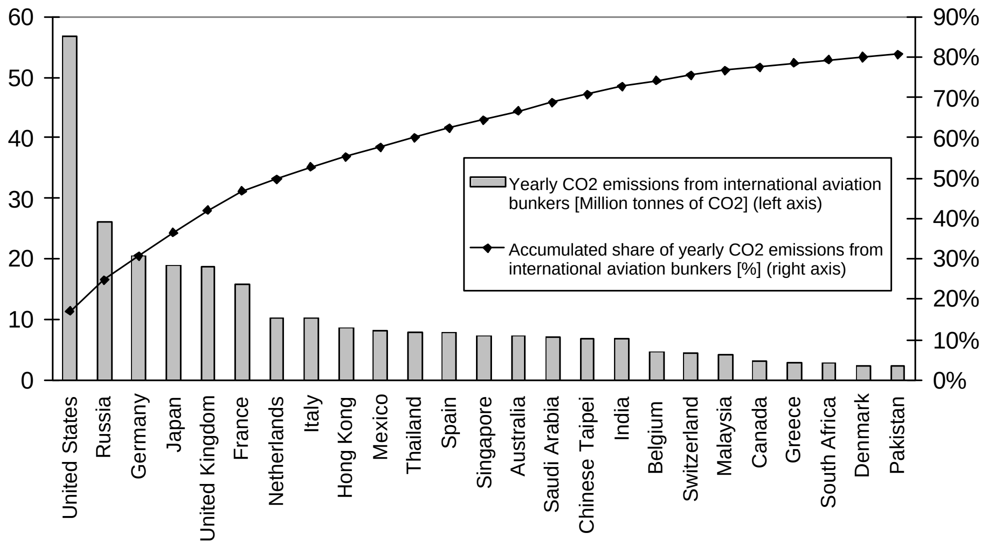

Figure 12: Top-25 consumers of international aviation bunkers. Source: [IEA 2001].

[19] The rules for entry into force of the Kyoto Protocol require 55 Parties to the Convention to ratify (or approve, accept, or accede to) the Protocol, including Annex I Parties accounting for 55% of that group’s carbon dioxide emissions in 1990. At the current time of writing 97 Parties have ratified, among those 26 Annex I Parties and 71 non-Annex I Parties. The 26 Annex I Parties that have ratified represent in total 37,4% of the total emissions from Annex I countries.

While Figure 12 illustrates the biggest consumers of jet fuel for international aviation activities, Figure 13 illustrate the top-25 consumers per capita. Again, as also noted in section 7.2.1, dealing with both domestic and international aviation, some relatively small countries have relatively high per capita sales of jet fuel.

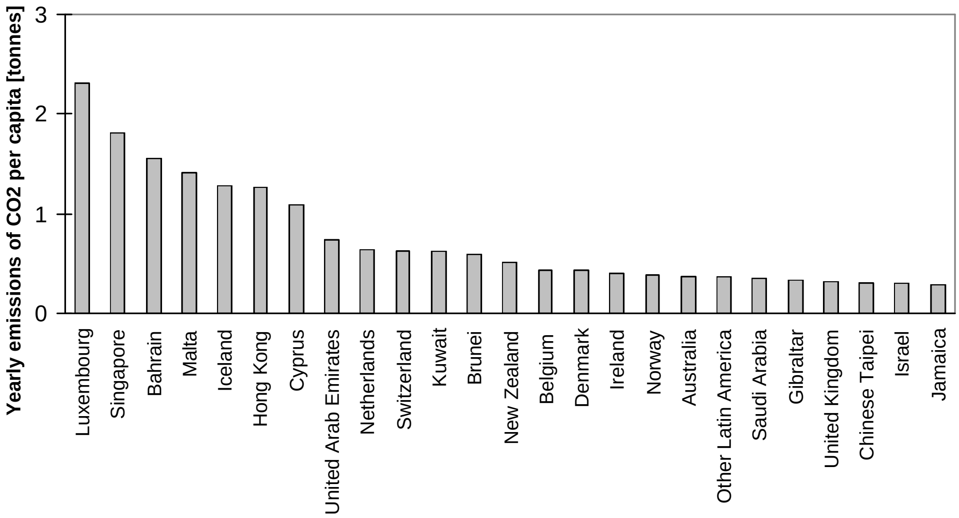

Figure 13: Top-25 consumers of international aviation bunkers per capita. Source: [IEA 2001].

Figure 14 illustrates the 25 countries where CO_2 emissions from international bunkers constitute the highest shares of national emissions of CO_2.

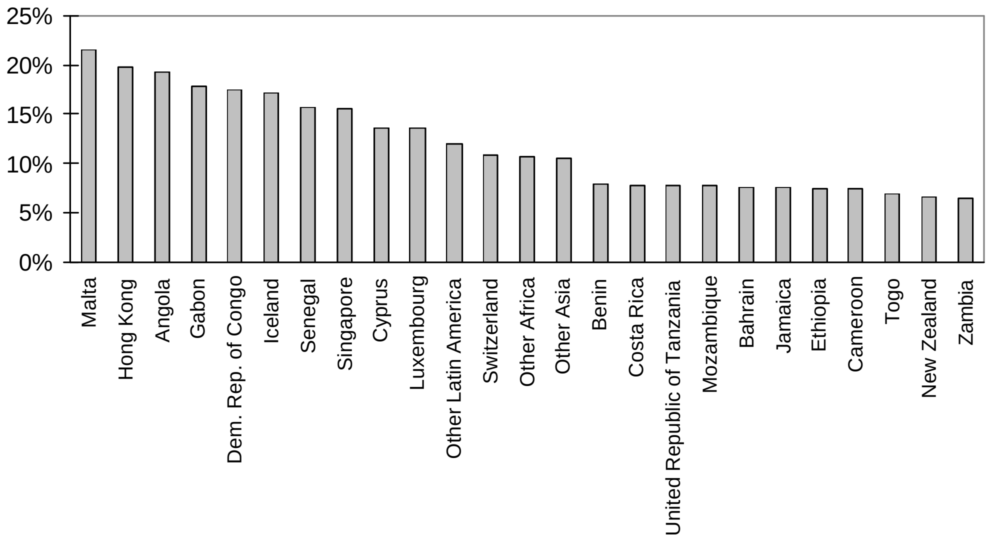

Figure 14: The 25 Parties where international aviation bunkers constitute the largest share of total national CO2 emissions. Source: [IEA 2001].

It should be noted that such a comparison is to some extent biased by the fact that national CO_2 emissions does not only depend on the use of energy services within a country, but also on the fuel intensity, that is for example the amount of fuel consumed per vehicle kilometre driven, and the types of primary energy used in each country’s energy production system (countries that utilize CO_2 neutral energy sources such as hydro and wind or nuclear have lower CO_2 emissions per energy unit produced than countries using primarily fossil fuels). The differences between the rankings in Figure 13 and

Figure 14 can thus be explained by differences between countries in the CO_2-intensity (fuel mix).

Figure 15 illustrates the significance of CO_2 emissions from international aviation bunkers for Annex I countries. The figure basically illustrates the same elements as those shown in Figure 13 and Figure 14, but this time only for Annex I countries. It goes beyond the scope of this report to describe in more detail the differences in activity, energy intensity and fuel mix that are underlying factors behind the figure. The data shown can however be used to exemplify the how different Annnex I countries could be affected if emissions of CO_2 from international aviation were to be allocated to Parties according to where the fuel is sold. We note that other allocation options are also possible that could involve other ways of distributing emissions between countries. This is discussed further in chapter 10.

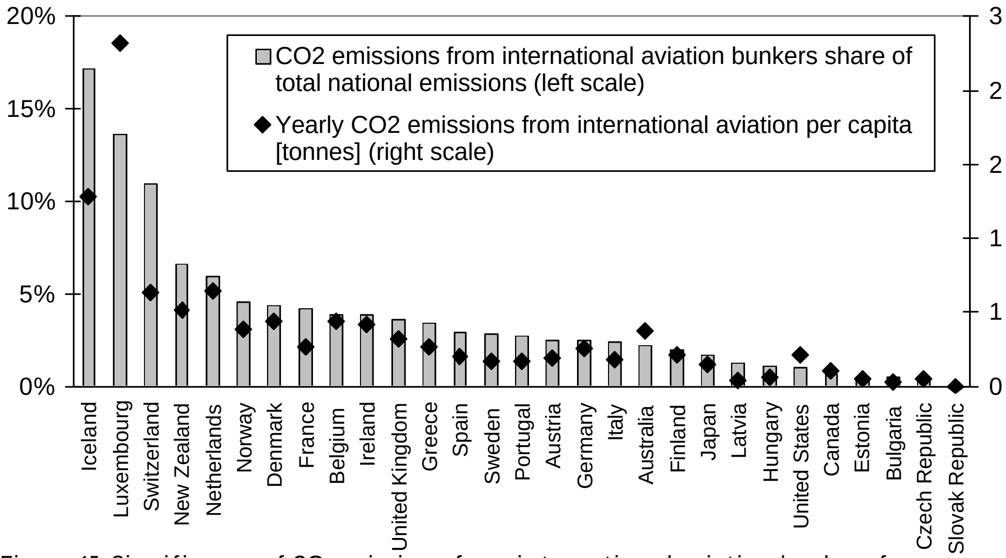

Figure 15: Significance of CO_2 emissions from international aviation bunkers for Annex I countries. Source: [IEA 2001].

7.2.4 Comparison of international aviation bunker emission statistics from IEA and UNFCCC – Annex I countries

This section continues by comparing the IEA data discussed in sections 7.2.2 and 7.2.3 to data reported by Parties to the UNFCCC.

A recent synthesis and assessment report from the UNFCCC describing the greenhouse gas inventories submitted by Annex 1 countries in 2001 contains a section wherein the data on aviation fuel consumption submitted to the UNFCCC are compared to similar data submitted to the International Energy Agency (IEA). This comparison shows that there is rather good agreement between the overall figures for total aviation fuel consumption but that for some Parties there are major discrepancies in the way the split between domestic and international uses are reported to the UNFCCC and the IEA [UNFCCC 2002b], see Table 17, Appendix G. Table 2 shows the deviation between data from the UNFCCC and the IEA for CO_2 emissions from international aviation bunkers for Annex I countries. As can be seen, for some countries there are quite big variations up to above 50%.

	IEA	UNFCCC	Deviation
Australia	7,15	7,268	2%
Austria	1,54	1,615	5%
Belgium	4,53	4,364	-4%
Bulgaria	0,21	0,319	52%
Canada	3,09	3,032	-2%
Czech Republic	0,53	0,539	2%
Denmark	2,33	2,314	-1%
Estonia	0,07		
Finland	1,09	1,058	-3%
France	15,78	13,753	-13%
Germany	20,49	16,656	-19%
Greece	2,85	2,266	-20%
Hungary	0,64	0,596	-7%
Iceland	0,36	0,363	1%
Ireland	1,54	1,624	5%
Italy	10,06	7,468	-26%
Japan	18,86	18,519	-2%
Latvia	0,09		
Luxembourg	1,02	1,019	0%
Netherlands	10,13	10,066	-1%
New Zealand	1,96	1,959	0%
Norway	1,74	0,975	-44%
Portugal	1,64	0,874	-47%
Slovak Republic			
Spain	7,75	7,746	0%
Sweden	1,47	2,103	43%
Switzerland	4,49	4,52	1%
United Kingdom	18,76	25,593	36%
United States	56,83	60,97	7%

Table 2: Comparison of data from IEA and UNFCCC for international aviation bunkers. See Table 17, Appendix G for more information on differences between UNFCCC and IEA data. Sources: [UNFCCC 2002b] and [IEA 2001].

Table 3 shows the deviation between data reported by Parties to the UNFCCC and the IEA for shares of fuel sold for domestic aviation in selected countries. Table 3 suggests that these large countries use significant shares of their total aviation fuel consumption for domestic purposes. The United States alone generate somewhere between 154-198 million tonnes of CO_2 from domestic aviation alone. For comparison, this corresponds to about 50% of the total emissions from international aviation bunkers globally. It should be noted that some of the difference between the shares of fuel sold for domestic and international aviation shown in Table 3 may be attributable to the before mentioned fact that the UNFCCC guidelines requires that Parties report fuel consumption for military aviation under the Source/sink category 1A5, “Other” while this is included under domestic aviation under IEA reporting guidelines [IEA 2001].

	UNFCCC	IEA
Australia	36%	41%
Canada	81%	81%
France	31%	21%
Japan		37%
United States	71%	77%

Table 3: Shares of fuel sold for domestic aviation, selected countries. Source: [UNFCCC 2002b, p. 50]. See Table 17, Appendix G for more countries.

7.3 Discussion on statistics on fuel consumption and emissions

A few studies have been conducted aimed at describing the methods used to collect data and estimate and report emissions from aviation bunker fuels[20]. These studies report that aviation emissions are complicated to estimate because the statistical basis is relatively weak. Especially the distinction between fuel used for domestic and international purposes is difficult [IEA 2001] [Velzen 1999] [UNFCCC 1999b and 1999f]. Another problem is the separation of fuel consumed by military aircraft from fuel consumed by civil aircraft. According to the UNFCCC guidelines Parties should report fuel consumption for military aviation under the Source/sink category 1A5, "Other" while this is included under domestic aviation under IEA reporting guidelines [IEA 2001].

Of the 32 Annex I Parties, 12 Parties report CO_2 emissions from domestic aviation in all the years from 1990-1999 while 16 Parties report CO_2 emissions from international aviation in all the years from 1990-1999. Fewer Parties report the other emissions species from aviation for the whole period 1990-1999 [UNFCCC 2002c]. Thus, currently there seems to be an inadequate geographical coverage of the data reported to the UNFCCC by Annex I Parties.

The UNFCCC Secretariat has requested CAEP to explore opportunities to examine and improve the quality of data reporting and comparability of aviation bunker fuel data [UNFCCC 2002a]. CAEPs Steering Group Meeting in September 2002 agreed that the ICAO Secretariat should take the necessary steps to organize a "scoping meeting", involving the UNFCCC Secretariat, the rapporteurs of some of CAEPs working groups and experts on emissions inventory and data reporting [CAEP 2002a]. This initiative may bring new insights of relevance to this report, but the deadline of work lies beyond the deadline of this report, and the initiative is therefore not described further here.

Eurostat and the International Energy Agency are preparing a joint manual on annual energy statistics to help Member States' statistical authorities in filling in the energy statistics questionnaires. Eurostat also organises training workshops for officials from these authorities to discuss problems in data collection and.

In a recent ECAC initiative European countries that participate in ECAC are encouraged to begin using the Detailed Corinair Methodology for calculating aircraft emissions (see section 8.2). This may improve the ability of European countries to separate better emissions for international air transport from emissions for domestic air transport.

Another recent European initiative has been launched in a co-operation between the European Environment Agency, Eurocontrol and Eurostat to improve the data availability involving the use of a database supplied by Eurocontrol on actual flights performed in Europe and the use of the detailed Corinair emission calculation methodology. This effort may offer the opportunity to compare the data reported by European countries to the data calculated by EEA, Eurocontrol and Eurostat (see section 8.3). At the time of writing this report the final results of the work has not been published.

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[20] See for instance [Olivier 1999], [UNFCCC 1999f] and [UNFCCC 2000b].

Eurostat finances specific projects in the Member States which aim to eliminate differences in energy data reported to Eurostat and those used for the calculation of CO_2 emissions reported to the UNFCCC). This work will also improve reporting of marine and aviation bunker fuels. The projects will examinine the energy data used in the two submissions for the years 1990, 1995 and 2000, identifying and explaining the differences. The projects furthermore aim at establishing a procedure at national level that will eliminate diversions of the two reporting mechanisms in the future and also aim at providing the updated energy data in the form of annual questionnaires for the period 1990-2000, ensuring comparable data under the two reporting mechanisms.

Besides the need to improve the methodologies for separating emissions from international aviation from emissions from domestic aviation there is another related question that is applicable to the reporting of aviation emissions in the European Union: Since the European Union has ratified the Kyoto Protocol the question arises whether the EU inventory should merely represent the sum of national inventories or if international intra-EU flights should be regarded as “domestic” in the EU inventory. If it is decided that the EU inventory should include international intra-EU flights as domestic these emissions have to be separated from the emissions reported as international by EU Member States. The emission calculation work currently under way in the co-operation between the European Environment Agency, Eurostat and Eurocontrol may be used to produce the data needed for that process (see section 8.3 for further details).

Another problem that may remain in Europe is whether countries that have overseas territories should include flights to these areas in their national inventories or if these emissions should be reported as domestic emissions. Table 4 gives an overview of the territories in question. According to the IPCC/UNFCCC reporting guidelines, administered territories should be included in national inventories, but for many countries they are not at present.

	Overseas territories	
Member State	**EU**	**Non-EU**
Belgium		
Denmark		Greenland, Faroe Islands
Germany		
Greece		
Spain	Balearics, Ceuta and Melilla	Canary Islands
France	Corsica, French Guiana, Guadeloupe,Martinique, Réunion	French Polynesia, French Southern Territories, Mayotte, New Caledonia, Saint Pierre and Miquelon, Wallis and Futuna
Ireland		
Italy	Elba, Sardinia, Sicily	Campione d'Italia
Luxembourg		
Netherlands		Netherlands Antilles and Aruba
Austria		
Portugal	Azores, Madeira	Cape Verde
Finland	Åland Islands	
Sweden	Gotland, Öland	
Great Britain and Northern Ireland		Anguilla, Antartica, Ascension Island, Bermuda, British Indian Ocean Territory, British Virgin Islands, Cayman Islands, Channel Islands, Falkland Islands, Gibraltar, Isle of Mann, Montserrat, Montserrat, Pitcairn, Saint Helena, South Georgia and South Sandwich Islands, Tristan da Cunha, Turks and Caicos Islands

Table 4: Overview over EU Member States’ overseas territories. Source: [Lock 2002]

8 Aircraft emission inventories and reporting guidelines

This chapter gives a brief summary of some main methodologies for calculating emissions from air transport, focusing mainly on the European CORINAIR methodology.

8.1 EMEP/CORINAIR reporting guidelines

One example of a detailed programme for calculating emissions from aircraft is contained in the so-called CORINAIR (Core Inventory of Air Emissions in Europe) that has been developed under EMEP (Co-operative Programme for Monitoring and Evaluation of the Long Range Transmission of Air Pollutants in Europe) to support countries participating in the European-wide emission inventory programme EMEP/CORINAIR.

The CORINAIR methodology is continually being refined and updated and the current version is published in the "third Edition Emission Inventory Guidebook", published electronically via the European Environment Agency Internet web site. A further revision of the Guidebook is anticipated in late 2002 [CORINAIR 2001].

Until recently the CORINAIR methodology for calculating aircraft emissions contained only guidelines for calculating fairly detailed landing and take off (LTO) and more rough cruise emission estimates [Winther 2001]. In the later years the CORINAIR system has been updated. The main improvements are the inclusion of more aircraft types and fuel use and emission data per distance flown for those aircraft (see Table 6 and Figure 16) [CORINAIR 2001]. A recent Danish report exemplifies that the detailed CORINAIR methodology can produce markedly other results than the old methodology. For Denmark, the use of the detailed CORINAIR methodology has, among other things, doubled the national estimate for fuel consumption for domestic aviation [Winther 2001].

Within different countries, there may be large differences in the resources and data availability as well as the relative importance of aircraft emissions. Therefore, within CORINAIR, three methodologies, the Very Simple Methodology, the Simple Methodology and the Detailed Methodology, have been developed for calculating emissions from air traffic. Furthermore, some Member States use national models that may be more detailed than the CORINAIR Detailed Methodology, using additional detailed data such as specific engines and specific LTO operating times.

		LTO	Cruise and climb
Very Simple	Activity	LTO aggregated Time-in-mode (ICAO)	Fuel residual
	Emission factor	Generic aircraft	Generic aircraft
Simple	Activity	LTO per aircraft type (generic aircraft) Time-in-mode (ICAO)	Fuel residual
	Emission factor	Per aircraft type	One generic aircraft
Detailed	Activity	LTO per aircraft type (generic aircraft) (option also engine type) Time-in-mode: Actual if available otherwise ICAO	Distances flown Independent estimate of cruise fuel use
	Emission factor	Per aircraft type (generic aircraft) (option also engine type)	Per aircraft type (generic aircraft) and distance flown

Table 5: Overview of CORINAIR methodologies [Corinair 2001]

The difference between the methodologies lies mainly in the aggregation level assumed for the number of aircraft types in the aircraft fleet. In the Very Simple Methodology, estimations are made without considering the actual aircraft types used. The Simple Methodology requires information on the types of aircraft that operate in the country. The Detailed Methodology takes into account cruise emissions for different flight distances.

The three methodologies require different types of data. For the Very Simple Methodology only the total quantity of fuel consumed for domestic and international flights and the total number of aircraft movements for domestic and international flights is needed. The Very Simple Methodology can be used when the number of aircraft movements is known, but the individual aircraft types and their routes are not. The Simple Methodology may be used when additional data on movements by aircraft types used on domestic and international routes are available, but the precise destinations are not available. The Detailed Methodology may be used when data on individual aircraft movements as well as details of departure and arrival airports of individual aircraft on domestic and international flights are known.

When preparing an emission inventory, using one of the three CORINAIR emission calculation methodologies, grouping of the aircraft fleet into representative aircraft categories is used for the calculations in LTO and cruise. In the Very Simple Methodology only a few representative aircraft are included. The Simple methodology is more detailed using 19 representative aircraft categories for calculating LTO emissions while, like it is the case in the Very Simple methodology, only a few representative aircraft categories are used for calculating fuel used and emissions in cruising mode. In the detailed methodology calculations of fuel used and emissions in both LTO and cruise are modelled through using average data on fuel consumption and specific emissions in the LTO phase as well as the cruise phase, including detailed estimates of the specific fuel consumption in cruising modes of different lengths, for around 30 representative categories of aircraft which are meant to represent the world's civil jet fleet. An example of the type of data on fuel consumption and emissions used in the Detailed CORINAIR methodology is shown in Table 6. Recently additional data on a number of turboprop powered regional aircraft has been added, raising the level of detail further.

	km	232	463	926	1389	1852	2778	3704	4630	5556	6482	7408
Fuel (kg)												
	Flight total	4094	5862	8616	11360	14122	19791	25634	31715	38044	44312	51006
	LTO	2232	2232	2232	2232	2232	2232	2232	2232	2232	2232	2232
	Taxi out	437	437	437	437	437	437	437	437	437	437	437
	Take off	269	269	269	269	269	269	269	269	269	269	269
	Climb out	681	681	681	681	681	681	681	681	681	681	681
	Climb/cruise/descent	1862	3631	6384	9128	11890	17559	23403	29483	35812	42080	48774
	Approach landing	408	408	408	408	408	408	408	408	408	408	408
	Taxi in	437	437	437	437	437	437	437	437	437	437	437
NOx (kg)												
	Flight total	88	130	141	174	206	274	347	425	510	588	678
	LTO	36	36	36	36	36	36	36	36	36	36	36
	Taxi out	2,06	2,06	2,06	2,06	2,06	2,06	2,06	2,06	2,06	2,06	2,06
	Take off	9,24	9,24	9,24	9,24	9,24	9,24	9,24	9,24	9,24	9,24	9,24
	Climb out	18,46	18,46	18,46	18,46	18,46	18,46	18,46	18,46	18,46	18,46	18,46
	Climb/cruise/descent	52	93	105	137	170	238	310	389	473	551	642
	Approach landing	4,31	4,31	4,31	4,31	4,31	4,31	4,31	4,31	4,31	4,31	4,31
	Taxi in	2,06	2,06	2,06	2,06	2,06	2,06	2,06	2,06	2,06	2,06	2,06
EINOx (g/kg fuel)												
	Taxi out	4,71	4,71	4,71	4,71	4,71	4,71	4,71	4,71	4,71	4,71	4,71
	Take off	34,38	34,38	34,38	34,38	34,38	34,38	34,38	34,38	34,38	34,38	34,38
	Climb out	27,1	27,1	27,1	27,1	27,1	27,1	27,1	27,1	27,1	27,1	27,1
	Climb/cruise/descent	28,0	25,7	16,5	15,0	14,3	13,6	13,3	13,2	13,2	13,1	13,2
	Approach landing	10,56	10,56	10,56	10,56	10,56	10,56	10,56	10,56	10,56	10,56	10,56
	Taxi in	4,71	4,71	4,71	4,71	4,71	4,71	4,71	4,71	4,71	4,71	4,71
HC (g)												
	Flight total	4119	6079	8755	11336	13932	19263	24756	30473	36422	42274	48567
	LTO	2113	2113	2113	2113	2113	2113	2113	2113	2113	2113	2113
	Taxi out	987	987	987	987	987	987	987	987	987	987	987
	Take off	13,17	13,17	13,17	13,17	13,17	13,17	13,17	13,17	13,17	13,17	13,17
	Climb out	40,73	40,73	40,73	40,73	40,73	40,73	40,73	40,73	40,73	40,73	40,73
	Climb/cruise/descent	2006	3966	6642	9223	11819	17150	22642	28360	34309	40161	46454
	Approach landing	85,3	85,3	85,3	85,3	85,3	85,3	85,3	85,3	85,3	85,3	85,3
	Taxi in	986,7	986,7	986,7	986,7	986,7	986,7	986,7	986,7	986,7	986,7	986,7
EIHC (g/kg fuel)												
	Taxi out	2,26	2,26	2,26	2,26	2,26	2,26	2,26	2,26	2,26	2,26	2,26
	Take off	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05
	Climb out	0,06	0,06	0,06	0,06	0,06	0,06	0,06	0,06	0,06	0,06	0,06
	Climb/cruise/descent	1,08	1,09	1,04	1,01	0,99	0,98	0,97	0,96	0,96	0,95	0,95
	Approach landing	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21
	Taxi in	2,26	2,26	2,26	2,26	2,26	2,26	2,26	2,26	2,26	2,26	2,26
CO (g)												
	Flight total	25554	29744	33730	37113	40516	47511	54705	62206	70004	77417	85664
	LTO	21500	21500	21500	21500	21500	21500	21500	21500	21500	21500	21500
	Taxi out	1088	1088	1088	1088	1088	1088	1088	1088	1088	1088	1088
	Take off	107	107	107	107	107	107	107	107	107	107	107
	Climb out	279	279	279	279	279	279	279	279	279	279	279
	Climb/cruise/descent	4054	8244	12230	15613	19016	26011	33205	40706	48504	55917	64164
	Approach landing	938	938	938	938	938	938	938	938	938	938	938
	Taxi in	10088	10088	10088	10088	10088	10088	10088	10088	10088	10088	10088
EICO (g/kg fuel)												
	Taxi out	23,1	23,1	23,1	23,1	23,1	23,1	23,1	23,1	23,1	23,1	23,1
	Take off	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4
	Climb out	0,41	0,41	0,41	0,41	0,41	0,41	0,41	0,41	0,41	0,41	0,41
	Climb/cruise/descent	2,18	2,27	1,92	1,71	1,6	1,48	1,42	1,38	1,35	1,33	1,32
	Approach landing	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3
	Taxi in	23,1	23,1	23,1	23,1	23,1	23,1	23,1	23,1	23,1	23,1	23,1

Table 6: Example of fuel and emission data for Airbus A330 aircraft used CORINAIR Detailed methodology [Corinair 2001].

As illustrated in Table 6, the data used in the Corinair detailed methodology takes into account that the specific amount of emissions of gases from aircraft engines per amount of fuel burnt vary between phases of flight. The methodology also takes into account that the specific fuel burn per kilometre of aircraft depends strongly on the flight distance. As can be seen from Figure 16 the fuel burn per aircraft kilometre is comparably higher on relatively short distances than on longer routes. This is because the aircraft uses a relatively high amount of fuel per kilometre for the landing and take off (LTO) cycle as compared to the cruising phase.

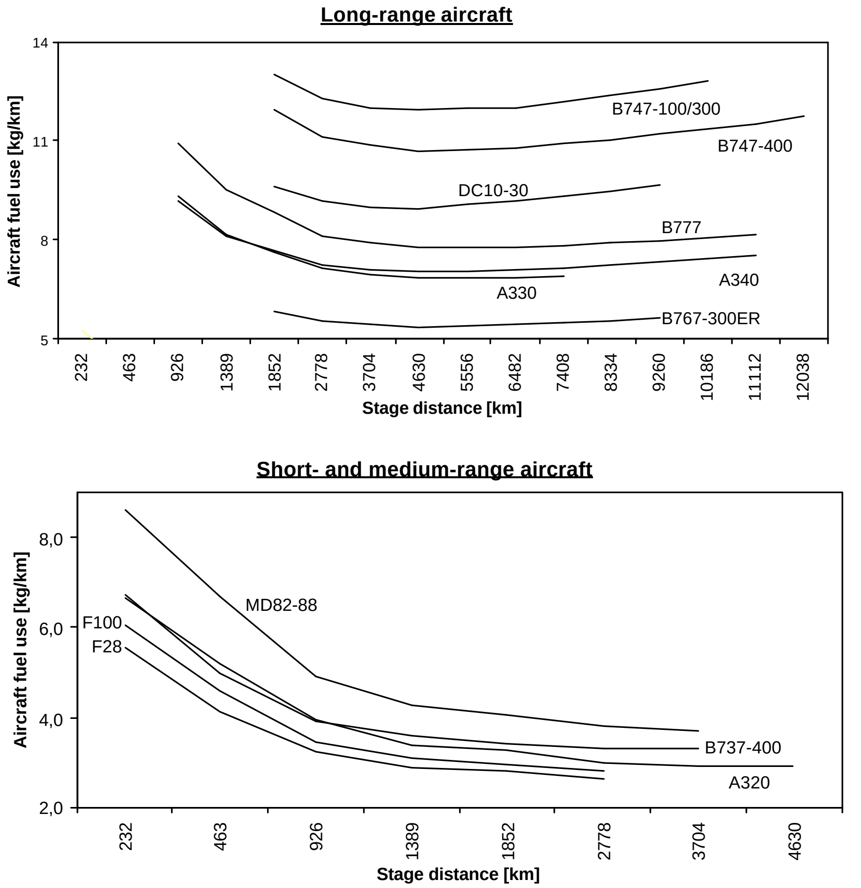

Figure 16: Examples of data on specific fuel consumption per kilometre for generic/representative aircraft categories used on long-range (upper part of the figure) and on short- and medium range (lower part of the figure) for trips of varying lengths [Falk 1999]

To sum up, countries that participate in the EMEP/CORINAIR inventory programme can choose to use the type of methodology that fits the national data availability and the resources available for the calculations. The advantage of the simple methodology over the very simple methodology is that the emission estimates for the LTO phase become more accurate when using more detailed aircraft data, whereas the estimates for the cruise phase become more accurate when using the detailed CORINAIR methodology or similar country specific models.

8.2 ANCAT/EMCAL reporting guidelines

In 1998 the European Civil Aviation Confence's (ECAC) Group of Experts on the Abatement of Nuisances caused by air transport (ANCAT) decided to establish a sub-group (EMCAL) dealing with emissions calculations. EMCAL circulated a questionnaire on emission matters to 37 ECAC Member States. Because the replies to the questionnaire indicated considerable variations among Member States in methodologies used for emission calculations and reporting ANCAT has produced an "*ECAC Recommendation* *on Methodology for Emissions Calculations*" [ECAC 2002a] and accompanying "*ECAC/ANCAT/EMCAL Guidance Material*" [ECAC 2002b] that was finally approved by ECAC Directors General March 2002.

The ANCAT methodology is basically based upon the EMEP/CORINAIR methodology and consists of three methods, ANCAT 1, ANCAT 2 and ANCAT 3, with different levels of accuracy and complexity, in line with the CORINAIR Very Simple, Simple and Detailed methods. In its "ECAC R*ecommendation on Methodology for Emissions Calculations*" ECAC encourages Member States to calculate the emissions of aviation as accurately as possible using ANCAT method 3 (the most detailed methodology described in the ANCAT Guidance Material). If Member States are not able to use such a detailed methodology or are unable to obtain detailed information on distances flown, they may use the less detailed ANCAT 2 methodology. If Member States are unable to obtain detailed information on aircraft types, they may use the least detailed ANCAT 1 methodology. If a peer reviewed and well-documented national methodology is available, which is more accurate than ANCAT method 3, Member States may use this national methodology when producing emission inventories.

However, probably the most important message of the ECAC Recommendation seems to be that Member States are urged, "*to progressively refine and improve the level of accuracy in recording aircraft emission data. States should aim towards calculation of emissions from their aviation activity in accordance with ANCAT method number three or a peer reviewed and well documented national methodology in order to achieve the best practicable level of accuracy* [ECAC 2002b, Article 5].

8.3 Eurostat/Eurocontrol/TRENDS emission inventory

The European Commission has started informal discussions with EUROCONTROL, the European Organisation for the Safety of Air Navigation, with a view to possibly concluding an agreement aimed at improving the monitoring of the environmental impacts of civil aviation in Europe. The objective of cooperation would be to enable the European Commission and the EU Member States to monitor better the environmental impact of civil aviation in Europe, in particular as regards GHG emissions, and to provide a basis for better transport statistics in the aviation sector. Eurostat participate in the discussions.

A major element of the envisaged cooperation would be the development of systems to support a regular, sustained supply of consistent and accurate data on emissions from aviation in Europe, including the split on various types of aviation (domestic, intra-EU, international, etc.).

In this context, EUROCONTROL is in a unique position to be able to provide the necessary information due to its role in pan-European air traffic management (ATM). Within EUROCONTROL, the Central Flow Management Unit (CFMU) continuously monitors the airspace and flow management situation throughout Europe. All aircraft operators must notify the CFMU of their intention to operate a civil aviation flight under Instrument Flight Rules (IFR) condition by filing a flight plan. Thus, the EUROCONTROL air traffic movement database constitutes a unique source of consistent, detailed and continuously updated information on every processed IFR flight operation within Europe. It should be noted that Visual

Flight Rules (VFR) flights and Military Operational Air Traffic (AOT) generally are not operated as controlled flights and thus are not included in the EUROCONTROL air traffic movement database.

One advantage offered by use of Eurocontrol data is that those Member States who have not been able to make reliable splits between fuel consumption at domestic and international routes will be able to make use of these data in a number of ways: traffic split, fuel consumption split or emissions split. Furthermore the project holds the advantage that international intra-EU flights can be reported separately. As discussed in chapter 7 such data may be needed in the future for the reporting of emissions in the European Union as a whole to the UNFCCC, if international intra-EU flights are to be reported as domestic [Lock 2002].

Recently, Eurostat has produced fuel consumption estimates within a project called TRENDS, which was primarily intended to produce environmental indicators for transport. The TRENDS model is based on the detailed CORINAIR methodology (see section 8.1 for a description of the CORINAIR methodology). IFR (Instrumental Flight Rule) flight data are provided by Eurocontrol and are used to produce estimates of fuel consumption and emissions for each airport/region pair, aircraft type, and time period, split by takeoff, cruise and landing. This is a rather large (350 MB) database in MS Access computing around 75 000 calculations per country per year [Lock 2002].

	Eurostat/TRENDS	UNFCCC	UNFCCC/Eurostat
Austria	1.663.200	1.725.139	96%
Czech Republic	554.400	551.674	100%
Denmark	2.475.900	2.464.143	100%
Spain	12.874.050	12.568.019	102%
Finland	1.552.950	1.523.000	102%
France	19.775.700	19.820.920	100%
Greece	3.937.500	3.945.230	100%
Ireland	1.622.250	1.623.788	100%
Italy	10.902.150	9.865.000	111%
Luxembourg	1.017.450	1.019.120	100%
Netherlands	10.391.850	10.486.430	99%
Norway	2.321.550	2.096.391	111%
Portugal	2.271.150	2.046.555	111%
Sweden	2.879.100	2.898.402	99%
United Kingdom	31.203.900	28.361.328	110%

Table 7: Comparison between total CO_2 emissions from international and domestic aviation in 1999 for selected countries according to Eurostat/TRENDS versus UNFCCC data [Million tonnes of CO_2]. Sources: [UNFCCC 2002b] and [Eurostat 2002].

Preliminary results of the TRENDS model are shown in Table 7 and Figure 17. Table 7 compares the results for total fuel consumption for domestic and international aviation computed in the TRENDS model to the fuel consumption data reported by selected European Annex I countries to the UNFCCC in 1999. For the countries shown in Table 7 the data calculated in TRENDS are fairly close to the data reported to the UNFCCC for most countries. However, for some of the countries that are not included in Table 7 the differences are very great and the variation between years is also large [Eurostat 2002]. The reason for not including the results for those countries is that they have not reported domestic and international fuel consumption data to the UNFCCC [UNFCCC 2002c].

Figure 17 illustrates that for most of the European Annex I countries that have reported fuel consumption for domestic and international aviation to the UNFCCC the share of fuel used for international aviation activities is quite close to what is reported from countries. However, for two of the countries shown here the TRENDS model seem to estimate that a much larger share of the fuel is used for international aviation than what is reported to the UNFCCC.

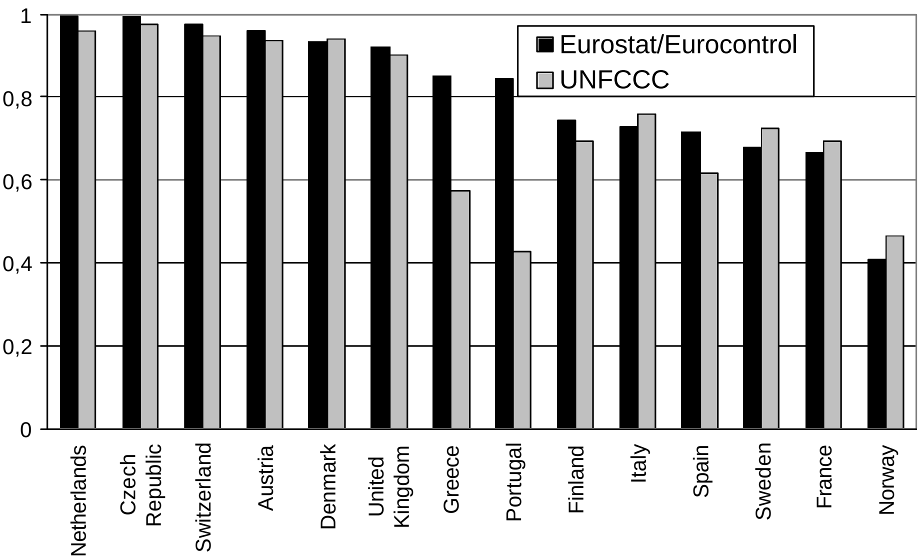

Figure 17: Comparison between the split between international and domestic according to Eurostat/Eurocontrol versus UNFCCC data. See Appendix I for further data. Sources: [UNFCCC 2002b] and [Eurostat 2002].

This initiative from the European Commission, Eurostat and EUROCONTROL may improve the data material and may also give the European countries the possibility to crosscheck their data to the data from Eurostat.

8.4 Global emission inventory models

A number of different models have been developed to compute three-dimensional (latitude, longitude, altitude) global inventories of civil (and military) aircraft fuel consumption and emissions. For example, such models have been developed by NASA (United States National Aeronautics and Space Administration), by ANCAT/EC (Group of Experts on the Abatement of Nuisances from Civil Air Transport/European Commission), by DLR (the Deutsches Zentrum für Luft- und Raumfahrt) and by the Dutch Ministry of Transport (AERO model). All four studies use models based on methodologies where the aircraft fleet is divided into a number of representative aircraft categories.

IPCC has compared the results of the three first mentioned models for 1992, noting that the inventory calculations are in good agreement, with total fuel used by aviation globally (including military aircraft) ranging between 129-139 million tonnes and total emissions of NOx (as NO_2) ranging between 1.7-1.8 million tonnes. Of these estimates between 17-26 million tonnes are consumed by military aircraft and around 4 million tonnes are consumed by general aviation. The estimates for the fuel consumed by civil commercial aviation (scheduled plus charter traffic) thus ranges between 110-112 million tonnes [IPCC 1999].

Later published results from the Dutch Ministry of Transport (AERO model) estimate fuel consumption about 17% higher because it uses a more comprehensive flight database. According to the AERO model calculations global aviation fuel consumption for civil scheduled and charter traffic and general aviation equals around 134 million tonnes in 1992, while emissions of NOx are estimated at 1,7 million tonnes [Pulles 2000a]. The 134 million tonnes of fuel is still significantly lower than the 165 million tonnes estimated for the same year by the IEA on the basis of fuel sales statistics (in 2000 the fuel consumption for aviation has grown to around 209 million tonnes [IEA 2002]). A part of the residual 31 million tonnes may have been consumed by military aircraft (estimated at between 17-26 million tonnes by NASA and ANCAT) and the authors of the report describing the AERO results note that a likely further explanation may be that statistical sources on global aviation fuel-use may not take into account that kerosene can be used for other purposes than aviation [Pulles 2000a].

The global inventory models described here are unfortunately only available for the year 1992.

8.5 Discussion on emission inventories

Currently Parties to the UNFCCC can use different methodologies of varying detail in their reporting of aviation emissions to the UNFCCC. A recent ECAC initiative may encourage European countries that participate in ECAC to begin using the Detailed Corinair Methodology for calculating aircraft emissions (see section 8.2). This may increase comparability and accuracy in the reporting from these countries to the UNFCCC.

Another recent initiative from the European Commission, Eurostat and EUROCONTROL, the TRENDS project, may also improve the data material and may also give the European countries the possibility to crosscheck their data to the data from Eurostat. The TRENDS initiative also opens the possibility of calculating fuel use and emissions separately for intra-EU flights. As discussed in the previous chapter such data may be needed for the EU emission inventory for the UNFCCC in the future.

In the current situation only Annex I countries report emissions from aviation to the UNFCCC, but around one third of the CO_2 emissions from international aviation bunkers in 1999 relate to fuel sold in non-Annex I countries that have not yet agreed to reduction targets under the Climate Convention. Much of the fuel sold in non-Annex I countries may be consumed by airlines registered in Annex I countries or may be consumed by airlines transporting passengers and goods originating from Annex I countries. In case CAEP/ICAO intends to set up an emissions trading scheme the development of a yearly updated global inventory may be useful for calculating the total emissions from aviation, and more exact figures than those available today may also be needed to set up the system. A few global inventories have been conducted, but to the knowledge of the author of this report only for the year 1992, and these inventories are neither as detailed as for example the detailed CORINAIR methodology and neither do they contain accurate data on flights actually performed by all airlines globally.

A working group “Alternative Emissions Methodology Task group” has been set down by CAEP aimed at understanding cruise emissions from aviation. Similarly, the European Commission is currently funding a programme in this area called “NEPAIR”. At this time, both projects are seeking to establish methodologies, but not standards, that could be used for certification of aircraft engine cruise emissions, that may be ready by 2003. Currently, the ICAO Emissions Databank only contains certificated data for LTO emissions but these new initiatives may in the future lead to recommendations for the development of standards for engine emissions at cruise [NEPAIR 2002].

9 Airline reporting on fuel consumption

In chapter 8 we have looked briefly at emission inventories and models. Another potential source of fuel consumption data is airline reporting on average overall yearly fuel intensity. Such reporting holds the advantage over models that the data reflect actual consumption data for actual flights with certain loads, i.e passengers and freight. Such data are unfortunately not generally publicly available as discussed further throughout this chapter. This chapter discusses the availability and usability of such data.

9.1 Evolution of the fuel intensity of passenger air travel

The fuel intensity per passenger kilometre of commercial civil air transport has been reduced by approximately 50% since the early 1970s. The use of more fuel-efficient aircraft engines and the introduction of bigger aircraft accommodating more seats per aircraft in combination with an increase in the average stage distances reduced the fuel use per available seat kilometre (ASK). The improvement in the specific fuel consumption has furthermore reduced the necessary amount of fuel that has to be carried on flights of comparable distances leading to additional fuel savings. Furthermore, the operation at higher passenger load factors has contributed to reduce the fuel use per revenue passenger kilometre (RPK)[21].

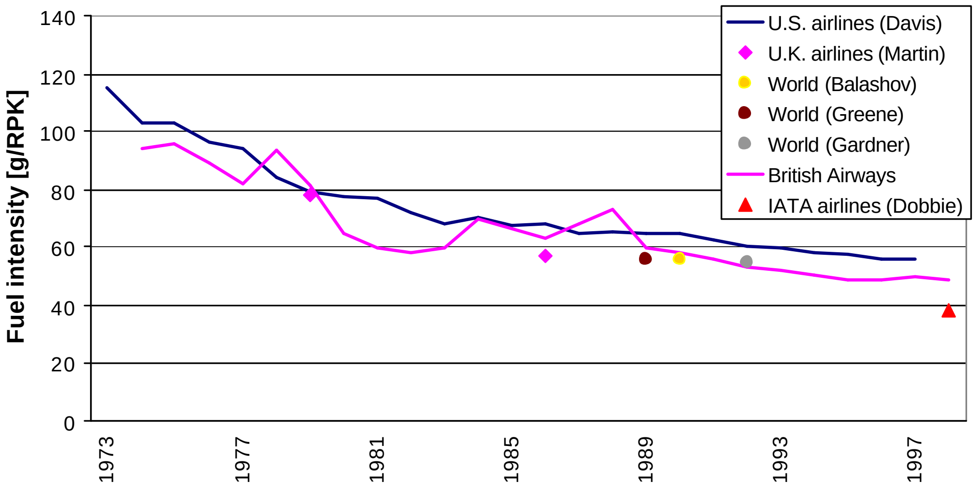

Figure 18: Fuel intensity per revenue passenger kilometre (RPK) of passenger air travel according to various sources [Davis 1999], [Martin and shock 1989], [Balashov and Smith 1992], [Greene 1990], [Gardner et. al. 1998], [British Airways 1999a] and [Dobbie 2001].

[21] For a further description of these improvements see for instance [Sarames 1984] [Martin and shock 1989] [Grieb and Simon 1990] [Balashov and Smith 1992] [Greene 1997] [Dings et. al. 1997] or [IPCC 1999].

The trend in the average specific fuel consumption per revenue passenger kilometre in commercial civil air transport is illustrated in Figure 18 that plots a number of different estimates that are given in the literature for all the US airlines [Davis 1999], for British Airways [British Airways 1999a], for all the UK airlines [Martin and Shock 1989] for the World's scheduled fleet [Greene 1990] [Balashov and Smith 1992] [Gardner et. al. 1998] and for the IATA fleet [Dobbie 2001]. We note that the estimates that are shown here include the total amount of fuel consumed by the airlines in question. The estimates are for various groups of airlines that operate at different routes at varying passenger load factors and freight load factors using fleets of various aircraft mixes. The major part of the fuel consumed by airlines is attributable to the carriage of passengers, but some is related to freight transport. Thus, the estimates for the average fuel consumption per passenger kilometre that are shown in Figure 18 can be said to be somewhat overrated. Section 9.3.2 discusses the relative importance of freight in passenger airline activities and analyses how the fuel consumption can be distributed between passenger and freight transport weights respectively.

9.2 Fuel intensity of different aircraft types

This section analyses the specific fuel intensity of different types of aircraft, based on recent information from some European and Asian airlines' yearly environmental audits as well as some recent operating statistics for the American air carriers that are submitted to the US Department of Transport and some information from a number of academic studies that analyse the fuel intensity of aircraft in some earlier years.

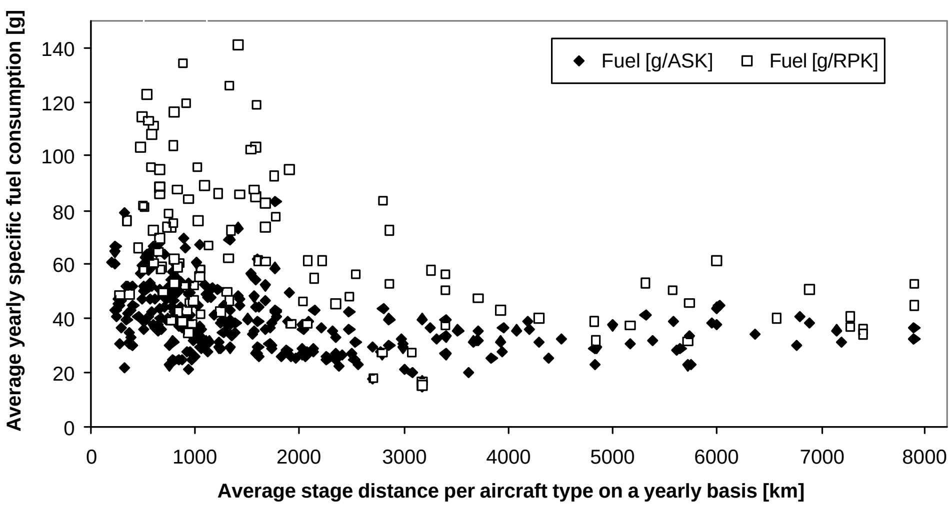

Figure 19: Specific fuel consumption per ASK and RPK versus stage distance for different types of aircraft. For an explanation of the data included see the explanations for Table 8 and Table 9. Data sources: [Premiair 2001] [All Nippon Airways 1999, 2000a and 2000b] [Lufthansa 1999 and 2000] [Lufthansa City Line 1999] [Swissair 1999] [SAS 1999b and 2000] [Sarames 1984] [Air Baltic 2001] [DOT 2001] [Norwegian Air Shuttle 2001] [AEA 1999]

Figure 19plots the average specific fuel consumption per available seat kilometre (ASK) and per revenue passenger kilometre (RPK) for a range of different aircraft types for the average stage lengths at which they are used. Most of the data refer to the use in recent years, but a few older data are included as well (see the notes to Table 8 and Table 9 for a further description of the data that are included in Figure 19). The data includes subsonic jets and turboprops in operation in various years from the beginning of the 1970s and onwards. The data for the fuel consumption per ASK and per RPK for each aircraft type refers to the usage cycle for a specific airline, or a number of airlines, in a specific year, including the specific load factor and the average stage distance flown by type of aircraft in that year.

Some data for the older aircraft types are derived from academic studies analysing 1970s and 1980s fuel intensity of a number of American and British airlines by aircraft type and are summarised in Table 9. The data for the aircraft types that are currently in use are summarised in Table 8 and represents data for use in the period between 1998-2000 of airlines that are situated in the United States, in Europe and in the Asia/Pacific region. It should be noted that different airlines use different methodologies for calculating the specific fuel consumption per passenger kilometre. For example, Lufthansa subtracts the fuel attributable to lifting the belly-hold freight in the company's passenger aircraft. Therefore, the further analyses' in the following sections primarily concentrate on comparisons of data between airlines or groups of airlines for which the data are consistent, unless otherwise is mentioned.

The fuel use per revenue passenger kilometre (RPK) is higher than the fuel consumption per available seat kilometre (ASK), due to non-optimal passenger load factors. Aircraft that are used for short-haul regional flights are typically operating at load factors below average and are typically quite fuel intensive, as compared to aircraft that are used at medium-haul and long-haul, using normally around 50-90g per RPK (Table 8 and Figure 19). The most fuel-intensive subsonic passenger aircraft that are currently in use (among the airlines studied here) are low-capacity regional turboprops and jets using up to 119g per RPK.

The aircraft used at medium-haul typically use around 30-50g/RPK, but the most fuel-efficient types consume less than 20g/RPK. However, the old DC9s operating in the medium-capacity market use up to around 111g per RPK on average when operated on short-haul routes at below average load factors.

Aircraft that are used for long-range flights normally consume around 40-50g/RPK. The most fuel-efficient long-range aircraft consume below 30g/RPK whereas the least efficient types consume up to 60g/RPK. The supersonic Concorde, that has not been included in Figure 3.4, is in a class of its own among the long-range aircraft, using 175g/ASK and 313g/RPK. That is, the Concorde use about ten times as much fuel per revenue passenger kilometre as do the most efficient subsonic long-range jets. Furthermore, the Concorde cruise at much higher altitude (18 kilometres) than subsonic aircraft (typically around 10-12 kilometres), leading potentially to a more severe environmental impact per kilo of fuel burned than aircraft cruising at lower altitudes.

Aircraft type	*Average stage distance [km]*	*Fuel [g/ASK]*	*Fuel [g/RPK]*	*Seats*	*No. of Airlines*
Bae jet stream 31**	231-245	60-66	119*	19	2
Bae jet stream 41**	390	52	96	30	1
Embraer 120**	359-411	45-52	86*	30	2
Dornier 328**	385	43	65	32	1
Saab 340B**	304-338	46-52	84*	34	2
Embraer 135	567-613	37-64	83*	37	2
De Havilland DHC 8-100**	259-272	45	76*	37-39	2
ATR 42**	235-365	39-47	70*	46-48	5
Saab 2000**	456	41	66	47	1
Fokker 50**	278-368	30	48-76	46-50	4
Embraer 145	513-796	40-47	72*	50	3
ATR 72**	295-399	30-36	56*	64-68	6
Fokker 28	512-585	50-59	81-94	65-75	2
De Havilland DHC 8-Q400**	500	36	58	72	1
AVRO RJ 85	532-661	63*	89[L]-112	69-80	2
Canadair jet 100/145	621-1107	32 –63	46-87	48-50	4
DC-9-10	640-1040	65-68	107*	60-78	3
Bae 146-300	513	39	60	89	1
Fokker 100	494-961	41-54	66*	97-98	3
DC-9-30	552-1181	33-58	77*	83-117	8
B737-100/200	229-1250	28-64	62*	95-123	13
DC-9-40	782-1390	38-54	69*	100-127	3
B737-500	604-1274	37-39	57*-72[L]	103-122	4
MD-87	741-852	38-44	61-64*	110-125	3
B717-200	759	23	33	119	1
DC-9-50	203-743	48-61	80*	115-134	3
A319	808-2131	28-32	42-53[L]	120-126	5
B737-300/700	685-2525	24[C]-36	46*-59[L]	120-155	12
B727-100	2062	37	79	170	1
B727-200	319-1887	36-83	66*	95-179	15
MD-80 & DC-9-80	855-1790	31-40	51*	114-160	10
A320-100/200	696-2700	16[C]-38	18[C] -52	110-183[C]	14
MD-90-30/50	645-1340	29-40	48*-53	141-150	4
B737-400	630-2257	24-33	46*	140-170	6
B737-800	1126-3848	26-36	38*-58	146-179	4
A321	763-787	16[C]-24	18[C] -40	182-220[C]	3
B757-200	1600-3617	17[C] -29	19[C] -38*	158-233[C]	14
A310-300	994-3401	27	37-52[L]	222	2
B757-300	NR	NR	25[CL]	252	1
B767-200/200ER	941-5746	23-37	46*	168-264	6
A300-600	1333-2705	30*	40-47[L]	228-270	2
A300B4-120	2794	27[C]	27[C]	298[C]	1
B767-300/300ER	796-5387	19[C] -32	21[C] -52	188-322[C]	9
L-1011-500	1776	42	56	244	1
DC-10-10	2073-3702	21-42	48*	267-379	7
A330-200/300	3081-3169	19[C]-21[C]	20[C]-28	196-409[C]	3
A340-200/300	7393	NR	29 –36[L]	212-291	2
DC-10-30	4085-6023	29[C] -45	34[CL]-46*	229-370[CL]	7
MD-11	4384-7150	23-41	31-60*	232-376	5
L-1011-100/200	2021-2998	30-37	43*	299-361	2
B777-200/300	870-7888	18[D] -36	27[D] -56	202-477[D]	7
B747-200/300	589-6817	23-52	32-108	310-389	5
B747-100/100SR	921-5735	28[D]-33	40-46	447-536[D]	4
B747-400	970-7883	24[D] -34	37[L] -53	343-569[D]	6

Table 8: Recent airline reporting on specific aircraft fuel consumption 1998-2000
* US airline average, ** Turboprops, NR Not reported by any of the airlines, C In charter all-economy class configuration, D In domestic all-economy class configuration, L lufthansa
Note that the data that are shown here are generally for the total fuel consumption in passenger aircraft, including the fuel used for lifting belly-hold freight. However, for the aircraft that are operated by Lufthansa the fuel consumption related to freight transport in passenger aircraft has been subtracted and the figures for the fuel consumption per RPK are therefore lower than for similar aircraft that are operated by other airlines. Lufthansa's figures are marked with an L. In the case of the B747-400 Lufthansa reports the lowest fuel consumption per RPK because this type of aircraft carry much belly-hold freight. Lufthansa and Cathay Pacific Airways do not report their fuel consumption per ASK. For the aircraft operated by Lufthansa Condor, Japan Airlines, Cathay Pacific and Air 2000 it has not been possible to get data for the average stage distances, and their aircraft are therefore not included in Figure 19. For the American air carriers, the specific fuel consumption per ASK and RPK of each type of aircraft that is operated is shown as the average for all carriers.
Data sources: [Condor 2000] [Premiair 2001] [Air 2000 2001] [Cathay Pacific Airways Limited 2000] [All Nippon Airways 1999 and 2000] [Japan Airlines 2000] [Lufthansa 1999, 2000a and 2000b] [Lufthansa City Line 1999] [Swissair 1999] [SAS 1999b and 2000] [Air Baltic 2001] [DOT 2001] [Norwegian Air Shuttle 2001] [AEA 1999].

Aircraft type	*Average stage distance [km]*	*Fuel [g/ASK]*	*Fuel [g/RPK]*	*Seats*	*Year*	*Airline*
Shorts 360**	-	51	87	36	1986	British airline's average
Fokker 27**	-	46	85	44	1986	British airline's average
Vickers Viscount**	-	80	94	60	1986	British airline's average
BAC 1-11	-	57	78	65-99	1986	British airline's average
B707 (all)	1587	62	119	129	1973	US airline average
DC-9-30	538	64	123	90	1973	US airline average
DC-9	-	41	67	85-110	1986	British airline's average
B737 (all)	496	59	114	94	1973	US airline average
B737 (all)	-	32	34	106-149	1986	British airline's average
DC-8-10/50	1416	73	141	127	1973	US airline average
DC-8-60/70	1580	54	103	169	1973	US airline average
B757-200	-	30	37	189-225	1986	British airline's average
B767-200	-	23	23	273	1986	British airline's average
L-1011	1907	49	95	222	1973	US airline average
L-1011	-	46	55	226-234	1986	British airline's average
DC-10	1577	44	85	233	1973	US airline average
DC-10	-	39	52	233-379	1986	British airline's average
B747 (all)	2799	43	84	332	1973	US airline average
B747 (all)	-	39	55	370-475	1986	British airline's average
Concorde	-	175	313	100	1986	British airline's average

Table 9: Examples of 1970s and 1980s airline reporting on specific aircraft fuel use
**Turboprops
Note that the figures for British airlines in 1986 do not give information on the average stage distances and are therefore not included in Figure 19.
Sources: [Martin and shock 1989] [Sarames 1984].

9.2.1 Old versus new aircraft

A look at the data presented in Table 8 and Table 9 reveals the impact of the technological improvements to some main aircraft models that were operated by the American air carriers in 1973 and 1998 respectively. For example, in 1973 the B737s consumed around 59g of fuel per ASK on average and had 94 seats on average. For comparison, the B737-500s that are operated by American major airlines in 1998 use 37g of fuel per ASK and have 110 seats on average. A second example for comparison is the long-range B747. In 1973 the B747s used 43g per ASK and had 332 seats on average. In 1998 the B747-400s use 32g per ASK and have 383 seats on average. A third example for comparison is that the 233-seat DC-10 tri-jet introduced in the early 1970s used around 44g per ASK while the 290-seat B777-200 twinjet introduced in the mid-1990s consume around 28g per ASK [Sarames 1984] [Aircraft Economics 1999f and 1999c]. Many airlines are today replacing their current aircraft by bigger types and this makes it possible to operate at lower specific fuel consumption.

9.2.2 Load factors - passengers and freight

Generally, the average yearly passenger load factors of commercial air carriers have been improved through the last decades from around 50 percent in the early 1970s to around 70 percent currently [ICAO 1999a]. There are considerable differences among airlines concerning load factors. Passenger load factors are reported from around 50% to above 75% by scheduled airlines, although most major airlines operate above 65% [ICAO 1998f] [AEA 1998]. European charter carriers generally operate at above average passenger load factors, some of them close to the optimum, one example being Premiair reporting a passenger load factor of 98% in 1999 [Premiair 2001].

The weight load factors, that is the weight of passengers and their baggage plus the weight of the freight transported as belly-hold over the available capacity (measured as available tonne kilometres, are generally lower than the passenger load factors. Freight's share in total scheduled traffic range from less than 10% to above 40% for the World's major airlines [Cranfield College of Aeronautics 2000b]. Freight's share of the total weight transported is generally higher on long-haul routes than on medium-haul while being almost insignificant on short-haul [AEA 1999] [DOT 2001], see Section 9.2.2 for a further discussion of this issue.

The fuel use per revenue passenger kilometre and per freight tonne kilometre is generally reduced at higher load factors. However, the total aircraft fuel use increases as the load factor increases, because of the weight that is added to the aircraft when carrying additional passengers and freight and this is also reinforced by the aircraft carrying more fuel. The connection between load factors and the fuel-burn per seat vary according to the aircraft type and the distance flown. A recent study proposes, that for modern medium- to large-capacity aircraft such as B747-400, B777-200, B757-200 and B737-700, the additional fuel burn at high load factors is rather small. For example, an increase in the passenger load factor from 70% to 100% is suggested to generally lead to an increase of less than 5% in the total fuel use on trips of average lengths for those aircraft [Daggett et. al. 1999]. For smaller short-haul aircraft as well as for some older medium-capacity jets the fuel consumption increase considerably more than what is suggested for modern medium-haul and long-haul jets [IPCC 1999, p. 280].

An example of the importance of the freight load factors for the fuel consumption per revenue freight tonne kilometre transported by all-cargo carriers is illustrated in Figure 20. In 1998, the main types of aircraft used by the three major US all-cargo carriers (UPS, DHL and FedEx) operated at weight load factors of between 47% and 67%. The fuel consumption per revenue freight tonne kilometre is therefore around 1,5 to 2 times as high as the fuel consumed per available tonne kilometre, that is the available capacity. The aircraft shown to the left in Figure 20 are operating at short distances with average revenue loads of between 10-30 tonnes and those to the right are long-haul aircraft with revenue loads of up to 65 tonnes.

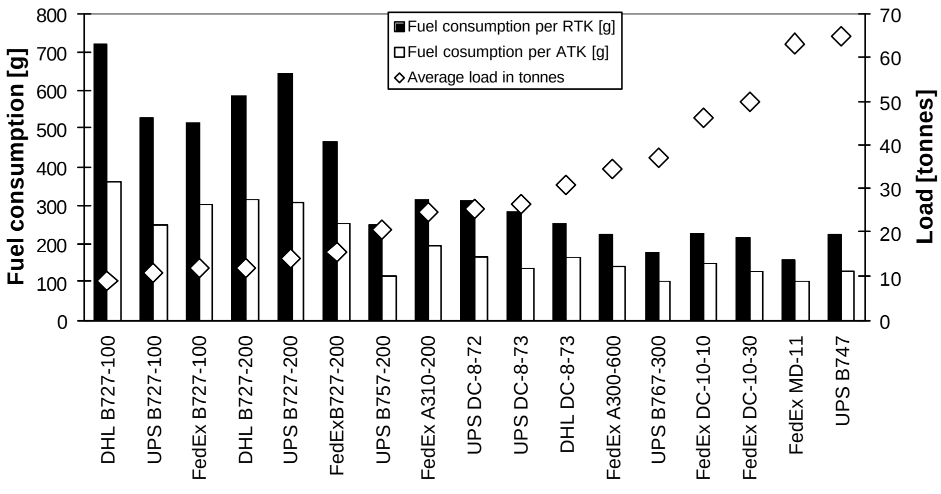

Figure 20: The specific fuel consumption of the main aircraft models operated by the three major US all-cargo carriers in 1998
Source: [Aircraft Economics 1999d]

9.2.3 Seat configuration

Airlines operate aircraft that are configured for different purposes. For example, some aircraft are configured in all-economy class high-density seat-configuration while others are configured with two or three different classes, where the seats in the business class and first class sections are more spacious. Thereby three-class seat-configuration aircraft have lower seat density than all-economy class configured aircraft. Some scheduled airlines operate aircraft featuring high-density seat configuration at domestic routes while using low-density seat-configuration aircraft on international routes. For instance, All Nippon's B777-200s accommodates 376 passengers in all-economy seat-configuration but only 250 in the three-class international version, while the B747-400 accommodates 569 passengers in the all-economy seat-configuration and only 337 in three-class mode.

Similarly, European charter carriers and many low-cost scheduled carriers generally use high-density seat-configuration aircraft, thereby operating at lower fuel consumption per available seat kilometre than scheduled flag carriers. Many examples can be drawn from the data shown in Table 8, showing considerable differences in the seat-configurations, especially in the segment for long-haul aircraft. For example, the European charter carrier Premiair operates A330-200s and A330-300s accommodating 30% and 50% more seats respectively than similar aircraft types operated by Swissair and Cathay Pacific respectively. A similar comparison in the medium-range segment shows that the European charter carrier Air 2000 operates A320s and A321s with 20-25 percent more seats than Lufthansa's aircraft. The operation at above average passenger load factors and the negligible amounts of freight loads combined with the use of new-generation aircraft in high-density seat-configuration, explain why the fuel intensity of Premiair and Air 2000 is around half of the global average for the world fleet.

9.3 Fuel intensity of a number of airlines

Some airlines publish environmental reports giving estimates for their fleets' average yearly fuel intensity. Such data are compared in Table 10 and Table 11 for a number of airlines.

The airlines represented in Table 10 report average fuel-burns of between 24-46g/ASK, and between 26-81g/RPK. European charter airlines are generally the most fuel-efficient. Scheduled airlines that are operating relatively old aircraft mainly at short- and medium-haul routes, such as SAS in 1998, are more than twice as fuel intensive as the most efficient charter airlines. Commuter- and regional airlines, like Lufthansa City Line, which often operate at below average load factor at short-range routes, generally use around twice as much fuel per passenger kilometre than do the major scheduled airlines. It should be noted that the yearly averages reported by airlines constantly changes as a consequence of changes in the composition of their aircraft fleets as well as changes in load factors and other operating characteristics.

	Fuel [g/ASK]	*Fuel [g/RPK]*	*Fuel [g/ATK]*	*Fuel [g/RTK]*	*Passenger Load factor %*	*Freight weight share in passenger aircraft*
Lufthansa average****	30	39	-	-	75	-
Lufthansa Scheduled	-	(37)* 42	-	-	-	17%
Lufthansa City Line	46	81	-	-	57	-
Lufthansa Condor***	-	28	-	-	81	-
KLM	-	-	227	298	77	-
SAS	40	62	285	479	66	-
British Airways	35	(35)* 49	248	370	67	30%
Braathens	38	70	-	-	-	-
Finnair 1997	30	44	-	377	72	-
Swissair	-	35	390	-	-	-
SairLines**	-	38	-	-	-	-
Air France	-	(42)* 49	-	-	-	-
All Nippon Airways	30	47	-	-	64	22%
Japan Airlines	-	-	246	-	69	-
Cathay Pacific	-	35	-	-	-	-
Delta Airlines 1999	-	47	-	-	-	-
American Airlines 1999	34	-	-	-	-	-
American Eagle 1999	43	-	-	-	-	-
Premiair* 1999**	24	26	-	-	98	-

Table 10: The average specific fuel consumption of passenger airlines[22]
All data are for 1998 except when anything else noted.
*The figures in brackets represent airline estimates where fuel used for lifting belly-hold freight in passenger aircraft is subtracted. Note that the three airlines that give such estimates for the fuel which is attributable to belly-hold freight all use different methodologies in the calculation
**(Swiss Air, Crossair, Balair/(CTA) altogether).
***European charter carriers.
****Average for Lufthansa Scheduled, Lufthansa City Line and Lufhansa Condor.
Sources: [Lufthansa 1999 and 2000a] [Lufthansa City Line 1999] [Condor 2000] [KLM 1999] [SAS 1999a and 1999b] [British Airways 1999a and 1999b] [Braathens 1998] [Finnair 1998] [Swissair 1999] [Air France 2000] [All Nippon Airways 1999] [Japan Airlines 2000] [Cathay Pacific Airways Limited 2000] [Delta Airlines 2000] [American airlines 2000] [Premiair 2001].

Similarly, Air France and Lufthansa Cargo report their average fuel use per revenue freight tonne-kilometre (RFTK) performed. These are averages over the fuel consumed for freight transport in their all-cargo freighters and the fuel that is attributable to lifting the belly-hold freight in their passenger aircraft. According to these estimates from Air France and Lufthansa Cargo around five times as much fuel is consumed for transporting one tonne of freight one kilometre as is used per passenger kilometre on average. However, this is an average over a number of different aircraft models that operate at different stage lengths. The specific fuel consumption of airfreight on short haul in passenger aircraft can be more than twice as high as the average. Furthermore, the fuel consumption per RFTK in some of the all-cargo aircraft that are operated by Air France, Lufthansa Cargo, KLM, UPS, FedEx and DHL are shown in Figure 20. These data show that the specific fuel consumption in all-cargo freighters ranges from around 165g per RFTK

[22] It should be noted that these yearly averages are constantly changing. For example, British Airways nearly halved specific fuel intensity in the period between 1974 and 1999, see Figure 18. This is representative for the general historic trend reported by most major scheduled airlines.

to 644g per RFTK. The lowest figures reported are for long-haul MD11s that operate at average loads of above 60 tonnes while the highest figures represents old B727s that operate at average stage distances of around 500-1300 kilometres carrying average loads of around 10-20 tonnes, see Figure 20. The average specific fuel consumption of the operations performed by the three Major US all-cargo carriers in 1998 can be estimated from the data described earlier in Figure 20 at around 237g per revenue freight tonne kilometre (RFTK) transported and some 138g per available tonne kilometre (ATK). Note that these data do only cover the most used types of aircraft by the carriers in question [Aircraft Economics 1999d].

	Average	*Medium-haul passenger aircraft*	*Long-haul passenger aircraft*	*Medium-haul freighter*	*Long-haul freighter*
	Fuel g/RFTK	**Fuel g/RFTK**	**Fuel g/RFTK**	**Fuel g/RFTK**	**Fuel g/RFTK**
Air France	232	360[a]	215[a]		245
Lufthansa cargo 1999	210	160-550[d]	165-212[d]		165[f]-204[e]
KLM 1999	-	-	-		262[c]
UPS	-			176-644[d]	224[b]
FedEx	-			215-513[d]	158[f]
DHL	-			250-721[d]	

Table 11: The specific fuel consumption of airfreight
a) Average over a number of models, b) B747-F, c) B747-300F, d) various aircraft models, e) B747-200F, f) MD-11.
Sources: [Air France 2000] [Lufthansa 2000b] [Lufthansa Cargo 2000] [KLM 2000] [Aircraft Economics 1999d]

The fuel intensity estimates for the different airlines that are presented here are not directly comparable between airlines because of the differences in reporting methodologies. One example is that some airlines subtract a part of the fuel consumption which is attributable to freight transport in passenger aircraft, whereas others include this use in the estimate for the specific fuel use per revenue passenger kilometre. All airlines carry both passengers and freight. Some freight is carried in freight-only freighter aircraft, some in combi-aircraft where a freight section replaces a part of the passenger section, while some is carried as belly-hold freight in standard passenger aircraft.

For airlines that carry much freight in passenger aircraft the fuel used for lifting the freight can contribute to a rather high proportion of the total fuel consumption. For example, British Airways' average fuel consumption per RPK is 49g for the whole passenger fleet on average, but if taking freight into account the efficiency improves to 35g per RPK (see the figure in brackets in Table 10) [British Airways 1999b, p. 21]. Similarly, Lufthansa's and Air France's Scheduled services uses 42g and 49g per RPK respectively, but the numbers are reduced to around 37g and 42g when subtracting the fuel used for lifting belly-hold freight. The fuel consumption figures for scheduled airlines can be more realistically compared to charter carriers if using estimates for the fuel consumption where the fuel use attributable to lifting and carrying freight is subtracted, because charter carriers generally transport negligible amounts of freight.

The division of fuel use between passengers and freight is not straightforward. For example, British airways attributes 30% of their fuel use to freight because around 30% of its revenue load (measured in tonne-kilometres) is freight [British Airways 1999b, p. 21]. Other airlines argue, that transporting one tonne of freight requires less fuel than transporting one tonne of passengers and luggage. For example, Lufthansa attributes 1,7 times as much fuel to passenger weight than to freight weight [Lufthansa 2000b, p. 51] while Air France uses a factor of 1,4 for medium-haul aircraft and up to a factor of 2 for some long-haul jets [Air France 2000, p. 9]. These ratios are supposed to account for the weight and space within an aircraft that is acquired for in-flight passenger services such as seats, galleys, flight crews, catering supplies etc. Only three of the airlines mentioned in Table 10 have reported specifically on both the passenger load factors and the freight loads in their passenger aircraft.

Another example of the differences in reporting methodologies between airlines is the use of different assumptions for the average weight of passengers and their baggage when calculating the ratio between the weight that is attributable to passengers and freight respectively.

Yet another example of the differences in airline reporting methodologies is that for some scheduled airlines the passenger load factor refers to passengers that have paid a certain percentage of the normal fare. Children oftentimes get discounts or travel for free, as do frequent flyers having earned bonus points. The actual load factor is therefore sometimes higher than seen from the statistics and the fuel use per passenger may be somewhat lower.

9.3.1 A closer look at the fuel intensity of American air carriers

This section takes a closer look at the specific fuel consumption of the American air carriers. The data material shown here covers the overall traffic performance of all the US carriers in the years 1982 and 1999. These data are not biased by the fuel consumption of all-cargo carriers that was included in the overall data shown in Figure 18. However, the data still include the fuel consumption that is attributable to belly-hold freight in passenger aircraft.

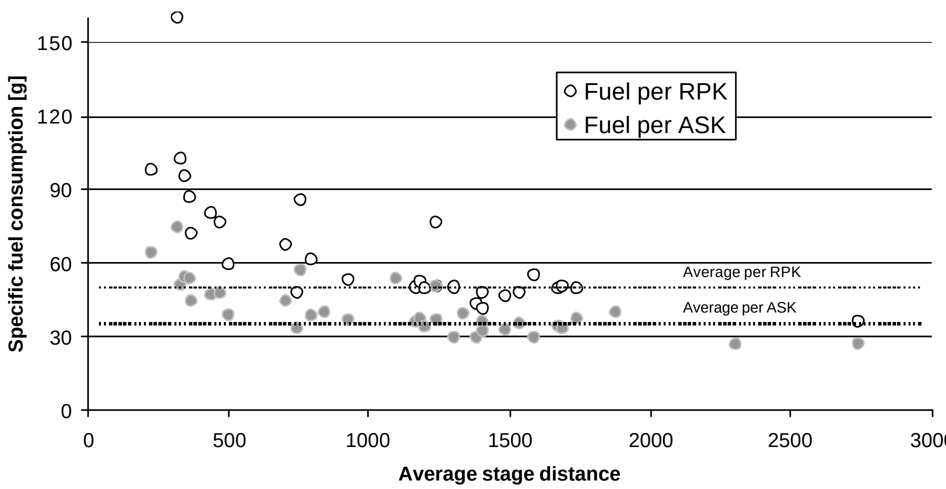

Figure 21: Illustration of the specific fuel consumption per ASK and RPK of American air carriers in domestic operations in 1999
Source: [DOT 2001]

Figure 21 shows the average yearly specific fuel consumption per ASK and per RPK of US air carriers on domestic routes in 1999. The specific consumption varies between 27g and 64g per ASK and between 36g and 102g per RPK, if excluding a single carrier that uses some 74g per ASK and 160g per RPK. Among the Major US airlines that performed around 90% of the domestic revenue passenger kilometres in the United States in 1999 the specific consumption ranges between 30-37g per ASK and 44-53g per RPK. The large regional carriers, such as American Eagle and Continental Express, typically use around 50% more fuel per ASK and per RPK than the Major air carriers do. The overall average specific fuel consumption on domestic routes is around 35g per ASK and 50g per RPK. In 1982 the average specific consumption per ASK was about 43g suggesting a reduction of approximately 8g per ASK in the period or about 19%.

We note that the data availability on fuel consumption by American air carriers is much better than for European and Asian carriers because the American air carriers are required by law to report their operating characteristics to the American Department of Transportation. Similar arrangements do not seem to exist in Europe or in Asia.

9.3.2 Methodologies for allocating airline fuel consumption between passengers and freight loads in passenger aircraft

This section quantifies how much freight that is transported as belly-hold in passenger aircraft by different aircraft and airlines and discusses how much of the fuel that is attributable to passenger and freight revenue weight respectively on different routes.

Currently, freight and passengers account for around 30% and 70% respectively of the total number of revenue tonne kilometres that is performed by the World's airlines. However, some of this freight is carried in all-cargo aircraft.

In 1999, 29 billion revenue freight tonne kilometres (RFTKs) were transported by the American air carriers [DOT 2000, p. 326]. Eight all-freight carriers alone carried more than half of this total. That is, less than 13 billion RFTKs were carried by the passenger airlines, representing some 18% of the total amount of RTKs transported. The average weight share of freight is therefore less than 18% for the US passenger carriers.

Similarly, in Europe, around 44% of the freight that is carried by the scheduled airlines is transported in passenger aircraft and the residual in all-cargo aircraft. The freight's weight share in the total scheduled passenger services is 23%. The share is 29% in international long-haul scheduled passenger services, 10% in international short/medium haul scheduled passenger services and around 4% in domestic scheduled passenger services [AEA 2001].

In Japan, All Nippon Airways report the weight shares of freight in their passenger aircraft at 13% on domestic routes and at 36% on international routes [All Nippon Airways 2000b].

These data suggest that, as a general rule of thumb, Asian carriers transport the highest shares of freight in their passenger aircraft while the US passenger airlines transport a lower share of freight than the European passenger airlines. This is probably due to the large share of domestic traffic performed by the US air carriers that accounts for around two-thirds of all the RTKs and about three fourths of all the RPKs [DOT 2000, p. 323].

Generally, the overall statistics mentioned above suggest that the freight share is higher in long-haul traffic than in medium-haul and short-haul. A look at some statistics on the freight weight shares in individual aircraft confirms this picture (see Figure 22).

As was touched upon briefly in section 9.3 the airlines use different methodologies for the allocation of their fuel consumption on passengers and freight. Most airlines attribute all the fuel consumed to their passenger services. Some airlines attribute the same amount of fuel to a tonne of freight as to one tonne of passenger weight (including their baggage). Other airlines multiply the passenger weight with a factor of between 1,4 and 2 to account for the weight that is attributable to a number of in-flight passenger services (see section 9.3 for a further description of this issue).

The average revenue of the World's airlines per tonne of freight is around 60% lower than the average revenue for a tonne of passengers [ICAO 1996c and 2000d]. One could argue that this factor should also be taken into account in a discussion of which methodology that could potentially be used for the allocation. Therefore, if the fuel is distributed between freight and passenger loads according to their revenue shares, the weight of the passengers should be multiplied by a factor of around 2,5.

The four different methodologies for distributing the fuel between freight and passengers are illustrated in Figure 22. Not surprisingly, the most extreme difference in the estimate for the specific fuel consumption per revenue passenger kilometre appears between the methodology where all the fuel is attributed to passenger transport and the methodology where the fuel is distributed evenly between passengers and freight on an equal weight basis. In the latter case the specific fuel consumption per RPK is reduced by around 24-35% for long-haul trips in a B747-400 and by around 5-13% on medium-haul trips with B757s and A320s. The implication of this finding is that the figures for the specific fuel consumption of aircraft and airline operations that includes the fuel which is attributable to freight (for example those figures that are shown in Figure 19) would typically be reduced by 5-13% on medium range and by 24-35% on long-haul. We note that these are rough estimates and may differ between airlines and between different types of aircraft (see Figure 22)

The selected aircraft shown in Figure 22 are arranged with the most fuel-efficient aircraft, measured in fuel consumption per RTK, on the left hand side of the figure. The B767-300/300ER is the most fuel efficient when considering the fuel consumption per RTK and therefore also per RPK when distributing the fuel consumption on an equal weight basis between passengers and freight (methodology 2). The relative difference between the specific fuel consumption figures of methodology 1 and 2 is greatest for the MD-11s, the B767s and the B777s. For these aircraft RPK2 is between 35-38% smaller than RPK1. For the DC-10s, the 747s, the B767-200s and the A300-600s RPK2 is between 18-30% smaller than RPK1. That is, if comparing the specific fuel consumption figures of these long haul aircraft to the most fuel-efficient medium haul aircraft (B757-200s, A320s and B737-800s) they are at level or even more fuel-efficient if using methodology 2.

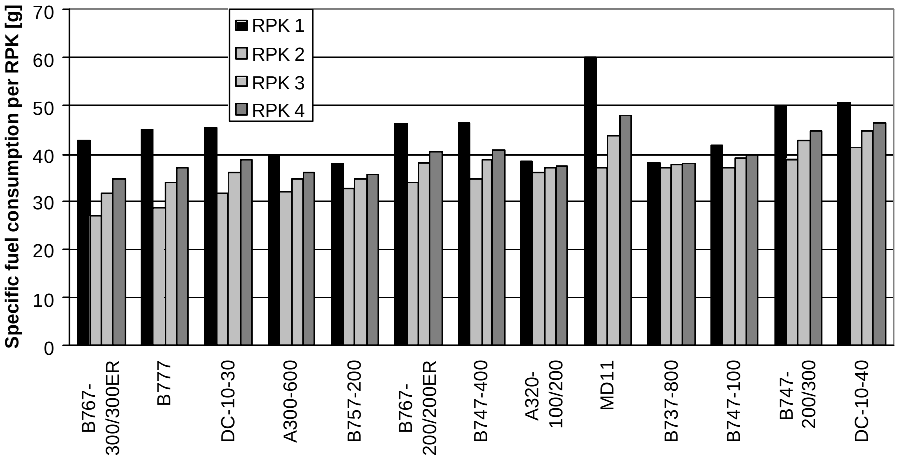

Figure 22: The variation in the specific fuel consumption per RPK when using four different methodologies for attributing fuel to freight
RPK1 represents the methodology where all the fuel is attributed to passenger transport. RPK2 represents the methodology where the fuel is distributed equally between passengers and freight on a weight basis. RPK3 represents the methodology where the weight of the passengers is multiplied by a factor of 1,7 before distributing the fuel consumption between the weight of passengers and freight. RPK4 represents the methodology where the weight of the passengers is multiplied by 2.5. The examples here are for selected aircraft operated by American air carriers in 1999. The average passenger loads factors as well as the average freight weight may vary considerable between airlines and may change from year to year.
Sources: Fuel consumption from [DOT 2001] and freight loads from [Air Transport Association 1999, 2000e and 2001].

9.4 Discussion on airline reporting

In this section some of the problems related to the issues described in this chapter are presented and discussed briefly.

As we have shown throughout this chapter, the airlines that currently report their fuel intensity in environmental reports do not use a common standard. The fuel intensity estimates reported by different airlines are not directly comparable because of the differences in reporting methodologies. One example is that some airlines subtract a part of the fuel consumption which is attributable to freight transport in passenger aircraft, whereas others include this use in the estimate for the specific fuel use per revenue passenger kilometre. As we have illustrated in this chapter, the division of fuel use between passengers and freight is not straightforward.

In the United States all airlines of a certain size are required by law to report their operating statistics to the Department of Transportation (the so-called form 41 arrangement). Therefore, in the United States, a comprehensive database exists with data for the fuel consumption of airlines and their aircraft spanning back several decades. This type of data can be used to make comparisons between airlines and for indexing their fuel efficiency in the way it was shown in Figure 21 in section 9.3.1. To the knowledge of the author such data are not systematically reported to the same detail to governments, ICAO or elsewhere from airlines registered in other countries, although most airlines almost certainly gather such data for internal purposes.

One interesting question is whether it would be possible to establish some sort of global reporting requirements for all the World’s airlines in line with the US

Form 41 establishment. Since ICAO and CAEP are currently investigating possibilities for setting up voluntary agreements with airlines on reducing their specific emissions of CO_2 that process might involve setting up a scheme for airline reporting of fuel consumption and emissions. Furthermore, ICAO and CAEP are currently investigating the possibility to set up a global system for emissions trading. Such a system may come to involve the setting of an emission cap and the allocation of certain emission quotas to airlines and may also involve new reporting requirements for airlines.

Even though airline fuel consumption could be estimated using bottom-up modelling, for example by using the Corinair-model, actual fuel consumption data from airlines may be needed because airlines might not be likely to accept being accredited for modelled fuel consumption data. At least at present, the models that have been constructed to calculate emissions from air traffic on a global scale do not contain a comprehensive database on flights actually being performed and furthermore relies on calculating fuel consumption and emissions by using less detailed aircraft categories than those used in the detailed CORINAIR methodology. Furthermore, all the models constructed to date are disadvantaged by not containing detailed information on the actual passenger- and freight loads transported within the aircraft. These loads may become relevant for example in the case that airlines should become required to reduce their emissions per passenger kilometre and per freight tonne kilometre in a voluntary scheme. Detailed data on the passenger and freight loads may also become necessary for some of the more sophisticated models for allocating emissions from international aviation to Parties that are discussed in chapter 10. However, it should be mentioned that these sophisticated models of allocation currently do not seem to be the most likely to be chosen if Parties to the Climate Convention should agree upon implementing an allocation option.

10 Allocation options – discussion on data requirements

Parties to the UN Climate Convention have not yet been able to agree upon a methodology for allocating emissions from international aviation to Parties. Therefore, these emissions are not included in the national emission inventories that are to be reported the UNFCCC by Annex I countries, but are reported separately under international bunkers in conjunction with emissions from international marine transport. This chapter briefly summarises the options for allocation that have been considered by SBSTA and discusses the data requirements for each option. We note, that this report is not intended to point out which options may be politically feasible.

10.1 Allocation options considered by SBSTA

SBSTA has considered the following options for allocating emissions from international aviation [UNFCCC 1996a]:

1. No allocation
2. Allocation in proportion to national emissions of Parties
3. Allocation to the country where the fuel is sold
4. Allocation to the nationality of airlines
5. Allocation to the country of destination or departure of aircraft. Alternatively, the emissions related to the journey of an aircraft could be shared by the country of departure and the country of arrival
6. Allocation to Parties according to the country of departure or destination of passenger or cargo. Alternatively, the emissions related to the journey of passengers or cargo could be shared by the country of departure and the country of arrival
7. Allocation to the country of origin of passengers or owner of cargo
8. Allocation according to emissions generated within each party’s national space

In relation to the discussion of options for allocating emissions from international aviation SBSTA considers the following questions relevant [UNFCCC 1996b]:

a) Would it be feasible for the Party to control the emissions allocated to it?
b) Could the required data be generated with sufficient precision?
c) Is the method based on the "polluter pays" principle?
d) Is the method equitable?
e) Does the allocation method cover all international emissions?
f) Is the method suitable for all greenhouse gases?
g) Should the method apply to both aviation and marine emissions?
h) Does the method provide a suitable basis for making projections?

In 1996 SBSTA concluded that options 1, 3, 4, 5 and 6 should be the basis for the further work and that with respect to option 1 (non-allocation) the responsibilities of the international community to address issues related to international bunker fuels should be recognised [UNFCCC 1996b, paragraph 55].

10.2 The European Commission's considerations over allocation

By 1999, Parties were given the chance to comment on the conclusions of an informal paper, "*Methods used to Collect Data, Estimate and Report Emissions from International Bunker Fuels*" [UNFCCC 1999f] requested from a consultant by the UNFCCC Secretariat. On that occasion some Parties gave their views on which allocation methodologies that might be preferable if emissions from international bunker fuels were to be allocated to Parties. Finland commented the informal paper on behalf of the European Community and its member states, and stated that "*…any decision on the inclusion of emissions from international bunker fuels in the national inventories of Parties (i.e. on allocation) should enter into force during the second commitment period, because such a decision would require a change in the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, which shall be applied in the first commitment period pursuant to Article 5 of the Kyoto Protocol and Decision 2/CP.3. Therefore, Parties should continue to report these emissions separately from national totals in the first commitment period.*

The EU believes that the issue of the inclusion of emissions from international bunker fuels in national inventories of Parties should be solved in time for negotiations for the second commitment period, i.e. before 2005. In order to have a reasonable choice of options by 2005, the assessment of options addressed in this submission should be done as soon as possible.

Based on the conclusions of SBSTA 4, the EU sees the following twin-track approach (main options I and II) noting that different options could be pursued for aviation and marine bunker fuels.

I. No inclusion of emissions from international bunker fuels in the national inventories of Parties (option 1) as in the current situation. Limitation or reduction of these emissions would be under the general responsibility of the international community (as acknowledged in FCCC/SBSTA/1996/20, para. 55), to be pursued through ICAO and IMO. The EU may consider option 1 (no allocation) further, if ICAO and IMO make demonstrable progress, taking into account the overall emission reduction target of the Kyoto Protocol, in accordance with the timetables and mitigation plans set out above.

II. Inclusion of emissions from international bunker fuels in the national inventory of the Party (options 3, 4, 5 and 6).

This approach may increase the incentives to take action at the international level. It would lead to considerable changes in emission levels at least for some Annex I Parties. Therefore, it would have to be taken into account in agreeing on future commitments for Annex I Parties for the second and future commitment periods.

With regard to the allocation options (options 3, 4, 5, and 6), the SBSTA should compare and discuss these with a view to being in a position to reach agreement on one option by 2005. In that context, the EU presents the following initial views.

The EU shares the analysis in para. 34 of FCCC/SBSTA/1999/INF.4 that it might take Parties three to five years to put in place adequate systems to collect and report information in a consistent manner on emissions from international bunker fuels for options 4, 5 or 6. If one of these options is to be pursued, the necessary methodological work would have to be initiated very soon. The EU would like to request the Secretariat to give recommendations on solving the problems identified in the informal paper "Methods used to Collect Data, Estimate and Report Emissions from International Bunker Fuels (for instance, clarification on definitions or build-up of relevant databases.

In addition, the EU suggests that the issue of control options (such as internationally coordinated instruments, inter alia taxes) in these areas should also be addressed in the further work regarding best practices in policies and measures in consultation with Working Group 5 (Market-Based Options) of the ICAO Committee on Environment Protection, which is already pursuing this matter, and with the MEPC of IMO, which is already conducting a study on greenhouse gas emissions from ships.

The EU also believes it necessary to explore ways to further strengthen the exchange of information between ICAO, IMO and SBSTA. In addition, the EU requests that the Secretariat give recommendations on the possibility of forming a joint working group of the FCCC (SBSTA/SBI) with ICAO (CAEP) as well as with IMO (MEPC) as a means to strengthen the exchange of information between these bodies and the co-operation at the working level" [UNFCCC 1999e].

In the October 2001 Conclusions by the European Environment Council on the preparation of CoP7 in Marrakesh 29 October to 9 November 2001, the European Environment Council reiterates that urgent action remains necessary to curb the expected growth in emissions from international aviation. The European Council of Ministers notes that ICAO's Assembly Resolution A33-7 endorses the establishment of an open emissions trading system for international aviation (see section 6.3 for a description of the contents of ICAO's Assembly Resolution A33-7). The European Council of Ministers stresses that in order for this emissions trading system to be compatible with the Kyoto Protocol, it will be necessary to submit international aviation to emission limitation and reduction commitments *and to establish a methodology for allocating emissions to Parties*. Therefore, the European Environment Council considers that this question should be examined by the SBSTA jointly with ICAO. The European Council of Ministers furthermore recalls the need for further development with ICAO of practical guidance on the use of voluntary mechanisms and gaseous emissions related levies as soon as possible, while taking into account the economic, environmental and competitive impact of such measures. Finally, the Council recalls that it agreed in its common position on the 6th Environmental Action Programme that the Community should identify and undertake specific action to reduce greenhouse gas emissions from aviation if no such action is agreed within ICAO by 2002 [EU Environment Council Conclusions 29th October 2001; article 5].

10.3 December 2002 survey on preferences among European Union Member States and the European Commission towards the allocation issue

In a December 2002 survey performed by the Danish EU Presidency on behalf of EUs group of climate change policy experts (PAM) EU Member

States and the European Commission were asked to give their initial views on the allocation issue. At the deadline of this report responses had been received from 6 Member States and the European Commission.

In the survey a questionnaire was circulated to Member States and the European Commission asking, among other things, which types of allocation options seem feasible (data availability and legal aspects), which advantages and disadvantages MS see for each allocation option, which data would be needed for each allocation option and how long time would it take MS to set up a system for collecting the data needed for each type of allocation option.

It should be noted that Member States and the European Commission emphasize in their responses that the initial views given to the questions on the feasibility and preferability of different options for allocation are preliminary views that may not necessarily reflect the official views of MS or the European Commission. As can be seen from the table below, at the deadline for this report, only relatively few respondents have stated preliminary preferences for allocation options, and these preferences differ widely (1 indicates first preference).

	Option 3	Option 4	Option 5	Option 6	Other options
Commission	Aviation: 1 Ships: 2	3	Ships: 1 Aviation: 2	4	-
Austria	2		3		1*
Denmark					
Finland**					
Netherlands**					
Spain***	2	1	3	4	
United Kingdom**					

*Allocation to airlines and shipping companies but not to countries, combined with individual caps for companies. The overall reduction cap for Annex I Parties should be reflected in the overall cap for Airlines.
** Member States that cannot provide any ranking at this stage.
*** The ranking is based on aviation.

The Commission confirms its earlier statement (see section 10.2) that emissions from international aviation (and shipping) should be allocated to Parties, beginning in the second commitment period under the Kyoto Protocol.

The Commission feels that the most important criteria for allocating bunker fuel emissions should be that for any option chosen:

- it should be consistent with the ‘polluter pays’ principle and therefore should be equitable – although it is not always clear who should be considered as the ‘polluter’ (the passengers/cargo exporters/importers, the airline/shipping company or the company selling the bunker fuel);
- it should allow the Party (either the EC or the individual Member States) to exercise a degree of control over the emissions allocated to it;
- it should be possible to ensure the accuracy of the required data; and
- it should cover all international bunker fuel emissions.

In addition to this, there are other criteria that should ideally be met:

- the allocation option should to the widest extent possible depend on existing data rather than require setting up completely new, complex data collection systems
- the method chosen should not encourage the use of strategies simply to avoid emissions being allocated to a particular Party e.g. ‘tankering’ of fuel by over-loading with fuel in another country or registering aircraft or ships in a different country to that where they normally operate.

10.4 Description of allocation options and data requirements

This section briefly describes the 8 allocation options considered by SBSTA and discusses data requirements for each option. Much of this discussion is being based on a literature review[23] of some earlier studies that have discussed different allocation options examining several aspects such as data requirements and data availability and concerns over equity and efficiency (in terms of giving Parties an incentive to reduce emissions from international aviation). Furthermore the discussion is based on the response given by the European Commission to the questionnaire mentioned in section 10.3. In this report we focus on describing the data availability and data requirements, and the issue of equity is also briefly discussed.

10.4.1 No allocation (option 1)

Option 1 is among the options chosen by SBSTA for further investigation.

Under this option the emissions from international aviation are not allocated to Parties. This option represents the status quo where Parties report emissions from international aviation separately from national emissions. This option merely requires data on the global emissions due to international aviation activities. As discussed in chapter 6 it is generally acknowledged that the international statistics on fuel consumption and emissions related to international aviation activities needs to be improved. Parties are generally having difficulties in estimating the split between fuel consumed for domestic and international aviation This subject is scheduled for discussion at SBSTA 18 and CAEP has decided to organize a “scoping meeting” in 2003, involving the UNFCCC Secretariat, the rapporteurs of some of CAEPs working groups and experts on emissions inventory and data reporting (see chapter 7).

The underlying idea of the option not to allocate emissions is that Parties may consider implementing control options at the global level, for example through ICAO, to reduce emissions from international aviation activities. Any such control options may require specific types of data. Therefore, the type of data needed will depend on the types of control options chosen. As described in section 6.3 CAEP is currently investigating the possibilities for setting up voluntary agreements with airlines on future improvement of their energy efficiency. CAEP is furthermore investigating the possible option of implementing an open scheme for emissions trading. Such control options, if implemented, may likely require that airlines begin reporting in detail on their fuel consumption and emissions. For this purpose some of the methodological aspects discussed in chapter 8 may become relevant. Additionally, as recently

[23] Studies on allocation reviewed for this report are: [Wit 1996], [UNFCCC 1996a, 1996b and 1999f], [Velzen 2000] and [Danish Energy Agency 2001].

pointed out by the UK Royal Commission on Environmental Pollution, if an emissions trading scheme is implemented, emissions from international aviation would have to be included in national greenhouse gas inventories of Parties to avoid double-counting of emission reductions attained in other sectors [Royal Commission on Environmental Pollution 2002]. Therefore, on the longer term, it seems that emissions from international aviation may have to be included also in the case where emissions reduction is pursued through ICAO.

10.4.2 Allocation in proportion to national emissions of Parties (option 2)

Option 2 is not among the options chosen by SBSTA for further investigation.

This option would allocate emissions in proportion to the contribution of a Party to global emissions. For example, the 1990 share of global international aviation was about 1,3% per cent of the global CO_2 emissions from all sources [IEA 2001]. With proportional allocation, each Party would add about 1,3 per cent to its domestic emissions in order to cover all international emissions jointly. For this allocation data is needed merely on the total national emissions of each Party and the total emissions from international aviation.

Under option 2 countries with relatively low national emissions in the base year will be allocated a similarly small share of international aviation emissions. Examples are countries such as Austria, France, Sweden and Switzerland, where national CO_2 emissions per capita are relatively low owing to the high share of hydro and/or nuclear power in national energy production. In contrast, countries with relatively high national CO_2 emissions per capita, would be allocated a comparatively large share of international aviation emissions. See Table 21 in Appendix J for a comparison between CO_2 emission allocated to each country under option 2 and the other seven options as given in a Dutch study on "*National allocation of international aviation and marine CO_2 emissions*" [Velzen 2000].

Option 2 does not allocate emissions in proportion to each Party's level of aviation activities and is therefore not based on the "polluter pays principle" and thereby also raises fundamental equity considerations.

10.4.3 Allocation to the country where the fuel is sold (option 3)

Option 3 is among the options chosen by SBSTA for further investigation.

There does not seem to be major problems with getting data for option 3 since data on fuel sales are already available and because no distinction is needed between domestic and international.

This option would allocate emissions to Annex I Parties on the basis of aviation fuel sales. The option appears to resemble the way emissions from fuel use in road transport are allocated since fuel for road transport may be sold in one country and emissions may occur in another.

For aviation, in the majority of cases, the option is consistent with the 'polluter pays' principle because the aircraft is likely to depart from the country where it buys the fuel. However, it should be mentioned that this option does not take into account the problem of fuel "tankering", e.g. aircraft taking extra fuel onboard to be used for its next flight stage. If, for example, an aircraft take onboard extra fuel in one country, then flies on to another country without using all the fuel, and finally uses the rest of the fuel on a second flight stage to a third destination, the fuel spent at the second flight stage is attributed to the country where the fuel was originally loaded. Therefore, countries that sell the fuel at the lowest cost are likely to be accredited for extra fuel sales because the airlines will tend to buy the fuel where it is cheapest. Thus, option 3 does not fully allocate emissions in proportion to each Party's level of aviation activities and thereby raises some equity considerations.

Furthermore, as it is also the case with options 5 and 6, for option 3 more than one third of the emissions from international aviation will be allocated to non-Annex I countries. From an equity point of view this allocation could be questioned due to the fact that much of the fuel sold for international aviation in these countries may actually relate to air travel performed by people living in Annex I countries.

Finally, as it is also the case for options 5 and 6, option 3 disfavours countries with a high level of aviation activities (for example countries that house large international hub airports) and this can cause equity considerations in cases where a large portion of the passengers and the freight is transported through the country in transit.

10.4.4 Allocation to the nationality of airlines (option 4)

Option 4 is among the options chosen by SBSTA for further investigation.

Option 4 involves allocation to Parties according to the nationality of the transporting company, the country where the aircraft is registered, or the country of the operator. This set of three options has the common feature that the owner/operator relationship is a primary determinant for allocation. The first case has the advantage that national airlines typically maintain information on the amount of fuel they have uplifted. States/Parties would need to ensure that its airlines collected and reported information on the amount of fuel it used over the course of each year splitting that usage into domestic and international according to the IPCC reporting guidelines. One question is whether Parties could start collecting these fuel consumption data from airlines in a consistent and adequate way.

One problem related to option 4 is whether airlines could change flag, for example to non-Annex I countries. Similarly, as airlines are increasingly privatised and have fewer links with a particular country, option 4 does not necessarily always apply the 'polluter pays' principle. Countries with large national airlines would be allocated a large proportion of global emissions, even if many of the flights does not depart or arrive within the country itself.

Option 4 may involve that a higher share of the emissions from international aviation will be allocated to Annex I countries, because much of the fuel sold in non-Annex I countries is lifted by airlines registered in Annex I countries (see the comparison between option 4 and the other options in Table 21 in Appendix J). From an equity point of view option 4 could be considered more equitable for non-Annex I countries due to the fact that much of the fuel sold for international aviation in these countries may likely relate to air travel performed by people living in Annex I countries.

10.4.5 Allocation to the country of destination or departure of aircraft (option 5)

Option 5 is among the options chosen by SBSTA for further investigation.

Option 5 involves allocation to Parties according to the country of departure or destination of an aircraft. Alternatively the emissions related to the journey of an aircraft or vessel could be shared between the country of departure and the country of arrival.

This option would require sharing information between Parties. It might be feasible, in particular for long flights, but it would be much more complex for short flights, in so far as it would require breaking fuel intake or consumption down by country of departure and destination. Nevertheless, if aircraft movements could be broken down by aircraft types this allocation option could account for differences in emissions between various aircraft. Fuel consumption and emissions would need to be estimated from movement data (for example by use of the detailed CORINAIR methodology described in section 8.1). Reliable civil air traffic data are stored by air traffic control authorities such as Eurocontrol and, provided they agree to make them available, no new data collection would be needed. However, the data needed for this type of calculation may take some time to collect since many countries are today not using the more detailed methodologies discussed in chapter 8.

Option 5 seems to result in a similar allocation of CO_2 emissions between countries as options 3 and 6 (see Table 21 in Appendix J), although options 5 and 6 might be able to take fuel tankering better into account than option 3.

Furthermore, as it is also the case with options 3 and 6, for option 5 more than one third of the emissions from international aviation will be allocated to non-Annex I countries. From an equity point of view this allocation could be questioned due to the fact that much of the fuel sold for international aviation in these countries may actually relate to air travel performed by people living in Annex I countries.

Finally, as it is also the case for options 3 and 6, option 5 disfavours countries with a high level of aviation activities (for example countries that house large international hub airports) and this can cause equity considerations in cases where a large portion of the passengers and the freight is transported through the country in transit.

10.4.6 Allocation to the country of destination or departure of passengers or cargo (option 6)

Option 6 is among the options chosen by SBSTA for further investigation, but is considered to be less practical because of additional data requirements.

Option 6 involves allocation to Parties according to the country of departure or destination of passenger or cargo. Alternatively, the emissions related to the journey of a passenger or cargo could be shared by the country of departure and the country of arrival. This option would require Parties to compile information based on the destination of the cargo and passengers. The statistics would have to be cross-referenced to fuel use. While conceptually possible, at the present time there is no system to acquire the data or methodology to calculate the emissions. Acquiring the detailed information would also involve additional administration and some extra cost [UNFCCC 1996b].

Under this allocation option the allocation of emissions between passengers and cargo would be complex. As discussed in chapter 9 airlines do most often not report such data, and when they do, different methodologies are used. An agreed methodology would therefore be required.

Option 6 seems to result in a similar allocation of CO_2 emissions between countries as options 3 and 5 (see Table 21 in Appendix J). We note that the result in Table 21 is for the case where the fuel consumption is distributed equally between the total weight of passengers and freight on an equal weight basis. As discussed in section 9.3.2 there may be need for the use of other methodologies for allocating fuel consumption between passengers and freight.

Furthermore, as it is also the case with options 3 and 5, for option 6 more than one third of the emissions from international aviation will be allocated to non-Annex I countries. From an equity point of view this allocation could be questioned due to the fact that much of the fuel sold for international aviation in these countries may actually relate to air travel performed by people living in Annex I countries.

Finally, as it is also the case for options 3 and 5, option 6 disfavours countries with a high level of aviation activities (for example countries that house large international hub airports) and this can cause equity considerations in cases where a large portion of the passengers and the freight is transported through the country in transit.

10.4.7 Allocation to the country of origin of passengers or owner of cargo (option 7)

Option 7 is not among the options chosen by SBSTA for further investigation and is considered to be less practical because of its substantial data requirements.

Unlike options 2, 3, 4, 5, 6 and 8 option 7 allocates emissions in proportion to the origin of the passengers and the freight. The transport work could be measured in terms of for example passenger kilometres and freight tonne kilometres. Thereby this option allows for the allocation of emissions to the Party from which the passengers and cargo can be said to originate. This option is thereby based on the “polluter pays principle” and seems to be an equitable solution to the allocation problem. Thereby this allocation option seems to solve the problem that aircraft can carry passengers and freight originating in a variety of different countries and that these aviation activities may not necessarily be beneficial to the countries of departure and destination. One example of this could be transit passengers passing through a country with the sole purpose of shifting from one aircraft to another.

However, it should be mentioned that an equitable allocation is difficult to define. In this context, it appears to be fair to allocate emissions proportionally to the country to which the economic benefit accrues. However, in practice, the benefits generated by a flight may accrue to many different countries. Often, the most obvious beneficiaries are the countries of departure and arrival of a flight, while other beneficiaries include the country of the aircraft operator (the aircraft operator may not necessarily originate in the countries of departure and arrival), and the country of origin of the passengers and freight being transported (an aircraft operator originating in one country may transport passengers and products originating in several other countries).

The main disadvantage of option 7 is that it requires the same data as option 6 plus statistics on the origin of passengers and cargo that are not readily available. As noted in a recent study commissioned by the Danish Energy Agency in conjunction with the Danish Ministry for Transport, the airlines may have statistics on origin of passengers and freight but these are most often not publicly available. It may be possible for airlines to report these data, but the cost is unknown and there may be legal or competition implications. Another possibility mentioned in the Danish study would be to use surveys on travel behaviour [Danish Energy Agency 2001]. However, such surveys are not applicable in all countries and methodologies and accuracy may vary substantially.

As it is the case for option 6, option 7 would have to take into consideration the problems related to estimating aircraft fuel consumption and find ways to allocate these emissions between passengers and freight transported in passenger aircraft. Additionally, these data would have to be cross referenced with data on the origin of passengers and freight.

Option 7 may likely involve that a higher share of the emissions from international aviation will be allocated to Annex I countries than for any of the other options. This is because much of the fuel sold in non-Annex I countries is lifted by airlines registered in Annex I countries (see the comparison between option 7 and the other options in Table 21 in Appendix J). From an equity point of view option 4 could be considered more equitable for non-Annex I countries due to the fact that much of the fuel sold for international aviation in these countries may actually relate to air travel performed by people living in Annex I countries. However, it should be noted that emissions are allocated in proportion to GDP for option 7 in the examples shown in Table 21 because data on the nationality of passengers and cargo is generally not available. Thus, the origin of travellers and cargo cannot be estimated at present.

10.4.8 Allocation according to emissions generated within each party's national space (Option 8)

Option 8 is not among the options chosen by SBSTA for further investigation. Under this option emissions from international aviation are not fully allocated to individual countries since emissions over international territories are not allocated. This option has a precedent in other sectors, where emissions are allocated to the Party where the emissions occur in accordance with the IPCC Guidelines. In the case of aviation, it would require cross-referencing between fuel consumption and flight route. A correlation with aircraft type would lead to more accuracy. However, this option would not lead to full coverage of emissions from international aviation, many of which occur above international waters. It is therefore not seen as a feasible option by SBSTA [UNFCCC 1996a].

10.5 Discussion on allocation options

The twin-track approach suggested by the European Community aims at either not allocating emissions from international aviation in the national inventories of Parties (option 1), and to pursue limitation or reduction of these emissions through ICAO, or to include emissions from international aviation in the national inventory of the Parties in the second commitment period of the Kyoto Protocol. The remaining question seems to be whether it may be possible to reach an agreement on the allocation issue before 2005. Furthermore, recent developments suggest that ICAO may be heading towards investigating further the potential use of an open emissions trading scheme for aviation, allowing the aviation industry to buy emission permits in other sectors (see section 6.3). As recently pointed out by the UK Royal Commission on Environmental Pollution, if an emissions trading scheme is implemented, emissions from international aviation would have to be included in national greenhouse gas inventories of Parties to avoid double-counting of emission reductions attained in other sectors [Royal Commission on Environmental Pollution 2002]. Therefore, on the longer term, it seems that emissions from international aviation may have to be included also in the case where emissions reduction is pursued through ICAO.

SBSTA and the European Commission seem to agree that any allocation option chosen should be consistent with the ‘polluter pays’ principle and therefore should be equitable. The problem is that it is not always clear who should be considered as the ‘polluter’. Furthermore there is the problem that it should be possible to ensure the availability and accuracy of the data required for allocating emissions. Option 3, allocation to the Party where the fuel is sold, seems to be the easiest way to allocate emissions from aviation because the data are to a wide extent already available. Furthermore, a comparison of options 3, 5 and 6 show that, for most countries, the different methodologies used for each option do not produce radically different results (see Table 21 Appendix J). The main problem with the data reported by Parties to the UNFCCC on fuel consumed for international aviation, is that Member States are having difficulties in separating fuel consumed for domestic and international purposes (see section 7.2). In the case of option 3, the separation of fuel sales into domestic and international does not seem to be necessary if emissions from international aviation are to be included in national totals. However, option 3 does not take into account that aircraft can tanker extra fuel. Some countries that sell aviation fuel at relatively low prices may therefore be disfavoured by option 3 as compared to options 4 (allocation to the nationality of airlines), 5 (allocation to the country of destination or departure of aircraft) and 6 (allocation to Parties according to the country of departure or destination of passenger or cargo). Option 5 may solve the tankering problem but would require that Parties use models to calculate fuel consumption. Option 6 is disfavoured by the fact that it would require even more complicated models and data details than option 5. Options 3, 5 and 6 disfavours countries with a high level of aviation activities (for example countries that house large international hub airports) and this can cause equity considerations in cases where a large portion of the passengers and the freight is transported through the country in transit. Option 4 is disfavoured by the fact that countries do not currently gather data on the fuel consumption of national airlines. However, such data may be relatively easy to collect. The main disadvantage of option 4 seems to be that it does not necessarily always apply the ‘polluter pays’ principle because countries with large national airlines would be allocated a large proportion of global emissions, even if many of the flights do not depart or arrive within the country itself. However, option 4 may involve that a higher share of the emissions from international aviation will be allocated to Annex I countries than what is the case for options 3, 5 and 6. From an equity point of view option 4 could be considered more equitable for non-Annex I countries due to the fact that much of the fuel sold for international aviation in these countries may actually relate to air travel performed by people living in Annex I countries. Finally it should be mentioned that option 7 (allocation to the country of origin of passengers or owner of cargo) is probably the option which is most in line with the "polluter pays principle" and would most likely be favourable to non-Annex I countries and countries that house large international hub airports, but this option was discarded by SBSTA due to its substantial data requirements.

11 Conclusions

11.1 Availability and quality of the reporting by Parties to the UNFCCC on emissions from international aviation

Emissions from international aviation are complicated to estimate because the distinction between fuel used for domestic and international purposes is difficult. Another problem is the separation of fuel consumed by military aircraft from fuel consumed by civil aircraft.

Of the 32 Annex I Parties to the UNFCCC, 12 Parties report to the UNFCCC their CO_2 emissions from domestic aviation in all the years from 1990-1999 while 16 Parties report CO_2 emissions from international aviation in the period. Fewer Parties report the other emissions species from aviation for the whole period 1990-1999. Thus, currently there seems to be an inadequate geographical coverage of the data reported to the UNFCCC by Annex I Parties.

The UNFCCC Secretariat has requested CAEP to explore opportunities to examine and improve the quality of data reporting and comparability of aviation bunker fuel data [UNFCCC 2002a]. CAEPs Steering Group Meeting in September 2002 agreed that the ICAO Secretariat should take the necessary steps to organize a “scoping meeting”, involving the UNFCCC Secretariat, the rapporteurs of some of CAEPs working groups and experts on emissions inventory and data reporting. This initiative may bring new insights of relevance on the topic.

Eurostat and the International Energy Agency are preparing a joint manual on annual energy statistics to help Member States’ statistical authorities in filling in the energy statistics questionnaires. Eurostat also organises training workshops for officials from these authorities to discuss problems in data collection and reporting.

In a recent ECAC initiative European countries that participate in ECAC are encouraged to begin using the Detailed Corinair Methodology for calculating aircraft emissions. This may improve the ability of European countries to separate better emissions for international air transport from emissions for domestic air transport.

Another recent European initiative has been launched in a co-operation between the European Environment Agency, Eurocontrol and Eurostat to improve the data availability involving the use of a database supplied by Eurocontrol on actual flights performed in Europe and the use of the detailed Corinair emission calculation methodology. This effort may offer the opportunity to compare the data reported to the UNFCCC by European Parties to ECAC to the data calculated by EEA, Eurocontrol and Eurostat.

Eurostat finances specific projects in the Member States that aim at eliminating differences in energy data reported to Eurostat and those used for the calculation of CO_2 emissions reported to the UNFCCC. This work will also improve reporting of fuel consumption for international aviation. The projects will examine the energy data used in the submissions for the years 1990, 1995 and 2000, identifying and explaining the differences.

Besides the need to improve the methodologies for separating emissions from international aviation from emissions from domestic aviation there is another related question that is applicable to the reporting of aviation emissions in the European Union: Since the European Union has ratified the Kyoto Protocol the question arises whether the EU inventory should merely represent the sum of national inventories or if international intra-EU flights should be regarded as “domestic” in the EU inventory. If it is decided that the EU inventory should include international intra-EU flights as domestic these emissions have to be separated from the emissions reported as international by EU Member States. The emission calculation work currently under way in the co-operation between the European Environment Agency, Eurostat and Eurocontrol may be used to produce the data needed for that process.

Another problem that may remain in Europe is whether countries that have overseas territories should include flights to these areas in their national inventories or if these emissions should be reported as domestic emissions. According to the IPCC/UNFCCC reporting guidelines, administered territories should be included in national inventories, but for many countries they are not at present.

11.2 Availability and quality of inventory models

Currently Parties to the UNFCCC can use different methodologies of varying detail in their reporting of aviation emissions to the UNFCCC. A recent ECAC initiative aims at encouraging European countries that participate in ECAC to begin using the Detailed Corinair Methodology for calculating aircraft emissions. This may increase comparability and accuracy in the reporting from these countries to the UNFCCC.

Another recent initiative from the European Commission, Eurostat and EUROCONTROL, the so-called TRENDS project, may also improve the data material and may also give the European countries the possibility to crosscheck their reporting to the UNFCCC to the data from Eurostat. The TRENDS initiative also opens the possibility of calculating fuel use and emissions separately for intra-EU flights. Such data may be needed for the EU emission inventory submitted to the UNFCCC.

In the current situation only Annex I countries report emissions from aviation to the UNFCCC, but around one third of the CO_2 emissions from international aviation bunkers in 1999 relate to fuel sold in non-Annex I countries that have not yet agreed to reduction targets under the Climate Convention. Much of the fuel sold in non-Annex I countries may be consumed by airlines registered in Annex I countries or may be consumed by airlines transporting passengers and goods originating from Annex I countries. In case CAEP/ICAO intends to set up an emissions trading scheme the development of a yearly updated global inventory may be useful for calculating the total emissions from aviation, and more exact figures than those available today may also be needed to set up the system. A few global inventories have been conducted, but only for the year 1992, and these inventories are neither as detailed as for example the detailed CORINAIR methodology in their use of aircraft categories and emission indexes and neither do they contain accurate data on flights actually performed by all airlines globally.

A working group “Alternative Emissions Methodology Task group” has been set down by CAEP aiming at providing a better understanding of cruise emissions from aviation. Similarly, the European Commission is currently funding a programme in this area called “NEPAIR”. At this time, both projects are seeking to establish methodologies, but not standards, that could be used for certification of aircraft engine cruise emissions, that may be ready by 2003. Currently, the ICAO Emissions Databank only contains certificated data for Landing and Take Off (LTO) emissions but these new initiatives may in the future lead to recommendations for the development of standards for engine emissions at cruise [NEPAIR 2002].

11.3 Availability and quality of airline data

The fuel intensity estimates currently reported by different airlines are not directly comparable because of the differences in reporting methodologies. One example is that some airlines subtract a part of the fuel consumption which is attributable to freight transport in passenger aircraft, whereas others include this use in the estimate for the specific fuel use per revenue passenger kilometre. The division of fuel use between passengers and freight is not straightforward.

In the United States all airlines of a certain size are required by law to report their operating statistics to the Department of Transportation (the so-called “Form 41” arrangement). Therefore, in the United States, a comprehensive database exists with data for the fuel consumption of airlines and their aircraft spanning back several decades. This type of data can be used to make comparisons between airlines and for indexing their fuel efficiency. Such data are currently not being systematically reported to the same detail to governments, ICAO or elsewhere by airlines in other countries, although most airlines almost certainly gather such data for internal purposes.

One interesting question is whether it would be possible to establish some sort of global reporting requirements for all the World’s airlines in line with the US “Form 41” establishment. Since ICAO and CAEP are currently investigating possibilities for setting up voluntary agreements with airlines on reducing their specific emissions of CO_2 that process might involve setting up a scheme for airline reporting of fuel consumption and emissions. Furthermore, ICAO and CAEP are currently investigating the possibility to set up a global system for emissions trading. Such a system may come to involve the setting of an emission cap and the allocation of certain emission quotas to airlines and may also involve new reporting requirements for airlines.

Even though airline fuel consumption could be estimated using bottom-up modelling, for example using the Corinair-model, actual fuel consumption data from airlines may be needed because airlines might not be likely to accept being accredited for modelled fuel consumption data. At least at present, the models that have been constructed to calculate emissions from air traffic on a global scale do not contain a comprehensive database on flights actually being performed and furthermore relies on calculating fuel consumption and emissions by using less detailed aircraft categories than those used in the detailed CORINAIR methodology. Furthermore, all the models constructed to date are disadvantaged by not containing detailed information on the actual passenger loads and freight loads transported by the aircraft. These loads may become relevant for example in the case that airlines should become required to reduce their emissions per passenger kilometre and per freight tonne kilometre in a voluntary scheme. Detailed data on the passenger and freight loads may also become necessary for some of the more sophisticated models for allocating emissions from international aviation to Parties. However, these sophisticated models of allocation currently do not seem to be the most likely to be chosen if Parties to the Climate Convention should agree upon implementing an allocation option.

11.4 Allocation of emissions from international aviation

Parties to the UN Climate Convention have not yet been able to agree upon a methodology for allocating emissions from international aviation to Parties. Therefore, these emissions are not included in the national emission inventories that are to be reported to the UNFCCC by Annex I countries, but are reported separately under international bunkers in conjunction with emissions from international marine transport.

SBSTA has considered the following options for allocating emissions from international aviation [UNFCCC 1996a]:

9. No allocation
10. Allocation in proportion to national emissions of Parties
11. Allocation to the country where the fuel is sold
12. Allocation to the nationality of airlines
13. Allocation to the country of destination or departure of aircraft. Alternatively, the emissions related to the journey of an aircraft could be shared by the country of departure and the country of arrival
14. Allocation to Parties according to the country of departure or destination of passenger or cargo. Alternatively, the emissions related to the journey of passengers or cargo could be shared by the country of departure and the country of arrival
15. Allocation to the country of origin of passengers or owner of cargo
16. Allocation according to emissions generated within each party's national space

In 1996 SBSTA 4 concluded that options 1, 3, 4, 5 and 6 should be the basis for the further work and that with respect to option 1 (non-allocation) the responsibilities of the international community to address issues related to international bunker fuels should be recognised. Options 2, 7 and 8 were discarded by SBSTA for different reasons. The main reason for discarding option 2 is lack of equity because emissions are not allocated in proportion to the amount of aviation activities performed by each Party. The problem with option 7 is that the data needed on the origin of passengers and freight simply is not generally publicly available. Finally, option 8 was discarded because of its inadequate global coverage since all emissions above international waters are not allocated to Parties under this option.

By 1999, in a statement to SBSTA, the European Community stated that any decision on the inclusion of emissions from international bunker fuels in the national inventories of Parties (i.e. on allocation) should enter into force during the second commitment period. Based on the conclusions of SBSTA 4, the EU proposed a twin-track approach (main options I and II). Option I is not to allocate emissions from international aviation in the national inventories of Parties (option 1) as in the current situation. Limitation or reduction of emissions from international aviation would be under the general responsibility of the international community to be pursued through ICAO. The EU may consider option 1 (no allocation) further, if ICAO makes demonstrable progress, taking into account the overall emission reduction target of the Kyoto Protocol. Option II is to include emissions from international aviation in the national inventory of the Parties. With regard to the allocation options (options 3, 4, 5, and 6), EU propose that the SBSTA should compare and discuss these with a view to being in a position to reach agreement on one option by 2005.

The remaining question seems to be whether it may be possible to reach an agreement on the allocation issue before 2005. Furthermore, recent developments suggest that ICAO may be heading towards investigating further the potential use of an open emissions trading scheme for aviation, allowing the aviation industry to buy emission permits in other sectors. It has recently been pointed out by the UK Royal Commission on Environmental Pollution that if an emissions trading scheme is implemented, emissions from international aviation would have to be included in national greenhouse gas inventories of Parties to avoid double-counting of emission reductions attained in other sectors [Royal Commission on Environmental Pollution 2002]. Therefore, on the longer term, it seems that emissions from international aviation may have to be allocated to Parties also in the case where emissions reduction is pursued through ICAO.

SBSTA and the European Commission seem to agree that any allocation option chosen should be consistent with the 'polluter pays' principle and therefore should be equitable. The problem is that, in the case of international aviation activities, it is not always clear who should be considered as the 'polluter'. Furthermore there is the problem that it should be possible to ensure the availability and accuracy of the data required for allocating emissions. Option 3, allocation to the Party where the fuel is sold, seems to be the easiest way to allocate emissions from aviation because the data are to a wide extent already available. Furthermore, a comparison of options 3, 5 and 6 show that, for most countries, the different methodologies used for each option do not produce radically different results. The main problem with the data reported by Parties to the UNFCCC on fuel consumed for international aviation, is that Member States are having difficulties in separating fuel consumed for domestic and international purposes. The separation of fuel sales into domestic and international does not seem to be necessary if emissions from international aviation are to be included in national totals according to where the fuel is sold. However, option 3 does not take into account that aircraft can tanker extra fuel for a given trip. Some countries that sell aviation fuel at relatively low prices may therefore be disfavoured by option 3 as compared to options 4 (allocation to the nationality of airlines), 5 (allocation to the country of destination or departure of aircraft) and 6 (allocation to Parties according to the country of departure or destination of passenger or cargo). Option 5 may solve the tankering problem but would require that Parties use bottom-up models to calculate fuel consumption. Option 6 is disfavoured by the fact that it would require even more complicated models and data details than option 5. Options 3, 5 and 6 disfavours countries with a high level of aviation activities (for example countries that house large international hub airports) and this can cause equity considerations in cases where a large portion of the passengers and the freight is transported through the country in transit. Option 4 is disfavoured by the fact that countries do not currently gather data on the fuel consumption of national airlines. However, such data may be relatively easy to collect. The main disadvantage of option 4 seems to be that it does not necessarily always apply the ‘polluter pays’ principle because countries with large national airlines would be held responsible for a large proportion of global aviation emissions, even if many of the flights does not depart or arrive within the country itself. However, option 4 may involve that a higher share of the emissions from international aviation will be allocated to Annex I countries than what is the case for options 3, 5 and 6. From an equity point of view option 4 could be considered more equitable for non-Annex I countries due to the fact that much of the fuel sold for international aviation in these countries may actually relate to air travel performed by people living in Annex I countries. Finally it should be mentioned that option 7 (allocation to the country of origin of passengers or owner of cargo) is probably the option which is most in line with the “polluter pays” principle and would most likely be favourable to non-Annex I countries and to countries that house large international hub airports, but this option has been discarded by SBSTA due to its substantial data requirements.

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13 Appendixes A-K

Appendix A: UNFCCC CO_2 emission data for 1990.

	Total GHGs[a]	Total GHGs[b]	Total fuel combustion	Transport[c]	Civil aviation (domestic)	Navigation (domestic)	International marine	Share fuel	International aviation	Share fuel	International bunkers total	Share fuel
	(Gg) CO_2 equivalent	(Gg) CO_2 equivalent	(Gg) CO_2	(Gg) CO_2	(Gg) CO_2	(Gg) CO_2	(Gg) CO_2	%	(Gg) CO_2	%	(Gg) CO_2	%
Australia	423852	493781	265.220	59.219	2555	2223,9	2.056	0,8%	4.345	1,6%	6.401	2,4%
Austria	76.939	67725	46.685	13.570	69	47,5			941	2,0%	941	2,0%
Belarus												
Belgium	136.463	134406	104.190	20.569			13.069	12,5%	2.690	2,6%	15.759	15,1%
Bulgaria	157.090	152433	95.495	12.639			874	0,9%	892	0,9%	1.766	1,8%
Canada	607.183	545684	421.613	145.831	10385	4732,6	2.995	0,7%	2.729	0,6%	5.724	1,4%
Croatia												
Czech Republic	189.839	187558	160.073	7.959								
Denmark	69.950	69034	51.676	10.356	184	536,3	3.095	6,0%	1.795	3,5%	4.890	9,5%
Estonia	40.732	29415	37.183	2.656								
Finland	77.093	53295	53.893	12.475	403	226,8	1.800	3,3%	974	1,8%	2.774	5,1%
France	553.262	493645	355.945	119.156	4541	1908,1	8.137	2,3%	8.618	2,4%	16.755	4,7%
Germany	1.207.427	1173708	986.832	162.281			7.980	0,8%	11.589	1,2%	19.569	2,0%
Greece	105.475	106724	76.474	18.039	1458	1824,8	8.028	10,5%	2.452	3,2%	10.480	13,7%
Hungary	101.633	98536	80.089	7.741								
Iceland	2.939		1.631	721			99	6,1%	220	13,5%	319	19,5%
Ireland	53.497	48477	29.577	4.961			56	0,2%	1.116	3,8%	1.173	4,0%
Italy	518.461	498240	408.019	101.769			4.396	1,1%	4.388	1,1%	8.784	2,2%
Japan	1.237.456	1153574	1.052.782	204.665	6843	13345,9	17.348	1,6%	13.178	1,3%	30.525	2,9%
Latvia	31.025	20199	22.963	6.011								
Liechtenstein	260	238										
Lithuania	51.548	42700	37.332	5.791								
Luxembourg	13.448	13153	12.133	2.625								
Monaco	100		98	40								
Netherlands	215.800	214300	158.536	29.095	492	877,5	35.560	22,4%	4.450	2,8%	40.010	25,2%
New Zealand	73.064	51427	22.398	8.660			1.031	2,0%	1.353	6,0%	2.384	10,6%
Norway	52.027	42437	26.366	11.077	682	1917,4	1.478	5,6%	605	2,3%	2.083	7,9%
Poland	564.286	529540	462.998	28.238								
Portugal	64.644	60650	39.558	11.221	799	486,5	1.173	3,0%	883	2,2%	2.057	5,2%
Romania	264.879	261954	185.575	7.893								
Russian Federation	3.040.062	2648062	2.298.900				9.500	0,4%	2.900	0,1%	12.400	0,5%
Slovakia	72.530	70104	55.724	5.070								
Slovenia	19.233	16940	13.294	3.179								
Spain	305.832	276580	205.673	58.004	4372	1884,6	11.780	5,7%	3.161	1,5%	14.940	7,3%
Sweden	69.562	49270	51.278	18.736	818	648,5	2.163	4,2%	1.826	3,6%	3.989	7,8%
Switzerland	53.005	49817	39.673	14.144					3.200	8,1%	3.200	8,1%
Ukraine	919.189	867082	672.075									
United Kingdom	741.882	750673	556.554	116.581	2158	3460,9	6.559	1,2%	14.791	2,7%	21.349	3,8%
United States of America	6.038.192	4978292	4.835.688	1.422.585	127534	59432,8	67.272	1,4%	46.728	1,0%	114.001	2,4%
Total	18.149.860	16252693	10.954.248	2.653.557	163293	93.554	206.449	1,9%	135.824	1,2%	342.273	3,1%
European Community	4.207.214	4.007.364	3.133.576	697.683			103.796	3,3%	60.073	1,9%	163.869	5,2%

Table 12: UNFCCC DATA: ANTHROPOGENIC CO2 EMISSIONS 1990, Annex 1 Parties (GIGAGRAMS CO2)

a) excluding land-use change and forestry, b) including land-use change and forestry, c) including domestic civil aviation and navigation

Sources: FCCC/SBI/2001/13 and FCCC/SBI/2001/13corr.1 and FCCC/WEB/SAI/2001

Appendix B: UNFCCC CO_2 emission data for 1999.

	Total GHGs[a]	Total GHGs[b]	Total fuel combustion	Transport[c]	Civil aviation (domestic)	Navigation (domestic)	International marine	Share fuel	International aviation	Share fuel	International bunkers total	Share fuel
	(Gg) CO_2 equivalent	(Gg) CO_2 equivalent	(Gg) CO_2	(Gg) CO_2	(Gg) CO_2	(Gg) CO_2	(Gg) CO_2	%	(Gg) CO_2	%	(Gg) CO_2	%
Australia	489.092	529.859	326.378	69.503	4109	1438,4	2.450	0,8%	7.268	2,2%	9.718	3,0%
Austria	79.224	71.591	50.658	17.643	110	58,4			1.615	3,2%	1.615	3,2%
Belarus												
Belgium	151.193	149.348	111.175	22.611			14.586	13,1%	4.364	3,9%	18.950	17,0%
Bulgaria	77.697	71.089	44.513	6.212	35	8,2	26	0,1%	319	0,7%	345	0,8%
Canada	698.619	678.341	491.410	179.332	13168	4831,1	3.549	0,7%	3.032	0,6%	6.582	1,3%
Croatia												
Czech Republic	140.578	137.177	117.501	12.016	13	32,3			539	0,5%	539	0,5%
Denmark	73.173	72.197	54.561	12.156	150	426,2	4.146	7,6%	2.314	4,2%	6.460	11,8%
Estonia	19.878	11.771	16.425	1.204	67	18,2	362	2,2%			362	2,2%
Finland	76.243	65.422	56.781	12.734	465	501,3	1.764	3,1%	1.058	1,9%	2.822	5,0%
France	552.209	483.214	379.591	138.822	6068	2039,4	9.311	2,5%	13.753	3,6%	23.064	6,1%
Germany	982.407	948.977	832.036	186.110			6.479	0,8%	16.656	2,0%	23.135	2,8%
Greece	123.253	123.448	90.471	22.908	1679	2760,8	9.838	10,9%	2.266	2,5%	12.104	13,4%
Hungary	86.547	82.047	56.490	9.568		2,1			596	1,1%	596	1,1%
Iceland	3.308		1.930	819	32	18,1	164	8,5%	363	18,8%	527	27,3%
Ireland	65.337	58.603	39.603	9.734		131,5	543	1,4%	1.624	4,1%	2.166	5,5%
Italy	541.127	525.028	429.759	121.165	2397	6956	3.046	0,7%	7.468	1,7%	10.514	2,4%
Japan	1.307.430		1.147.945	253.670	10308	14347,2	17.322	1,5%	18.519	1,6%	35.841	3,1%
Latvia	13.614	2.949	7.385	2.087	89	71						
Liechtenstein												
Lithuania												
Luxembourg	6.004	5.709	4.740	1.337		5,6			1.019	21,5%	1.019	21,5%
Monaco	133		129	49								
Netherlands	230.085	228.385	170.619	34.700	420	807,3	41.143	24,1%	10.066	5,9%	51.210	30,0%
New Zealand	76.831	54.713	26.984	11.729	757	218,5	953	3,5%	1.959	7,3%	2.912	10,8%
Norway	56.171	38.429	31.728	13.957	1121	2829,3	2.733	8,6%	975	3,1%	3.709	11,7%
Poland	400.260	356.712	318.963	31.382			1.378	0,4%	346	0,1%	1.723	0,5%
Portugal	79.304	74.612	52.449	18.650	1173	511,5	1.208	2,3%	874	1,7%	2.082	4,0%
Romania												
Russian Federation												
Slovakia	51.796	49.170	40.783	4.821	28	141,9						
Slovenia												
Spain	380.192	350.940	256.801	83.922	4822	3612,9	19.074	7,4%	7.746	3,0%	26.820	10,4%
Sweden	70.692	46.387	51.722	19.886	795	661,4	4.750	9,2%	2.103	4,1%	6.854	13,3%
Switzerland	53.455	49.229	41.104	15.316	255	70,8			4.520	11,0%	4.520	11,0%
Ukraine												
United Kingdom	637.865	642.597	509.917	121.576	2822	2710	6.357	1,2%	25.539	5,0%	31.896	6,3%
United States of America	6.746.072	5.755.672	5.453.088	1.677.714	148345	65551,7	46.376	0,9%	60.970	1,1%	107.345	2,0%
Total	14.269.794	12.974.490	11.213.640	3.113.332	199228	110761,1	197.556	1,8%	197.873	1,8%	395.430	3,5%
European Community	4.037.153	3.836.170	3.089.405	824.974			125.727	4,1%	97.963	3,2%	223.690	7,2%

Table 13: UNFCCC data: Anthropogenic CO2 emissions 1999, Annex 1 Parties (GIGAGRAMS CO2)
a) excluding land-use change and forestry, b) including land-use change and forestry, c) including domestic civil aviation and navigation.
Sources: FCCC/SBI/2001/13 and FCCC/SBI/2001/13corr.1 and FCCC/WEB/SAI/2001

Appendix C: UNFCCC data for CO_2 emissions from transport 1990 and 1999.

	Total fuel combustion			Transport[c]			Civil aviation (domestic)			Navigation (domestic)			International marine			International aviation		
	1990	1999	Change	1990	1999	Change	1990	1999	Change	1990	1999	Change	1990	1999	Change	1990	1999	Change
Australia	265.220	326.378	23,1%	59.219	69.503	17,4%	2555	4109	60,8%	2223,9	1438,4	-35,3%	2.056	2.450	19,2%	4.345	7.268	67,3%
Austria	46.685	50.658	8,5%	13.570	17.643	30,0%	69	110	59,4%	47,5	58,4	22,9%				941	1.615	71,6%
Belarus																		
Belgium	104.190	111.175	6,7%	20.569	22.611	9,9%							13.069	14.586	11,6%	2.690	4.364	62,2%
Bulgaria	95.495	44.513	-53,4%	12.639	6.212	-50,9%		35			8,2		874	26	-97,1%	892	319	-64,2%
Canada	421.613	491.410	16,6%	145.831	179.332	23,0%	10385	13168	26,8%	4732,6	4831,1	2,1%	2.995	3.549	18,5%	2.729	3.032	11,1%
Croatia																		
Czech Republic	160.073	117.501	-26,6%	7.959	12.016	51,0%		13			32,3						539	
Denmark	51.676	54.561	5,6%	10.356	12.156	17,4%	184	150	-18,5%	536,3	426,2	-20,5%	3.095	4.146	33,9%	1.795	2.314	29,0%
Estonia	37.183	16.425	-55,8%	2.656	1.204	-54,7%		67			18,2			362				
Finland	53.893	56.781	5,4%	12.475	12.734	2,1%	403	465	15,4%	226,8	501,3	121,0%	1.800	1.764	-2,0%	974	1.058	8,6%
France	355.945	379.591	6,6%	119.156	138.822	16,5%	4541	6068	33,6%	1908,1	2039,4	6,9%	8.137	9.311	14,4%	8.618	13.753	59,6%
Germany	986.832	832.036	-15,7%	162.281	186.110	14,7%							7.980	6.479	-18,8%	11.589	16.656	43,7%
Greece	76.474	90.471	18,3%	18.039	22.908	27,0%	1458	1679	15,2%	1824,8	2760,8	51,3%	8.028	9.838	22,5%	2.452	2.266	-7,6%
Hungary	80.089	56.490	-29,5%	7.741	9.568	23,6%					2,1						596	
Iceland	1.631	1.930	18,4%	721	819	13,6%		32			18,1		99	164	65,5%	220	363	65,4%
Ireland	29.577	39.603	33,9%	4.961	9.734	96,2%					131,5		56	543	864,5%	1.116	1.624	45,4%
Italy	408.019	429.759	5,3%	101.769	121.165	19,1%		2397			6956		4.396	3.046	-30,7%	4.388	7.468	70,2%
Japan	1.052.782	1.147.945	9,0%	204.665	253.670	23,9%	6843	10308	50,6%	13346	14347,2	7,5%	17.348	17.322	-0,1%	13.178	18.519	40,5%
Latvia	22.963	7.385	-67,8%	6.011	2.087	-65,3%		89			71							
Liechtenstein																		
Lithuania	37.332			5.791														
Luxembourg	12.133	4.740	-60,9%	2.625	1.337	-49,1%					5,6						1.019	
Monaco	98	129	32,3%	40	49	21,9%												
Netherlands	158.536	170.619	7,6%	29.095	34.700	19,3%	492	420	-14,6%	877,5	807,3	-8,0%	35.560	41.143	15,7%	4.450	10.066	126,2%
New Zealand	22.398	26.984	20,5%	8.660	11.729	35,4%		757			218,5		1.031	953	-7,6%	1.353	1.959	44,8%
Norway	26.366	31.728	20,3%	11.077	13.957	26,0%	682	1121	64,4%	1917,4	2829,3	47,6%	1.478	2.733	84,9%	605	975	61,3%
Poland	462.998	318.963	-31,1%	28.238	31.382	11,1%								1.378			346	
Portugal	39.558	52.449	32,6%	11.221	18.650	66,2%	799	1173	46,8%	486,5	511,5	5,1%	1.173	1.208	3,0%	883	874	-1,1%
Romania	185.575			7.893														
Russian Federation	2.298.900												9.500			2.900		-100,0%
Slovakia	55.724	40.783	-26,8%	5.070	4.821	-4,9%		28			141,9							
Slovenia	13.294			3.179														
Spain	205.673	256.801	24,9%	58.004	83.922	44,7%	4372	4822	10,3%	1884,6	3612,9	91,7%	11.780	19.074	61,9%	3.161	7.746	145,1%
Sweden	51.278	51.722	0,9%	18.736	19.886	6,1%	818	795	-2,8%	648,5	661,4	2,0%	2.163	4.750	119,6%	1.826	2.103	15,2%
Switzerland	39.673	41.104	3,6%	14.144	15.316	8,3%		255			70,8					3.200	4.520	41,3%
Ukraine	672.075																	
United Kingdom	556.554	509.917	-8,4%	116.581	121.576	4,3%	2158	2822	30,8%	3460,9	2710	-21,7%	6.559	6.357	-3,1%	14.791	25.539	72,7%
United States of America	4.835.688	5.453.088	12,8%	1.422.585	1.677.714	17,9%	127534	148345	16,3%	59433	65551,7	10,3%	67.272	46.376	-31,1%	46.728	60.970	30,5%
European Community	3.133.576	3.089.405	-1,4%	697.683	824.974	18,2%							103.796	125.727	21,1%	60.073	97.963	63,1%

Table 14: UNFCCC data: Comparison of CO2 emissions from transport in 1990 and 1999 (Gigagrams CO2) a) excluding land-use change and forestry, b) including land-use change and forestry, c) including domestic civil aviation and navigation. Sources: FCCC/SBI/2001/13 and FCCC/SBI/2001/13corr.1 and FCCC/WEB/SAI/2001.

Appendix D: Comparison of UNFCCC and IEA data for international aviation and marine CO_2 emissions 1990 and 1999.

	Total fuel combustion				International marine						International aviation					
	1990		1999		1990			1999			1990			1999		
	UNFCCC	IEA*	UNFCCC	IEA*	UNFCCC	IEA	Diff.	UNFCCC	IEA	Diff.	UNFCCC	IEA	Diff.	UNFCCC	IEA	Diff.
Australia	265.220	258.900	326.378	326.600	2.056	2.040	-0,8%	2.450	2.520	2,8%	4.345	4.300	-1,0%	7.268	7.150	-1,6%
Austria	46.685		50.658	61.700							941	920	-2,3%	1.615	1.540	-4,7%
Belarus				56.270												
Belgium	104.190		111.175	116.400	13.069	13.050	-0,1%	14.586	14.000	-4,0%	2.690	2.920	8,6%	4.364	4.530	3,8%
Bulgaria	95.495		44.513	43.110	874	180	-79,4%	26	30	17,5%	892	730	-18,2%	319	210	-34,2%
Canada	421.613	430.200	491.410	503.600	2.995	2.880	-3,8%	3.549	3.450	-2,8%	2.729	2.700	-1,1%	3.032	3.090	1,9%
Croatia				18.860					70						110	
Czech Republic	160.073		117.501	110.000								670		539	360	-33,2%
Denmark	51.676		54.561	53.600	3.095	3.050	-1,5%	4.146	4.110	-0,9%	1.795	1.930	7,5%	2.314	2.330	0,7%
Estonia	37.183		16.425	14.160				362	570	57,4%					70	
Finland	53.893		56.781	55.800	1.800	1.790	-0,6%	1.764	1.760	-0,2%	974	1.010	3,7%	1.058	1.090	3,0%
France	355.945		379.591	380.600	8.137	8.010	-1,6%	9.311	9.170	-1,5%	8.618	9.670	12,2%	13.753	15.780	14,7%
Germany	986.832		832.036	825.100	7.980	7.850	-1,6%	6.479	6.560	1,3%	11.589	14.210	22,6%	16.656	20.490	23,0%
Greece	76.474		90.471	84.200	8.028	8.030	0,0%	9.838	9.840	0,0%	2.452	2.430	-0,9%	2.266	2.850	25,8%
Hungary	80.089		56.490	60.500								510		596	640	7,3%
Iceland	1.631	1.900	1.930	2.100	99	100	1,0%	164	160	-2,4%	220	220	0,2%	363	360	-0,9%
Ireland	29.577	30.300	39.603	39.900	56	60	6,6%	543	540	-0,5%	1.116	1.070	-4,2%	1.624	1.540	-5,2%
Italy	408.019	399.400	429.759	422.400	4.396	8.430	91,7%	3.046	7.640	150,8%	4.388	6.540	49,0%	7.468	10.060	34,7%
Japan	1.052.782	1.018.700	1.147.945	1.127.400	17.348	16.320	-5,9%	17.322	16.660	-3,8%	13.178		-100,0%	18.519		-100,0%
Latvia	22.963		7.385	7.230												
Liechtenstein																
Lithuania	37.332								230							
Luxembourg	12.133	10.500	4.740	7.500								400		1.019	1.020	0,1%
Monaco	98		129													
Netherlands	158.536	159.800	170.619	170.600	35.560	34.530	-2,9%	41.143	40.210	-2,3%	4.450	4.470	0,4%	10.066	10.130	0,6%
New Zealand	22.398	21.900	26.984	29.800	1.031	1.020	-1,1%	953	890	-6,6%	1.353	1.360	0,5%	1.959	1.960	0,0%
Norway	26.366	28.500	31.728	38.200	1.478	1.410	-4,6%	2.733	2.690	-1,6%	605	1.290	113,3%	975	1.740	78,4%
Poland	462.998	340.700	318.963	304.400		1.350		1.378	1.710	24,1%		630		346	800	131,5%
Portugal	39.558	39.600	52.449	60.400	1.173	1.930	64,5%	1.208	1.860	54,0%	883	1.540	74,3%	874	1.640	87,7%
Romania	185.575	166.900										720			400	
Russian Federation	2.298.900				9.500						2.900					
Slovakia	55.724	55.400	40.783	40.100												
Slovenia	13.294	12.490										80			60	
Spain	205.673	206.400	256.801	266.800	11.780	11.560	-1,9%	19.074	18.680	-2,1%	3.161	3.440	8,8%	7.746	7.750	0,1%
Sweden	51.278	51.200	51.722	51.800	2.163	2.110	-2,5%	4.750	4.800	1,0%	1.826	860	-52,9%	2.103	1.470	-30,1%
Switzerland	39.673	39.900	41.104	41.100		60			40		3.200	3.110	-2,8%	4.520	4.490	-0,7%
Ukraine	672.075			337.260											2.080	
United Kingdom	556.554	560.300	509.917	519.200	6.559	7.920	20,8%	6.357	7.290	14,7%	14.791	12.980	-12,2%	25.539	18.760	-26,5%
United States of America	4.835.688	4.829.400	5.453.088	5.522.400	67.272	91.050	35,3%	46.376	82.550	78,0%	46.728	38.780	-17,0%	60.970	56.830	-6,8%
World		20.700.100		22.818.200		348.222			423.450			279.500			334.720	

Comparison of CO2 emission data for total fuel combustion and international marine and international aviation bunkers from UNFCCC and IEA for 1990 and 1999 (Gg CO2)
*Sectoral approach
Sources: FCCC/SBI/2001/13 and FCCC/SBI/2001/13corr.1 and FCCC/WEB/SAI/2001and IEA 2001, “CO2 emissions from fuel combustion 1971-1999”, International Energy Agency, Paris.

Appendix E: IEA data on CO2 emissions from international bunkers 1999 and comparisons to national totals.

	International marine bunkers CO_2	International aviation bunkers CO_2	Population	National CO2 emissions	International Marine bunkers	International aviation bunkers	CO2/cap	International marine bunkers CO2/cap	International aviation bunkers CO2/cap
	[million tonnes]	[million tonnes]	[millions]	[million tonnes]	[share of national total]	[share of national total]	[tonnes]	[tonnes]	[tonnes]
Canada	3,45	3,09	30,49	503,6	0,7%	0,6%	16,5	0,11	0,10
Mexico	2,61	8,16	97,43	348,3	0,7%	2,3%	3,6	0,03	0,08
United States	82,56	56,83	273	5522,4	1,5%	1,0%	20,2	0,30	0,21
Austria		1,54	8,09	61,7	0,0%	2,5%	7,6	0,00	0,19
Belgium	14	4,53	10,22	116,4	12,0%	3,9%	11,4	1,37	0,44
Czech Republic		0,53	10,28	110	0,0%	0,5%	10,7	0,00	0,05
Denmark	4,11	2,33	5,32	53,6	7,7%	4,3%	10,1	0,77	0,44
Finland	1,76	1,09	5,17	55,8	3,2%	2,0%	10,8	0,34	0,21
France	9,17	15,78	60,27	380,6	2,4%	4,1%	6,3	0,15	0,26
Germany	6,56	20,49	82,03	825,1	0,8%	2,5%	10,1	0,08	0,25
Greece	9,84	2,85	10,53	84,2	11,7%	3,4%	8,0	0,93	0,27
Hungary		0,64	10,07	60,5	0,0%	1,1%	6,0	0,00	0,06
Iceland	0,16	0,36	0,28	2,1	7,6%	17,1%	7,5	0,57	1,29
Ireland	0,54	1,54	3,75	39,9	1,4%	3,9%	10,6	0,14	0,41
Italy	7,64	10,06	57,63	422,4	1,8%	2,4%	7,3	0,13	0,17
Luxembourg		1,02	0,44	7,5	0,0%	13,6%	17,0	0,00	2,32
Netherlands	40,21	10,13	15,81	170,6	23,6%	5,9%	10,8	2,54	0,64
Norway	2,69	1,74	4,46	38,2	7,0%	4,6%	8,6	0,60	0,39
Poland	1,71	0,8	38,65	304,4	0,6%	0,3%	7,9	0,04	0,02
Portugal	1,86	1,64	9,98	60,4	3,1%	2,7%	6,1	0,19	0,16
Slovak Republic			5,4	40,1	0,0%	0,0%	7,4	0,00	0,00
Spain	18,68	7,75	39,42	266,8	7,0%	2,9%	6,8	0,47	0,20
Sweden	4,8	1,47	8,86	51,8	9,3%	2,8%	5,8	0,54	0,17
Switzerland	0,04	4,49	7,14	41,1	0,1%	10,9%	5,8	0,01	0,63
Turkey	0,89	1,52	65,82	181,2	0,5%	0,8%	2,8	0,01	0,02
United Kingdom	7,29	18,76	59,5	519,2	1,4%	3,6%	8,7	0,12	0,32
Australia	2,52	7,15	18,97	326,6	0,8%	2,2%	17,2	0,13	0,38
Japan	16,66	18,86	126,69	1127,4	1,5%	1,7%	8,9	0,13	0,15
Korea	20,71	1,43	46,86	400,9	5,2%	0,4%	8,6	0,44	0,03
New Zealand	0,89	1,96	3,81	29,8	3,0%	6,6%	7,8	0,23	0,51
Algeria	0,74	1,03	29,95	65,87	1,1%	1,6%	2,2	0,02	0,03
Angola		0,92	12,36	4,77	0,0%	19,3%	0,4	0,00	0,07
Benin		0,1	6,11	1,26	0,0%	7,9%	0,2	0,00	0,02
Cameroon	0,03	0,18	14,69	2,4	1,3%	7,5%	0,2	0,00	0,01
Congo			2,86	0,37	0,0%	0,0%	0,1	0,00	0,00
Dem. Rep. of Congo	0,01	0,36	49,78	2,06	0,5%	17,5%	0,0	0,00	0,01
Cote d'ivoire	0,28	0,27	15,55	6,3	4,4%	4,3%	0,4	0,02	0,02
Egypt	8,12		62,66	97,02	8,4%	0,0%	1,5	0,13	0,00
Eritrea		0,03	3,99	0,64	0,0%	4,7%	0,2	0,00	0,01
Ethiopia		0,22	62,78	2,92	0,0%	7,5%	0,0	0,00	0,00
Gabon	0,2	0,27	1,21	1,51	13,2%	17,9%	1,2	0,17	0,22
Ghana	0,08	0,19	18,79	4,37	1,8%	4,3%	0,2	0,00	0,01
Kenya	0,26		29,41	7,87	3,3%	0,0%	0,3	0,01	0,00
Libya	0,28	0,99	5,42	37,98	0,7%	2,6%	7,0	0,05	0,18
Morocco	0,04	0,91	28,24	29,48	0,1%	3,1%	1,0	0,00	0,03
Mozambique		0,09	17,3	1,15	0,0%	7,8%	0,1	0,00	0,01
Namibia			1,7	2,22	0,0%	0,0%	1,3	0,00	0,00
Nigeria	1,07	1,36	123,9	40,39	2,6%	3,4%	0,3	0,01	0,01
Senegal	0,24	0,55	9,29	3,5	6,9%	15,7%	0,4	0,03	0,06

South Africa	10,22	2,76	42,11	291,24	3,5%	0,9%	6,9	0,24	0,07
Sudan	0,03	0,12	28,99	5,36	0,6%	2,2%	0,2	0,00	0,00
Tanzania	0,07	0,12	32,92	1,53	4,6%	7,8%	0,0	0,00	0,00
Togo		0,06	4,57	0,87	0,0%	6,9%	0,2	0,00	0,01
Tunisia	0,03	0,98	9,46	17,25	0,2%	5,7%	1,8	0,00	0,10
Zambia		0,12	9,88	1,84	0,0%	6,5%	0,2	0,00	0,01
Zimbabwe		0,37	11,9	13,1	0,0%	2,8%	1,1	0,00	0,03
Other Africa	2,17	1,81	139,44	16,86	12,9%	10,7%	0,1	0,02	0,01
Bahrain		1,04	0,67	13,76	0,0%	7,6%	20,5	0,00	1,55
Iran	2,24	0,69	62,98	271,25	0,8%	0,3%	4,3	0,04	0,01
Iraq		1,31	22,8	70,69	0,0%	1,9%	3,1	0,00	0,06
Israel	0,46	1,86	6,11	55,59	0,8%	3,3%	9,1	0,08	0,30
Jordan	0,03	0,69	4,74	13,63	0,2%	5,1%	2,9	0,01	0,15
Kuwait	2	1,2	1,92	61,39	3,3%	2,0%	32,0	1,04	0,63
Lebanon	0,03	0,4	4,27	15,59	0,2%	2,6%	3,7	0,01	0,09
Oman	0,17	0,57	2,35	19,89	0,9%	2,9%	8,5	0,07	0,24
Qatar			0,57	35,85	0,0%	0,0%	62,9	0,00	0,00
Saudi Arabia	5,96	7,1	20,2	256,92	2,3%	2,8%	12,7	0,30	0,35
Syria		0,83	15,71	51,37	0,0%	1,6%	3,3	0,00	0,05
United Arab Emirates	0,35	2,11	2,82	66,46	0,5%	3,2%	23,6	0,12	0,75
Yemen	0,31	0,3	17,05	8,13	3,8%	3,7%	0,5	0,02	0,02
Albania			3,38	1,47	0,0%	0,0%	0,4	0,00	0,00
Bulgaria	0,03	0,21	8,21	43,11	0,1%	0,5%	5,3	0,00	0,03
Cyprus	0,48	0,83	0,76	6,09	7,9%	13,6%	8,0	0,63	1,09
Gibraltar	2,64	0,01	0,03	0,4	660,0%	2,5%	13,3	88,00	0,33
Malta	0,15	0,54	0,38	2,51	6,0%	21,5%	6,6	0,39	1,42
Romania		0,4	22,46	81,82	0,0%	0,5%	3,6	0,00	0,02
Former Yugoslavia	0,07	0,87	22,97	89,17	0,1%	1,0%	3,9	0,00	0,04
Bosnia and Herzegovina			3,88	4,19	0,0%	0,0%	1,1	0,00	0,00
Croatia	0,07	0,11	4,46	18,86	0,4%	0,6%	4,2	0,02	0,02
Macedonia		0,13	2,02	9,49	0,0%	1,4%	4,7	0,00	0,06
Slovenia		0,06	1,99	15,02	0,0%	0,4%	7,5	0,00	0,03
Yugoslavia		0,57	40,62	41,61	0,0%	1,4%	1,0	0,00	0,01
Armenia		0,07	3,81	2,96	0,0%	2,4%	0,8	0,00	0,02
Azerbaijan		0,49	7,98	26,5	0,0%	1,8%	3,3	0,00	0,06
Belarus			10,03	56,27	0,0%	0,0%	5,6	0,00	0,00
Estonia	0,57	0,07	1,44	14,16	4,0%	0,5%	9,8	0,40	0,05
Georgia		0,03	5,45	5,54	0,0%	0,5%	1,0	0,00	0,01
Kazakhstan		0,72	14,93	112,01	0,0%	0,6%	7,5	0,00	0,05
Kyrgyzstan			4,87	4,72	0,0%	0,0%	1,0	0,00	0,00
Latvia		0,09	2,43	7,23	0,0%	1,2%	3,0	0,00	0,04
Lithuania	0,23	0,08	3,7	12,86	1,8%	0,6%	3,5	0,06	0,02
Moldova		0,04	4,28	6,38	0,0%	0,6%	1,5	0,00	0,01
Russia		26,17	146,2	1461,78	0,0%	1,8%	10,0	0,00	0,18
Tajikistan		0,02	6,24	5,69	0,0%	0,4%	0,9	0,00	0,00
Turkmenistan			4,78	33,73	0,0%	0,0%	7,1	0,00	0,00
Ukraine		2,08	49,95	337,26	0,0%	0,6%	6,8	0,00	0,04
Uzbekistan			24,41	113,76	0,0%	0,0%	4,7	0,00	0,00
Argentina	2,31		36,58	134,24	1,7%	0,0%	3,7	0,06	0,00
Bolivia			8,14	9,38	0,0%	0,0%	1,2	0,00	0,00
Brazil	8,2		167,97	292,01	2,8%	0,0%	1,7	0,05	0,00
Chile	1,39	1,9	15,02	52,42	2,7%	3,6%	3,5	0,09	0,13
Colombia	0,54	2,06	41,54	56,24	1,0%	3,7%	1,4	0,01	0,05
Costa Rica	0,39	0,36	3,59	4,58	8,5%	7,9%	1,3	0,11	0,10
Cuba	0,36	0,88	11,18	28,8	1,3%	3,1%	2,6	0,03	0,08
Dominican Republic		0,21	8,4	16,78	0,0%	1,3%	2,0	0,00	0,03
Equador	0,75	0,5	12,41	15,85	4,7%	3,2%	1,3	0,06	0,04
El salvador		0,21	6,15	5,23	0,0%	4,0%	0,9	0,00	0,03
Guatemala	0,38	0,15	11,09	8,04	4,7%	1,9%	0,7	0,03	0,01
Haiti		0,09	7,8	1,47	0,0%	6,1%	0,2	0,00	0,01
Honduras		0,09	6,32	4,31	0,0%	2,1%	0,7	0,00	0,01
Jamaica	0,12	0,74	2,6	9,8	1,2%	7,6%	3,8	0,05	0,28
Netherlands Antilles	5,37		0,22	3,24	165,7%	0,0%	14,7	24,41	0,00
Nicaragua		0,08	4,92	3,38	0,0%	2,4%	0,7	0,00	0,02
Panama	3,27	0,02	2,81	4,6	71,1%	0,4%	1,6	1,16	0,01
Paraguay		0,05	5,36	3,99	0,0%	1,3%	0,7	0,00	0,01
Peru	0,14	1,22	25,23	25,3	0,6%	4,8%	1,0	0,01	0,05
Trinidad and Tobago	0,04	0,21	1,29	15,21	0,3%	1,4%	11,8	0,03	0,16

Uruguay	0,91		3,31	6,64	13,7%	0,0%	2,0	0,27	0,00
Venezuela	1,66	0,88	23,71	123,87	1,3%	0,7%	5,2	0,07	0,04
Other Latin America	0,73	1,3	3,55	10,81	6,8%	12,0%	3,0	0,21	0,37
Banladesh	0,11	0,41	127,67	25,21	0,4%	1,6%	0,2	0,00	0,00
Brunei		0,19	0,32	4,92	0,0%	3,9%	15,4	0,00	0,59
Chinese Taipei	12,1	6,83	22,03	201,18	6,0%	3,4%	9,1	0,55	0,31
India	0,28	6,75	997,52	875,72	0,0%	0,8%	0,9	0,00	0,01
Indonesia	0,98	1,38	207,02	246,83	0,4%	0,6%	1,2	0,00	0,01
DPR of Korea			23,41	200,75	0,0%	0,0%	8,6	0,00	0,00
Malaysia	1,24	4,22	22,71	99,14	1,3%	4,3%	4,4	0,05	0,19
Myanmar		0,17	45,03	8,72	0,0%	1,9%	0,2	0,00	0,00
Nepal		0,14	23,38	2,91	0,0%	4,8%	0,1	0,00	0,01
Pakistan	0,05	2,32	134,79	89,54	0,1%	2,6%	0,7	0,00	0,02
Philippines	0,78	1,52	74,26	68	1,1%	2,2%	0,9	0,01	0,02
Singapore	54,74	7,16	3,95	45,79	119,5%	15,6%	11,6	13,86	1,81
Sri Lanka			18,99	10,23	0,0%	0,0%	0,5	0,00	0,00
Thailand	2,72	7,84	60,25	147,49	1,8%	5,3%	2,4	0,05	0,13
Vietnam		1,06	77,52	36,6	0,0%	2,9%	0,5	0,00	0,01
Other Asia	0,24	0,73	34,19	6,87	3,5%	10,6%	0,2	0,01	0,02
People's Republic of China	11,59	1,53	1253,6	2931,35	0,4%	0,1%	2,3	0,01	0,00
Hong Kong	11,12	8,51	6,72	43,03	25,8%	19,8%	6,4	1,65	1,27
World	**423,52**	**335,75**	**5998,03**	**22148,31**	**1,9%**	**1,5%**	**3,7**	**0,07**	**0,06**

Table 15: IEA data on CO2 emissions from international bunkers 1999 and comparisons to national totals. Source: [IEA 2001, "CO2 emissions from fuel combustion 1971-1999"].

Appendix F: IEA data on CO2 emissions from international bunkers and comparisons to national totals - ranked.

	Yearly CO_2 emissions from international aviation and marine bunkers per cap [tonnes]		International aviation and marine bunkers' share of yearly national CO_2 emissions		International aviation bunkers' share of yearly national CO_2 emissions		International marine bunkers' share of yearly national CO_2 emissions
World	**0,13**	**World**	**3,4%**	**World**	**1,5%**	**World**	**1,9%**
Gibraltar	88,33	Gibraltar	662,5%	Malta	21,5%	Gibraltar	660,0%
Netherlands Antilles	24,41	Netherlands Antilles	165,7%	Hong Kong	19,8%	Netherlands Antilles	165,7%
Singapore	15,67	Singapore	135,2%	Angola	19,3%	Singapore	119,5%
Netherlands	3,18	Panama	71,5%	Gabon	17,9%	Panama	71,1%
Hong Kong	2,92	Hong Kong	45,6%	Dem. Rep. of Congo	17,5%	Hong Kong	25,8%
Luxembourg	2,32	Gabon	31,1%	Iceland	17,1%	Netherlands	23,6%
Iceland	1,86	Netherlands	29,5%	Senegal	15,7%	Uruguay	13,7%
Malta	1,82	Malta	27,5%	Singapore	15,6%	Gabon	13,2%
Belgium	1,81	Iceland	24,8%	Cyprus	13,6%	Other Africa	12,9%
Cyprus	1,72	Other Africa	23,6%	Luxembourg	13,6%	Belgium	12,0%
Kuwait	1,67	Senegal	22,6%	Other Latin America	12,0%	Greece	11,7%
Bahrain	1,55	Cyprus	21,5%	Switzerland	10,9%	Sweden	9,3%
Denmark	1,21	Angola	19,3%	Other Africa	10,7%	Costa Rica	8,5%
Greece	1,21	Other Latin America	18,8%	Other Asia	10,6%	Egypt	8,4%
Panama	1,17	Dem. Rep. of Congo	18,0%	Benin	7,9%	Cyprus	7,9%
Norway	0,99	Costa Rica	16,4%	Costa Rica	7,9%	Denmark	7,7%
United Arab Emirates	0,87	Belgium	15,9%	United Republic of Tanzania	7,8%	Iceland	7,6%
Chinese Taipei	0,86	Greece	15,1%	Mozambique	7,8%	Norway	7,0%
New Zealand	0,75	Other Asia	14,1%	Bahrain	7,6%	Spain	7,0%
Sweden	0,71	Uruguay	13,7%	Jamaica	7,6%	Senegal	6,9%
Spain	0,67	Luxembourg	13,6%	Ethiopia	7,5%	Other Latin America	6,8%
Saudi Arabia	0,65	United Republic of Tanzania	12,4%	Cameroon	7,5%	Chinese Taipei	6,0%
Switzerland	0,63	Sweden	12,1%	Togo	6,9%	Malta	6,0%
Brunei	0,59	Denmark	12,0%	New Zealand	6,6%	Korea	5,2%
Other Latin America	0,57	Norway	11,6%	Zambia	6,5%	Equador	4,7%
Ireland	0,55	Switzerland	11,0%	Haiti	6,1%	Guatemala	4,7%
Finland	0,55	Spain	9,9%	Netherlands	5,9%	Tanzania	4,6%
United States	0,51	New Zealand	9,6%	Tunisia	5,7%	Cote d'ivoire	4,4%
Australia	0,51	Chinese Taipei	9,4%	Thailand	5,3%	Estonia	4,0%
Korea	0,47	Jamaica	8,8%	Jordan	5,1%	Yemen	3,8%
Estonia	0,44	Cameroon	8,8%	Peru	4,8%	South Africa	3,5%
United Kingdom	0,44	Cote d'ivoire	8,7%	Nepal	4,8%	Other Asia	3,5%
France	0,41	Egypt	8,4%	Eritrea	4,7%	Kenya	3,3%
Gabon	0,39	Benin	7,9%	Norway	4,6%	Kuwait	3,3%

Israel	0,38	Equador	7,9%	Ghana	4,3%	Finland	3,2%
Portugal	0,35	Mozambique	7,8%	Denmark	4,3%	Portugal	3,1%
Jamaica	0,33	Bahrain	7,6%	Cote d'ivoire	4,3%	New Zealand	3,0%
Germany	0,33	Ethiopia	7,5%	Malaysia	4,3%	Brazil	2,8%
Oman	0,31	Yemen	7,5%	France	4,1%	Chile	2,7%
South Africa	0,31	Thailand	7,2%	El salvador	4,0%	Nigeria	2,6%
Italy	0,31	Togo	6,9%	Belgium	3,9%	France	2,4%
Japan	0,28	Guatemala	6,6%	Brunei	3,9%	Saudi Arabia	2,3%
Uruguay	0,27	France	6,6%	Ireland	3,9%	Thailand	1,8%
Malaysia	0,24	Zambia	6,5%	Yemen	3,7%	Ghana	1,8%
Libya	0,23	Chile	6,3%	Colombia	3,7%	Italy	1,8%
Chile	0,22	Ghana	6,2%	Chile	3,6%	Lithuania	1,8%
Canada	0,21	Haiti	6,1%	United Kingdom	3,6%	Argentina	1,7%
Costa Rica	0,21	Nigeria	6,0%	Chinese Taipei	3,4%	United States	1,5%
Trinidad and Tobago	0,19	Tunisia	5,9%	Greece	3,4%	Japan	1,5%
Austria	0,19	Portugal	5,8%	Nigeria	3,4%	United Kingdom	1,4%
Russia	0,18	Korea	5,5%	Israel	3,3%	Ireland	1,4%
Thailand	0,18	Malaysia	5,5%	United Arab Emirates	3,2%	Venezuela	1,3%
Jordan	0,15	Peru	5,4%	Equador	3,2%	Malaysia	1,3%
Egypt	0,13	Jordan	5,3%	Morocco	3,1%	Cameroon	1,3%
Cuba	0,11	Ireland	5,2%	Cuba	3,1%	Cuba	1,3%
Mexico	0,11	Kuwait	5,2%	Spain	2,9%	Jamaica	1,2%
Venezuela	0,11	Finland	5,1%	Vietnam	2,9%	Philippines	1,1%
Tunisia	0,11	Saudi Arabia	5,1%	Oman	2,9%	Algeria	1,1%
Equador	0,10	United Kingdom	5,0%	Sweden	2,8%	Colombia	1,0%
Lebanon	0,10	Nepal	4,8%	Zimbabwe	2,8%	Oman	0,9%
Senegal	0,09	Eritrea	4,7%	Saudi Arabia	2,8%	Israel	0,8%
Lithuania	0,08	Colombia	4,6%	Portugal	2,7%	Iran	0,8%
Angola	0,07	Estonia	4,5%	Libya	2,6%	Germany	0,8%
Poland	0,06	South Africa	4,5%	Pakistan	2,6%	Australia	0,8%
Macedonia	0,06	Cuba	4,3%	Lebanon	2,6%	Mexico	0,7%
Hungary	0,06	Italy	4,2%	Gibraltar	2,5%	Libya	0,7%
Argentina	0,06	Israel	4,2%	Austria	2,5%	Canada	0,7%
Colombia	0,06	El salvador	4,0%	Germany	2,5%	Poland	0,6%
Azerbaijan	0,06	Brunei	3,9%	Italy	2,4%	Sudan	0,6%
Algeria	0,06	Oman	3,7%	Nicaragua	2,4%	Peru	0,6%
Iraq	0,06	United Arab Emirates	3,7%	Armenia	2,4%	United Arab Emirates	0,5%
Peru	0,05	Philippines	3,4%	Mexico	2,3%	Turkey	0,5%
Syria	0,05	Libya	3,3%	Sudan	2,2%	Dem. Rep. of Congo	0,5%
Czech Republic	0,05	Kenya	3,3%	Philippines	2,2%	Banladesh	0,4%
Brazil	0,05	Germany	3,3%	Australia	2,2%	Indonesia	0,4%
Kazakhstan	0,05	Morocco	3,2%	Honduras	2,1%	People's Rep of China	0,4%
Guatemala	0,05	Japan	3,2%	Kuwait	2,0%	Croatia	0,4%
Iran	0,05	Mexico	3,1%	Finland	2,0%	Trinidad and Tobago	0,3%
Ukraine	0,04	Australia	3,0%	Myanmar	1,9%	Jordan	0,2%
Former Yugoslavia	0,04	Vietnam	2,9%	Guatemala	1,9%	Lebanon	0,2%
Croatia	0,04	Zimbabwe	2,8%	Iraq	1,9%	Tunisia	0,2%
Latvia	0,04	Brazil	2,8%	Azerbaijan	1,8%	Morocco	0,1%

Turkey	0,04	Sudan	2,8%	Russia	1,8%	Switzerland	0,1%
Yemen	0,04	Lebanon	2,8%	Japan	1,7%	Former Yugoslavia	0,1%
Cote d'ivoire	0,04	Algeria	2,7%	Banladesh	1,6%	Bulgaria	0,1%
El salvador	0,03	Pakistan	2,6%	Syria	1,6%	Pakistan	0,1%
Morocco	0,03	United States	2,5%	Algeria	1,6%	India	0,0%
Zimbabwe	0,03	Austria	2,5%	Trinidad and Tobago	1,4%	Angola	0,0%
Philippines	0,03	Lithuania	2,4%	Macedonia	1,4%	Luxembourg	0,0%
Slovenia	0,03	Nicaragua	2,4%	Yugoslavia	1,4%	Benin	0,0%
Bulgaria	0,03	Armenia	2,4%	Paraguay	1,3%	Mozambique	0,0%
Other Africa	0,03	Honduras	2,1%	Dominican Republic	1,3%	Bahrain	0,0%
Other Asia	0,03	Banladesh	2,1%	Latvia	1,2%	Ethiopia	0,0%
Dominican Republic	0,03	Venezuela	2,1%	Hungary	1,1%	Togo	0,0%
Nigeria	0,02	Myanmar	1,9%	United States	1,0%	Zambia	0,0%
Armenia	0,02	Iraq	1,9%	Former Yugoslavia	1,0%	Haiti	0,0%
Romania	0,02	Azerbaijan	1,8%	South Africa	0,9%	Nepal	0,0%
Pakistan	0,02	Russia	1,8%	Turkey	0,8%	Eritrea	0,0%
Benin	0,02	Argentina	1,7%	India	0,8%	El salvador	0,0%
Nicaragua	0,02	Trinidad and Tobago	1,6%	Venezuela	0,7%	Brunei	0,0%
Ghana	0,01	Syria	1,6%	Kazakhstan	0,6%	Vietnam	0,0%
Cameroon	0,01	Macedonia	1,4%	Moldova	0,6%	Zimbabwe	0,0%
Honduras	0,01	Yugoslavia	1,4%	Lithuania	0,6%	Austria	0,0%
Yugoslavia	0,01	Turkey	1,3%	Ukraine	0,6%	Nicaragua	0,0%
Vietnam	0,01	Canada	1,3%	Canada	0,6%	Armenia	0,0%
Togo	0,01	Paraguay	1,3%	Croatia	0,6%	Honduras	0,0%
Zambia	0,01	Dominican Republic	1,3%	Indonesia	0,6%	Myanmar	0,0%
Haiti	0,01	Latvia	1,2%	Georgia	0,5%	Iraq	0,0%
Indonesia	0,01	Iran	1,1%	Estonia	0,5%	Azerbaijan	0,0%
People's Rep of China	0,01	Hungary	1,1%	Romania	0,5%	Russia	0,0%
Moldova	0,01	Former Yugoslavia	1,1%	Bulgaria	0,5%	Syria	0,0%
Paraguay	0,01	Indonesia	1,0%	Czech Republic	0,5%	Macedonia	0,0%
Kenya	0,01	Croatia	1,0%	Panama	0,4%	Yugoslavia	0,0%
Eritrea	0,01	Poland	0,8%	Slovenia	0,4%	Paraguay	0,0%
Dem. Rep. of Congo	0,01	India	0,8%	Korea	0,4%	Dominican Republic	0,0%
India	0,01	Kazakhstan	0,6%	Tajikistan	0,4%	Latvia	0,0%
Nepal	0,01	Moldova	0,6%	Poland	0,3%	Hungary	0,0%
United Republic of Tanzania	0,01	Ukraine	0,6%	Iran	0,3%	Kazakhstan	0,0%
Georgia	0,01	Bulgaria	0,6%	People's Rep of China	0,1%	Moldova	0,0%
Mozambique	0,01	Georgia	0,5%	Netherlands Antilles	0,0%	Ukraine	0,0%
Sudan	0,01	Romania	0,5%	Uruguay	0,0%	Georgia	0,0%
Banladesh	0,00	Czech Republic	0,5%	Egypt	0,0%	Romania	0,0%
Myanmar	0,00	People's Rep of China	0,4%	Kenya	0,0%	Czech Republic	0,0%
Ethiopia	0,00	Slovenia	0,4%	Brazil	0,0%	Slovenia	0,0%
Tajikistan	0,00	Tajikistan	0,4%	Argentina	0,0%	Tajikistan	0,0%
Slovak Republic	0,00	Slovak Republic	0,0%	Slovak Republic	0,0%	Slovak Republic	0,0%
Congo	0,00	Congo	0,0%	Congo	0,0%	Congo	0,0%
Namibia	0,00	Namibia	0,0%	Namibia	0,0%	Namibia	0,0%
Qatar	0,00	Qatar	0,0%	Qatar	0,0%	Qatar	0,0%
Albania	0,00	Albania	0,0%	Albania	0,0%	Albania	0,0%

Bosnia Herzegovina	0,00		Bosnia Herzegovina	0,0%		Bosnia Herzegovina	0,0%		Bosnia Herzegovina	0,0%
Belarus	0,00		Belarus	0,0%		Belarus	0,0%		Belarus	0,0%
Kyrgyzstan	0,00		Kyrgyzstan	0,0%		Kyrgyzstan	0,0%		Kyrgyzstan	0,0%
Turkmenistan	0,00		Turkmenistan	0,0%		Turkmenistan	0,0%		Turkmenistan	0,0%
Uzbekistan	0,00		Uzbekistan	0,0%		Uzbekistan	0,0%		Uzbekistan	0,0%
Bolivia	0,00		Bolivia	0,0%		Bolivia	0,0%		Bolivia	0,0%
DPR of Korea	0,00		DPR of Korea	0,0%		DPR of Korea	0,0%		DPR of Korea	0,0%
Sri Lanka	0,00		Sri Lanka	0,0%		Sri Lanka	0,0%		Sri Lanka	0,0%

Table 16: IEA data on CO2 emissions from international bunkers and comparisons to national totals - ranked. Source: [IEA 2001, "CO2 emissions from fuel combustion 1971-1999"].

Appendix G: Comparison of data from UNFCCC and IEA for CO2 emissions from domestic and international aviation in 1999.

	1A3a civil aviation (domestic)						International			Total domestic + international			International share	
	Jet kerosene			Aviation gasoline			Jet kerosene			Total				
	UNFCCC	IEA	Diff.	UNFCCC	IEA	Diff.	UNFCCC	IEA	Diff.	UNFCCC	IEA	Diff.	UNFCCC	IEA
	CO2			CO2			CO2			CO2				
	[million tonnes]	[million tonnes]	%	[million tonnes]	[million tonnes]	%	[million tonnes]	[million tonnes]	%	[million tonnes]	[million tonnes]	%	%	%
Australia	4,0	5,0	25,7%	0,24	0,24	2,3%	7,4	7,5	0,6%	11,7	12,7	9,2%	64%	59%
Austria	0,1	0,1	6,1%	0,01	0,00		1,8	1,5	-14,7%	1,9	1,7	-13,8%	94%	93%
Belgium		0,2			0,01			4,5		0,0	4,8			95%
Bulgaria	0,0	0,2	335,3%	0,00	0,01		0,3	0,2	-33,0%	0,4	0,4	6,5%	90%	57%
Canada	13,0	13,3	2,5%	0,25	0,25	0,1%	3,1	3,2	6,0%	16,3	16,8	3,1%	19%	19%
Czech Republic	0,0	0,2	1449,7%		0,00		0,5	0,3	-35,0%	0,6	0,6	1,2%	98%	63%
Denmark	0,1	0,4	165,9%	0,01	0,01	30,1%	2,3	2,3	2,6%	2,4	2,7	12,1%	94%	86%
Estonia	0,1	0,0		0,00	0,00		0,0	0,1		0,1	0,1	-15,4%		94%
Finland	0,5	0,5	3,0%	0,01	0,01	17,0%	1,1	1,1	2,9%	1,5	1,6	3,0%	69%	69%
France	6,0	4,0	-32,8%		0,09		13,6	15,8	16,1%	19,6	19,9	1,5%	69%	79%
Germany		1,0			0,08			20,4		0,0	21,5			95%
Greece	1,7	1,1	-35,0%	0,00	0,00		2,3	2,8	25,9%	3,9	3,9	0,0%	57%	72%
Hungary	0,0	0,0		0,00	0,00		0,6	0,6	6,4%	0,6	0,6	6,4%	100%	100%
Iceland	0,0	0,0	1,8%	0,00	0,00	-18,2%	0,4	0,4	0,0%	0,4	0,4	-0,1%	92%	92%
Ireland	NE	0,1		NE	0,00		1,6	1,5	-3,9%		1,6			95%
Italy	2,4	0,9	-63,5%	0,03	0,03	2,0%	7,5	10,0	34,6%	9,9	10,9	10,9%	76%	92%
Japan	10,3	11,1	7,8%	NO	0,04		17,6	18,8	7,0%		30,0			63%
Latvia	0,1	0,0			0,00		NE	0,1			0,1			100%
Luxembourg	0,0	0,0		0,00	0,00			1,0		0,0	1,0			100%
Netherlands	0,4	0,3	-30,2%	0,00	0,01		9,7	10,1	3,8%	10,1	10,4	2,5%	96%	97%
New Zealand	NE	0,8		NE	0,05		NE	2,1			2,9			70%
Norway	1,1	0,6	-45,9%	0,01	0,00	-100,0%	0,9	1,7	84,4%	2,0	2,3	14,5%	47%	75%
Portugal	1,1	0,6	-44,1%	0,01	0,01	86,1%	0,8	1,6	92,4%	2,0	2,3	14,4%	43%	72%
Slovakia	NA	0,1		NA	0,00		NE	0,0			0,1			
Spain		5,1			0,03			7,7		0,0	12,9			60%
Sweden	0,8	1,4	84,6%	0,00	0,02	279,7%	2,0	1,5	-27,4%	2,8	2,9	3,7%	72%	51%
Switzerland	0,2	0,3	16,5%	IE	0,02		4,4	4,5	2,6%		4,8			94%
United Kingdom	2,6	12,5	372,7%	0,14	0,13	-4,8%	25,1	18,7	-25,5%	27,9	31,3	12,2%	90%	60%
United States	154,7	198,3	28,1%	2,91	3,32	14,2%	64,8	59,6	-8,0%	222,4	261,2	17,4%	29%	23%

Table 17: Source: Comparison of data from UNFCCC and IEA for CO2 emissions from domestic and international aviation in 1999. Source: [FCCC/WEB/SAI/2001, p. 50]

Appendix H: Distribution of air traffic on carriers situated in different geographical regions 1999.

	Aircraft fleet size		Passengers		RPKs		FTKs		Avrg RPKs per pass	RTK*		Weight shares	
			[000]	share	[000000]	share	[000]			[000]	share	Freight	Pass
Africa	155	1.0%	9852	0.6%	15321	0.5%	497520	0.4%	1555	2029620	0.5%	25%	75%
Asia/Pacific	2262	14.2%	337716	21.3%	678118	23.9%	41019060	33.1%	2008	108830860	26.7%	38%	62%
Canada	370	2.3%	28699	1.8%	69015	2.4%	1974165	1.6%	2405	8875665	2.2%	22%	78%
Europe	4197	26.4%	432852	27.4%	829301	29.3%	34692714	28.0%	1916	117622814	28.9%	29%	71%
Latin America/Carribb	705	4.4%	64568	4.1%	90752	3.2%	4084377	3.3%	1406	13159577	3.2%	31%	69%
Middle East	295	1.9%	30225	1.9%	60379	2.1%	3401938	2.7%	1998	9439838	2.3%	36%	64%
US Majors	4974	31.3%	563864	35.6%	997728	35.2%	29938202	24.1%	1769	129711002	31.8%	23%	77%
US Nationals	1182	7.4%	70670	4.5%	68890	2.4%	7566996	6.1%	975	14455996	3.5%	52%	48%
US Cargo	172	1.1%	-	-	-		784131	0.6%	-	784131	0.2%	100%	-
US Regional	1589	10.0%	43368	2.7%	25199	0.9%	106133	0.1%	581	2626033	0.6%	4%	96%
Total World	**15901**		**1581814**		**2834703**		**124065236**		**1792**	**407535536**		**30%**	**70%**

Table 18: Distribution of air traffic on carriers situated in different geographical regions 1999. *Calculated assuming that one RPK=100 kg. Source: [Air Transport World 2000]

Appendix I: Comparison of Eurostat/Eurocontrol data based on the TRENDS model to data from UNFCCC and IEA.

	International aviation			Domestic aviation			Total		
	Eurostat	**UNFCCC**	**IEA**	**Eurostat**	**UNFCCC**	**IEA**	**Eurostat**	**UNFCCC**	**IEA**
Austria	1,667246	1,806852	1,540385	0,068478	0,115785	0,122849	1,735724	1,922637	1,663234
Belgium	3,906618	4,364	4,523383	0,00809		0,236232	3,914708		4,759615
Germany	17,31274	16,656	20,44667	2,422331		0,979615	19,73507		21,42629
Denmark	2,184689	2,269922	2,327849	0,157163	0,139804	0,371727	2,341852	2,409725	2,699576
Spain	10,38359	7,746	7,736397	4,141226	4,822	5,13763	14,52482	12,568	12,87403
Finland	1,079008	1,05584	1,086782	0,37116	0,452684	0,466177	1,450168	1,508524	1,552959
France	12,24769	13,57093	15,75	6,163452	5,987261	4,025699	18,41114	19,55819	19,7757
Greece	2,851677	2,261727	2,847575	0,503026	1,675808	1,08989	3,354703	3,937535	3,937465
Ireland	1,691669	1,603046	1,540385	0,094072		0,081876	1,785741		1,622261
Italy	6,788405	7,458626	10,03903	2,52846	2,365714	0,863124	9,316864	9,824341	10,90215
Luxembourg	0,942442	1,019	1,01748	0,000154	0	0	0,942596	1,019	1,01748
Netherlands	7,867427	9,741476	10,10833	0,039405	0,405989	0,283493	7,906832	10,14746	10,39182
Portugal	2,013767	0,84949	1,634835	0,369438	1,139058	0,636287	2,383205	1,988548	2,271122
Sweden	2,082548	2,021892	1,467904	0,982327	0,764647	1,411177	3,064874	2,786538	2,879082
United Kingdom	25,42475	25,14108	18,72042	2,213802	2,64073	12,48344	27,63855	27,78181	31,20386

Table 19: Comparison of Eurostat/Eurocontrol data based on the TRENDS model to data from UNFCCC and IEA [Million tonnes of CO_2]. Sources: [Eurostat 2002], [IEA 2001] and [UNFCCC 2002b].

	International	Domestic	Total
Austria	8%	41%	10%
Belgium	10%		
Germany	-4%		
Denmark	4%	-12%	3%
Spain	-34%	14%	-16%
Finland	-2%	18%	4%
France	10%	-3%	6%
Greece	-26%	70%	15%
Ireland	-6%		
Italy	9%	-7%	5%
Luxembourg	8%		7%
Netherlands	19%	90%	22%
Portugal	-137%	68%	-20%
Sweden	-3%	-28%	-10%
United Kingdom	-1%	16%	1%

Table 20: Discrepancies between data from Eurostat and dat from UNFCCC. Calculated as ((UNFCCC-Eurostat)/UNFCCC). Sources: [Eurostat 2002] and [UNFCCC 2002b].

Appendix J: Summary of AERO model results for allocation options, 1992 data.

Country	Anthropogenic CO_2 emissions (Mton)	No allocation (option 1)	National emissions (option 2)	Country of fuel sale (option 3)	Airline nationality (option 4)	Country of aircraft dest. or departure (option 5)	Country of pax dest. or departure (option 6)	Nationality of pax or cargo owner (option 7)	Emissions in national airspace (option 8)
Australia	273.12		1.14%	2.85%	2.28%	2.86%	1.97%	1.17%	1.39%
Austria	61.88		1.14%	1.55%	1.40%	1.54%	1.48%	3.01%	2.00%
Belgium	116.09		1.14%	1.92%	1.78%	1.97%	1.94%	1.90%	0.68%
Brazil	212.00		1.14%	1.56%	1.54%	1.56%	1.48%	2.13%	1.20%
Canada	464.00		1.14%	1.31%	1.65%	1.32%	1.31%	1.30%	2.11%
Denmark	52.28		1.14%	3.27%	3.34%	3.21%	3.37%	2.72%	2.19%
Finland	53.80		1.14%	2.82%	2.60%	2.82%	1.87%	2.18%	0.94%
Former Soviet Union	3,174.51		1.14%	0.06%	0.12%	0.06%	0.06%	0.20%	0.24%
France	378.38		1.14%	2.65%	3.19%	2.65%	2.68%	3.57%	1.97%
Germany	1,014.16		1.14%	1.36%	1.66%	1.35%	1.38%	1.93%	0.55%
Greece	84.58		1.14%	2.18%	1.27%	2.18%	2.46%	0.94%	0.61%
Ireland	30.72		1.14%	2.91%	2.75%	2.92%	2.65%	1.49%	2.89%
Italy	432.15		1.14%	1.08%	0.96%	1.07%	1.08%	2.89%	0.46%
Japan	1,124.53		1.14%	1.63%	1.40%	1.63%	1.56%	3.29%	0.23%
Luxembourg	12.75		1.14%	3.68%	0.57%	3.32%	4.58%	1.14%	0.37%
Netherlands	167.55		1.14%	3.13%	4.39%	3.13%	3.52%	1.96%	0.55%
Norway	35.54		1.14%	1.46%	2.67%	1.59%	1.50%	3.29%	0.91%
Portugal	47.12		1.14%	2.72%	2.44%	2.71%	3.19%	1.65%	1.42%
Spain	226.42		1.14%	2.93%	2.02%	2.92%	3.01%	2.55%	1.02%
Sweden	55.45		1.14%	3.07%	2.58%	3.12%	2.86%	4.47%	1.26%
Switzerland	45.07		1.14%	7.80%	10.01%	7.85%	7.89%	5.84%	2.77%
United Kingdom	583.75		1.14%	2.84%	3.51%	2.83%	3.05%	1.86%	0.64%
USA	4,960.43		1.14%	0.89%	1.07%	0.90%	0.92%	1.26%	0.23%
Total	13,606.27		1.14%	1.14%	1.26%	1.14%	1.14%	1.47%	0.50%
Total, other countries	7,639.66		1.14%	1.15%	0.94%	1.15%	1.15%	0.56%	0.57%
TOTAL	21,245.93	1.14%	1.14%	1.14%	1.14%	1.14%	1.14%	1.14%	0.52%

Table 21: AERO model results on national allocations of international aviation CO_2 emissions in 1992, by allocation option, as a percentage of total national anthropogenic emissions. Source: [Velzen 2000].

Appendix K: UNFCCC data on emissions from domestic and international aviation 1990-1999.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Australia	2554,99									4108,68
Austria	69,48	80,12	83,78	82,23	83,64	91,98	100,86	103,6	124,44	110,33
Belgium										
Bulgaria										35,49
Canada	10384,68	9239,21	9426,4	9124,74	9772,35	10527,3	11558,3	12054	12582	13168,23
Czech Republic										13,24
Denmark	184,28	170,55	167,72	167,52	170,07	175,2	189,58	192,89	171,65	149,98
Estonia										67,18
European Community										
Finland	402,6	408,5	385,5	373,8	379,6	353	380,2	412,8	447	464,7
France	4540,76	4618,1	4498,45	4368,44	4571,12	5305,05	5725,64	5777,9	6080	6067,55
Germany										
Greece	1458,21	1461,37	1524,49	1600,25	1341,43	1215,18	1278,3	1227,7	1148,9	1679,15
Hungary										
Iceland										31,6
Ireland										NE
Italy									2239,8	2397,01
Japan	6842,88	7375,64	7825,32	8270,1	8812,65	9296,53	9220,77	9643,6	10401	10308,3
Latvia									87,79	89
Lithuania										
Luxembourg										
Netherlands	492,2						300	320,73	577,94	419,51
New Zealand										756,58
Norway	681,94									1121,19
Poland										
Portugal	799,36	839,83	893,39	857	837,08	965,07	1033,26	1065,4	1216,3	1172,96
Slovakia										27,86
Spain	4371,64	4391,69	4923,21	1740,36	2883,49	3308,24	3831,36	4064,2	4687,8	4822,22
Sweden	818	793	758	770	780	814	755	745	784	795,44
Switzerland										254,96
United Kingdom	2158,43	2120,85	2220,55	2281,42	2326,38	2448,22	2550,48	2641,1	2764,1	2822,12
United States of America	127534,4	117721	119723	121582	124338	129402	133225	138183	141591	148345,3

Table 22: Domestic aviation, CO_2 Emissions, Gg.
Source: UNFCCC 2002c, “Domestic and international aviation emission estimates and other inventory data for the years 1990-1999”, United Nations Framework Convention on Climate Change, July 2002.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Australia	4345,12	4520,39	4795,71	5199,38	5353,94	5857,67	6311,7	6501,21	7232,89	7268,09
Austria	941,25	1100,88	1172,4	1142,53	1201,38	1331,54	1470,52	1521,93	1835,44	1615,14
Belgium									4571,13	4364,1
Bulgaria										319,27
Canada	2729,27	2482,68	2685,15	2472,48	2460,75	2603,53	3073,52	2991,66	2877,64	3032,39
Czech Republic										538,67
Denmark	1794,52	1660,77	1718,79	1681,35	1843,88	1890,49	1986,36	2029,51	2181,12	2314,14
Estonia										
European Community	60073	59649	65448	72065	73341	76571	81665	86900	91250	97963
Finland	974	917	811	762	802	867	957	965	990	1058
France	8617,73	8336,38	9830,75	10243,88	10604,87	10512,57	11240,29	11633,68	12255,3	13752,92
Germany	11589	11367	12200	12892		13880	14401	15095	15442	16656
Greece	2452,45	2130,5	1869,08	2906,96	2787,02	2613,17	2502,71	2420,65	1829,35	2266,23
Hungary										596,29
Iceland										363,37
Ireland										1623,79
Italy									6397	7468
Japan	13177,83	13842,36	14101,54	14215,17	14877,12	16825,87	18151,61	19085,72	18301,73	18519,23
Latvia									NE	NE
Lithuania										
Luxembourg										1019,12
Netherlands	4450	4960	5910	6500	6720	7670	8300	8979	9520,95	10066,43
New Zealand										1959,18
Norway	604,89									975,39
Poland										345,6
Portugal	883,31	871,82	917,08	856,28	900,1	852,89	770,21	792,25	842,9	873,56
Slovakia										
Spain	3160,68	3173,13	3556,64	6484,01	5869,45	6210,93	6554,43	7068,17	7477,63	7746,02
Sweden	1826	1910	2133	1820	1811	1849	1940	1929	2103	2103,4
Switzerland										4520
United Kingdom	14790,5	14569,76	16120,55	17240,81	17856,11	19011,82	20237,57	21552,33	24122,22	25539,33
United States of America	46728,43	46681,66	47142,96	47615,43	48327,04	51093,4	52135,04	55899,42	54987,8	60969,72

Table 23: International aviation, CO_2 Emissions, Gg.
Source: UNFCCC 2002c, "Domestic and international aviation emission estimates and other inventory data for the years 1990-1999", United Nations Framework Convention on Climate Change, July 2002.

Domestic Aviation, Emissions, CH4, Gg

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Australia	0.25									0.23
Austria	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Belgium										
Bulgaria										0.00
Canada	0.66	0.55	0.53	0.52	0.54	0.59	0.60	0.61	0.64	0.64
Czech Republic										-
Denmark	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Estonia										-
European Community										
Finland	0.50	0.51	0.48	0.47	0.47	0.44	0.47	0.51	0.55	0.02
France										
Germany										
Greece	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02
Hungary										
Iceland										-
Ireland										NE
Italy									0.07	0.08
Japan	0.19	0.21	0.22	0.23	0.25	0.26	0.26	0.27	0.29	0.29
Latvia									0.00	0.00
Lithuania										
Luxembourg										
Netherlands	0.08						0.05	0.05	0.08	0.05
New Zealand										0.02
Norway	0.03									0.05
Poland										
Portugal	0.10	0.11	0.12	0.11	0.11	0.13	0.14	0.15	0.16	0.16
Slovakia										
Spain	0.04	0.05	0.05	0.05	0.05	0.05	0.06	0.07	0.06	0.07
Sweden		0.10	0.05	0.05	0.05	0.09	0.09	0.06	0.05	0.06
Switzerland										0.04
United Kingdom	0.12	0.11	0.12	0.12	0.12	0.13	0.13	0.13	0.14	0.14
United States of America	7.41	7.02	6.92	6.81	7.01	6.98	7.09	7.19	7.07	7.32

International Aviation, Emissions, CH4, Gg

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Australia	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03
Austria	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Belgium									0.01	-
Bulgaria										0.01
Canada	0.08	0.07	0.08	0.07	0.07	0.08	0.09	0.09	0.09	0.09
Czech Republic										0.16
Denmark	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Estonia										
European Community	5.00	5.00	5.00	5.00	5.00	5.00	6.00	6.00	6.00	5.00
Finland	1.21	1.14	1.01	0.95	1.00	1.08	1.19	1.20	1.23	0.05
France										
Germany	0.15	0.16	0.17	0.18		0.19	0.19	0.20	0.21	0.23
Greece	0.06	0.06	0.07	0.07	0.08	0.08	0.07	0.08	0.04	0.09
Hungary										
Iceland										0.00
Ireland										
Italy									0.21	0.23
Japan	0.35	0.37	0.38	0.38	0.40	0.45	0.51	0.51	0.49	0.50
Latvia									NE	NE
Lithuania										
Luxembourg										
Netherlands	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
New Zealand										0.04
Norway	0.02									0.03
Poland										0.01
Portugal	0.11	0.11	0.12	0.11	0.12	0.11	0.10	0.11	0.11	0.12
Slovakia										
Spain	0.05	0.05	0.05	0.05	0.06	0.06	0.07	0.07	0.07	0.09
Sweden		0.10	0.05	0.05	0.07	0.07	0.06	0.09	0.09	0.09
Switzerland										NE
United Kingdom	2.85	2.74	2.98	3.06	3.24	3.37	3.55	3.76	4.04	4.28
United States of America	1.28	1.28	1.30	1.31	1.33	1.41	1.44	1.54	1.52	1.68

Table 24: Emissions of CH4 from domestic and international aviation, Gg.
Source: UNFCCC 2002c, "Domestic and international aviation emission estimates and other inventory data for the years 1990-1999", United Nations Framework Convention on Climate Change, July 2002.

Domestic Aviation, Emissions, N2O, Gg

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Australia	0.08									0.13
Austria	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Belgium										
Bulgaria										-
Canada	1.02	0.91	0.92	0.90	0.96	1.03	1.13	1.18	1.23	1.29
Czech Republic										-
Denmark	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Estonia										0.00
European Community										
Finland	0.18	0.19	0.17	0.17	0.17	0.16	0.17	0.18	0.20	0.02
France										
Germany										
Greece	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.05
Hungary										
Iceland										0.00
Ireland										NE
Italy									0.05	0.06
Japan	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Latvia									0.00	0.00
Lithuania										
Luxembourg										
Netherlands	0.03						0.02	0.02	0.04	0.03
New Zealand										0.01
Norway	0.02									0.04
Poland										
Portugal	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Slovakia										
Spain	0.14	0.14	0.16	0.06	0.09	0.11	0.12	0.13	0.15	0.15
Sweden	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Switzerland										
United Kingdom	0.07	0.07	0.07	0.07	0.07	0.08	0.09	0.08	0.09	0.09
United States of America	5.52	5.29	5.22	5.26	5.52	5.38	5.66	5.62	5.75	5.80

International Aviation, Emissions, N2O, Gg

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Australia	0.13	0.14	0.14	0.16	0.16	0.18	0.19	0.19	0.22	0.22
Austria	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Belgium										-
Bulgaria										-
Canada	0.27	0.24	0.26	0.24	0.24	0.26	0.30	0.29	0.28	0.30
Czech Republic										0.02
Denmark	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.09	0.09
Estonia										
European Community	2.00	1.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Finland	0.44	0.42	0.37	0.34	0.36	0.39	0.43	0.44	0.45	0.05
France										
Germany	0.24	0.23	0.25	0.26		0.28	0.29	0.31	0.31	0.34
Greece	0.14	0.12	0.13	0.16	0.17	0.16	0.15	0.16	0.10	0.17
Hungary										
Iceland										0.01
Ireland										
Italy									0.10	0.11
Japan	NE, NO	NE	NE	NE	NE	NE	NE	NE	NE	NE
Latvia									NE	NE
Lithuania										
Luxembourg										
Netherlands	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
New Zealand										0.03
Norway	0.02									0.03
Poland										0.02
Portugal	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Slovakia										
Spain	0.10	0.10	0.11	0.21	0.19	0.20	0.21	0.22	0.24	0.25
Sweden	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Switzerland										NE
United Kingdom	0.45	0.45	0.50	0.53	0.55	0.58	0.62	0.66	0.74	0.79
United States of America	1.48	1.47	1.49	1.51	1.53	1.62	1.65	1.77	1.74	1.93

Table 25: Emissions of N2O from domestic and international aviation, Gg.
Source: UNFCCC 2002c, “Domestic and international aviation emission estimates and other inventory data for the years 1990-1999”, United Nations Framework Convention on Climate Change, July 2002.

Domestic Aviation, Emissions, NMVOC, Gg

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Australia	2.69									2.73
Austria	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.07	0.07
Belgium										
Bulgaria										0.01
Canada	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Czech Republic										0.08
Denmark	0.18	0.17	0.16	0.16	0.19	0.20	0.19	0.19	0.17	0.16
Estonia										0.05
European Community										
Finland	0.11	0.12	0.11	0.06	0.06	0.06	0.12	0.12	0.25	0.24
France	2.02	1.98	1.69	1.44	1.47	1.63	1.72	1.81	1.79	1.81
Germany										
Greece	0.09	0.09	0.09	0.10	0.09	0.09	0.10	0.11	0.10	0.13
Hungary										-
Iceland										0.01
Ireland										NE
Italy									0.66	0.71
Japan	1.74	1.88	1.99	2.11	2.25	2.37	2.35	2.46	2.65	2.63
Latvia									0.06	0.06
Lithuania										
Luxembourg										
Netherlands							1.20	1.10	1.16	1.11
New Zealand										0.19
Norway	0.39									0.46
Poland										
Portugal	0.93	0.99	1.04	1.01	1.02	1.17	1.28	1.28	1.41	1.41
Slovakia										0.09
Spain	1.25	1.28	1.41	0.70	0.97	1.08	1.24	1.32	1.41	1.50
Sweden	1.00	0.70	0.40	0.40	0.42	0.68	0.72	0.49	0.39	0.43
Switzerland										0.04
United Kingdom	1.38	1.34	1.38	1.42	1.44	1.51	1.57	1.61	1.68	1.72
United States of Americ	163.31	160.85	162.42	159.84	159.23	161.26	160.57	161.48	166.02	166.02

International Aviation, Emissions, NMVOC, Gg

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Australia	-	-	-	-	-	-	-	-	5.94	5.97
Austria	0.32	0.34	0.36	0.35	0.37	0.40	0.44	0.46	0.55	0.55
Belgium										
Bulgaria										0.08
Canada	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Czech Republic										3.83
Denmark	0.39	0.36	0.39	0.39	0.37	0.39	0.38	0.39	0.40	0.42
Estonia										0.97
European Community	59.00	58.00	68.00	66.00	79.00	72.00	75.00	81.00	84.00	89.00
Finland	0.28	0.26	0.23	0.13	0.14	0.15	0.16	0.16	0.46	0.49
France	2.89	2.58	2.68	2.50	2.37	2.28	2.37	2.35	2.40	2.53
Germany	9.30	9.30	10.00	10.00		11.00	11.00	12.00	12.00	13.00
Greece	0.65	0.60	0.66	0.78	0.81	0.78	0.73	0.79	0.45	0.87
Hungary										-
Iceland										0.10
Ireland										1.06
Italy									1.98	2.20
Japan	3.36	3.53	3.59	3.62	3.79	4.29	4.62	4.86	4.66	4.72
Latvia									NE	NE
Lithuania										
Luxembourg										
Netherlands	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
New Zealand										0.49
Norway	0.50									0.25
Poland										
Portugal	1.00	1.00	1.05	1.00	1.06	1.00	0.94	0.99	0.98	1.04
Slovakia										
Spain	2.80	2.80	3.14	5.65	5.13	5.44	5.75	6.18	6.51	6.79
Sweden	1.00	0.50	0.43	0.43	0.58	0.51	0.44	0.66	0.68	0.68
Switzerland										NE
United Kingdom	36.87	35.77	39.14	40.77	42.83	44.90	47.45	50.42	54.96	58.19
United States of Americ	11.51	11.50	11.62	11.74	11.94	12.63	12.89	13.82	13.59	15.07

Table 26: Emissions of NMVOC from domestic and international aviation, Gg. Source: UNFCCC 2002c, "Domestic and international aviation emission estimates and other inventory data for the years 1990-1999", United Nations Framework Convention on Climate Change, July 2002.

Domestic Aviation, Emissions, SO2, Gg

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Australia	0.48									0.78
Austria	0.05	0.06	0.06	0.06	0.06	0.06	0.03	0.03	0.04	0.04
Belgium										
Bulgaria										0.01
Canada	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Czech Republic										0.00
Denmark	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Estonia										-
European Community										
Finland	0.21	0.21	0.20	0.19	0.05	0.05	0.05	0.05	0.06	0.12
France	1.44	1.47	1.43	1.39	1.45	1.68	1.82	1.83	1.93	1.93
Germany										
Greece	0.44	0.44	0.46	0.48	0.40	0.36	0.38	0.36	0.33	0.49
Hungary										-
Iceland										0.00
Ireland										NE
Italy									0.72	0.77
Japan	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Latvia										
Lithuania										
Luxembourg										
Netherlands							0.20	0.21	0.22	0.23
New Zealand										NE
Norway	0.02									0.04
Poland										
Portugal	0.20	0.21	0.23	0.22	0.21	0.25	0.26	0.26	0.31	0.30
Slovakia										0.01
Spain	1.39	1.39	1.56	0.55	0.92	1.05	1.22	1.29	1.49	1.53
Sweden	-	-	-	-	-	0.34	0.36	0.20	0.20	0.22
Switzerland										0.06
United Kingdom	0.41	0.54	0.71	0.58	0.74	0.62	0.65	0.84	0.88	0.72
United States of America	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE

International Aviation, Emissions, SO2, Gg

Belgium										
Bulgaria										0.10
Canada	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Czech Republic										0.38
Denmark	0.12	0.11	0.11	0.11	0.12	0.12	0.13	0.13	0.14	0.15
Estonia										-
European Community	15.00	16.00	18.00	19.00	19.00	20.00	21.00	23.00	25.00	24.00
Finland	0.51	0.48	0.42	0.40	0.11	0.11	0.13	0.13	0.13	0.28
France	2.74	2.65	3.12	3.25	3.37	3.34	3.57	3.69	3.89	4.37
Germany	3.90	3.90	3.90	3.90		4.00	5.00	5.00	5.00	5.00
Greece	1.49	1.36	1.42	1.78	1.81	1.74	1.63	1.73	1.05	0.49
Hungary										-
Iceland										0.05
Ireland										0.51
Italy									2.36	2.63
Japan	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Latvia									NE	NE
Lithuania										
Luxembourg										
Netherlands	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
New Zealand										0.12
Norway	0.06									0.10
Poland										
Portugal	0.23	0.22	0.23	0.22	0.23	0.22	0.20	0.20	0.22	0.22
Slovakia										
Spain	1.00	1.01	1.13	2.06	1.86	1.97	2.08	2.24	2.37	2.46
Sweden	-	-	-	-	-	0.32	0.29	0.52	0.50	0.59
Switzerland										NE
United Kingdom	2.82	3.70	5.12	4.38	5.67	4.83	5.14	6.84	7.66	6.49
United States of America	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE

Table 27: Emissions of SO2 from domestic and international aviation, Gg.
Source: UNFCCC 2002c, “Domestic and international aviation emission estimates and other inventory data for the years 1990-1999”, United Nations Framework Convention on Climate Change, July 2002.

Domestic Aviation, Emissions, CO, Gg

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Australia	99.27									86.52
Austria	0.75	0.78	0.71	0.73	0.56	0.57	0.58	0.54	0.63	0.65
Belgium										
Bulgaria										0.07
Canada	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Czech Republic										0.28
Denmark	1.07	0.99	0.97	0.94	1.10	1.19	1.14	1.10	0.98	0.95
Estonia										0.10
European Community										
Finland	2.27	2.31	2.18	2.11	2.14	1.99	2.15	2.33	1.79	0.59
France	6.55	6.37	5.67	5.02	5.26	5.68	6.00	6.23	6.22	6.29
Germany										
Greece	2.09	1.93	2.07	2.22	2.10	2.10	2.23	2.39	2.37	3.03
Hungary										-
Iceland										0.08
Ireland										NE
Italy									2.80	3.01
Japan	11.63	12.53	13.30	14.05	14.97	15.80	15.67	16.39	17.67	17.52
Latvia									0.12	0.13
Lithuania										
Luxembourg										
Netherlands							5.40	5.42	5.79	5.77
New Zealand										1.27
Norway	2.38									2.04
Poland										
Portugal	3.96	4.00	4.17	3.72	4.26	4.76	4.78	4.78	4.86	5.29
Slovakia										0.67
Spain	10.13	10.22	11.42	4.34	6.91	7.87	9.10	9.65	10.98	11.32
Sweden	3.00	2.50	2.50	2.50	2.50	2.98	3.15	5.10	3.47	3.24
Switzerland										1.08
United Kingdom	7.77	7.57	7.86	8.06	8.22	8.62	8.97	9.24	9.66	9.88
United States of America	819.73	805.54	817.76	820.72	830.11	854.65	860.93	869.10	902.66	909.01

International Aviation, Emissions, CO, Gg

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Australia	-	-	-	-	-	-	-	-	11.93	11.98
Austria	0.81	0.87	0.93	0.90	0.94	1.03	1.14	1.17	1.41	1.42
Belgium										
Bulgaria										0.54
Canada	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Czech Republic										9.89
Denmark	1.85	1.73	1.82	1.82	1.76	1.84	1.91	1.98	1.99	2.15
Estonia										4.84
European Community	160.00	157.00	199.00	182.00	223.00	194.00	202.00	217.00	225.00	244.00
Finland	5.51	5.18	4.58	4.30	4.53	4.90	5.41	5.45	3.97	4.24
France	7.86	7.18	7.62	7.37	7.31	7.16	7.48	7.55	7.80	8.26
Germany	56.60	56.00	61.00	65.00		71.00	75.00	79.00	81.00	88.00
Greece	6.34	5.98	7.00	7.62	8.08	7.90	7.32	8.25	4.25	9.45
Hungary										0.11
Iceland										0.86
Ireland										4.37
Italy									5.45	6.08
Japan	22.38	23.50	23.94	24.14	25.26	28.57	30.82	32.41	31.08	31.44
Latvia									NE	NE
Lithuania										
Luxembourg										
Netherlands	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
New Zealand										3.17
Norway	1.55									1.52
Poland										
Portugal	3.10	3.09	3.20	2.98	3.22	2.87	2.66	2.78	3.47	3.61
Slovakia										
Spain	5.91	5.96	6.67	11.32	10.43	11.09	11.69	12.65	13.46	13.97
Sweden	4.00	3.70	3.70	3.70	3.70	0.73	0.50	3.28	4.75	4.65
Switzerland										NE
United Kingdom	60.06	58.33	63.88	66.67	69.96	73.42	77.64	82.51	90.13	95.42
United States of America	76.74	76.66	77.47	78.30	79.58	84.18	85.92	92.13	90.62	100.48

Table 28: Emissions of CO from domestic and international aviation, Gg.
Source: UNFCCC 2002c, “Domestic and international aviation emission estimates and other inventory data for the years 1990-1999”, United Nations Framework Convention on Climate Change, July 2002.

Domestic Aviation, Emissions, NOX, Gg

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Australia	-	-	-	-	-	-	-	-	38.71	38.89
Austria	3.33	3.84	4.09	3.99	4.19	4.64	5.13	5.31	6.40	6.49
Belgium										
Bulgaria										1.28
Canada	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Czech Republic										3.27
Denmark	7.30	6.75	6.97	6.81	7.45	7.64	8.00	8.17	8.78	9.33
Estonia										7.25
European Community	224.00	207.00	244.00	279.00	280.00	297.00	310.00	332.00	361.00	396.00
Finland	2.75	2.59	2.29	2.15	2.27	2.45	2.70	2.73	3.50	3.74
France	21.14	20.48	24.20	25.17	25.96	25.96	27.79	28.68	30.41	34.00
Germany	50.60	50.60	56.00	61.00		69.00	73.00	78.00	81.00	88.00
Greece	23.44	21.46	22.91	28.02	24.28	27.64	25.90	27.27	16.36	30.03
Hungary										-
Iceland										1.26
Ireland										3.43
Italy									34.91	38.89
Japan	54.07	56.80	57.86	58.33	61.05	69.04	74.48	78.32	75.10	75.99
Latvia									NE	NE
Lithuania										
Luxembourg										
Netherlands	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
New Zealand										8.07
Norway	1.71									3.03
Poland										
Portugal	3.70	3.66	3.85	3.60	3.79	3.59	3.25	3.35	3.54	3.67
Slovakia										
Spain	16.54	16.58	18.57	34.38	31.04	32.83	34.62	37.48	39.98	40.80
Sweden	4.00	4.20	4.00	4.00	4.00	4.31	3.96	7.31	6.70	7.14
Switzerland										NE
United Kingdom	72.79	71.86	79.63	85.49	88.36	94.29	100.46	107.03	120.21	127.28
United States of Americ	184.46	184.28	186.21	188.21	191.29	202.36	206.54	221.46	217.84	241.54

International Aviation, Emissions, NOX, Gg

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Australia	-	-	-	-	-	-	-	-	38.71	38.89
Austria	3.33	3.84	4.09	3.99	4.19	4.64	5.13	5.31	6.40	6.49
Belgium										
Bulgaria										1.28
Canada	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Czech Republic										3.27
Denmark	7.30	6.75	6.97	6.81	7.45	7.64	8.00	8.17	8.78	9.33
Estonia										7.25
European Community	224.00	207.00	244.00	279.00	280.00	297.00	310.00	332.00	361.00	396.00
Finland	2.75	2.59	2.29	2.15	2.27	2.45	2.70	2.73	3.50	3.74
France	21.14	20.48	24.20	25.17	25.96	25.96	27.79	28.68	30.41	34.00
Germany	50.60	50.60	56.00	61.00		69.00	73.00	78.00	81.00	88.00
Greece	23.44	21.46	22.91	28.02	24.28	27.64	25.90	27.27	16.36	30.03
Hungary										-
Iceland										1.26
Ireland										3.43
Italy									34.91	38.89
Japan	54.07	56.80	57.86	58.33	61.05	69.04	74.48	78.32	75.10	75.99
Latvia									NE	NE
Lithuania										
Luxembourg										
Netherlands	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
New Zealand										8.07
Norway	1.71									3.03
Poland										
Portugal	3.70	3.66	3.85	3.60	3.79	3.59	3.25	3.35	3.54	3.67
Slovakia										
Spain	16.54	16.58	18.57	34.38	31.04	32.83	34.62	37.48	39.98	40.80
Sweden	4.00	4.20	4.00	4.00	4.00	4.31	3.96	7.31	6.70	7.14
Switzerland										NE
United Kingdom	72.79	71.86	79.63	85.49	88.36	94.29	100.46	107.03	120.21	127.28
United States of Americ	184.46	184.28	186.21	188.21	191.29	202.36	206.54	221.46	217.84	241.54

Table 29: Emissions of NOx from domestic and international aviation, Gg.
Source: UNFCCC 2002c, "Domestic and international aviation emission estimates and other inventory data for the years 1990-1999", United Nations Framework Convention on Climate Change, July 2002.