HM TREASURY

Department for Transport

Aviation and the Environment

Using Economic Instruments

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Section 1
Context

Introduction

1.1 The Government intends to publish a White Paper later this year covering the future development of air transport in the UK for the next 30 years. The Air Transport White Paper will include:

- The Government's decisions on options for airport development;
- An environmental framework to ensure that the long-term development of aviation in the UK is sustainable.

The Government announced in the 2002 Pre-Budget Report[1] that it would discuss with stakeholders the most effective economic instruments for ensuring that the industry is encouraged to take account of, and where appropriate reduce, its contribution to global warming, local air and noise pollution.

1.2 This paper is intended to provide support for the discussions. The Government hopes that stakeholders will come forward with views about the desirability and effectiveness of a variety of different economic instruments at the discussions. The Government will set out its views in the Air Transport White Paper.

The Government's Objectives for Aviation

1.3 The Government's objectives for aviation are that:

- The development of aviation should be sustainable: that is to say, a proper balance should be struck and maintained between economic, environmental and social considerations. Policy for airports should aim to maximise the significant social and economic benefits, whilst seeking to minimise the environmental impacts.
- Within this framework, the polluter should pay and aviation, like other industries, should meet its external costs, including environmental costs.
- Economic instruments can be a useful way to reduce the environmental impact of aviation by encouraging the use of cleaner and quieter aircraft.
- Any use of such instruments should be appropriate and practical, taking account of factors such as international and European obligations. Examples of relevant obligations include, the need to adhere to mandatory European Union (EU) pollution limit values for local air quality purposes; to adhere to the technical standards to limit noise and exhaust emissions from aircraft recommended by the UN body for civil aviation, the International Civil Aviation Organisation (ICAO); and to meet the targets for limiting greenhouse gas emissions by 2008-12 agreed under the Kyoto Protocol.

[1] Pre-Budget Report, November 2002, HMT available online at www.hm-treasury.gov.uk/pre_budget_report/prebud_index.cfm

- Economic instruments are not the only means of promoting sustainability in aviation. The Government already uses other instruments such as regulation, for example to manage noise, including night noise, at the main London airports, and is considering further such measures.

- The extent to which increased demand should be met is the subject of the regional consultation documents, *The Future Development of Air Transport in the United Kingdom*[2]. These set out an appraisal of both the benefits and disadvantages of options for additional airport capacity and seek views on those options in the light of this information.

Structure of this Document

1.4 The document is separated into the following sections:

- Section 2 describes the process by which the Government makes decisions in the area of economic instruments, including consideration of impacts on, for example, social exclusion and competitiveness.

- Section 3 details the Government's estimates of aviation's environmental costs in terms of climate change, local air quality and noise, and translates these costs into monetary values where possible.

- Section 4 presents a range of questions the Government would like stakeholders to consider at the forthcoming discussions.

- Section 5 describes the next steps in the process of stakeholder discussions.

- The annexes provide background analysis to support the calculations in Section 3.

[2] *The Future Development of Air Transport in the United Kingdom*, July/August 2002 and February 2003 for the revised South East consultation document, DfT available online at www.airconsult.gov.uk

Section 2
Policy Appraisal

The Policy Development Process

2.1 At the 2002 Pre-Budget Report, the Government published its strategic framework for environmental taxes, *Tax and the Environment: Using Economic Instruments*. This builds on the Government's 1997 Statement of Intent on environmental taxation, and sets out the principles underpinning the Government's approach to using economic instruments such as taxes. The document outlines clearly the process the Government takes in determining whether and how to intervene to improve the environment. This involves a number of steps.

2.2 First, the Government identifies the environmental policy objective. The Government's principal environmental objective for aviation is that, where appropriate, the industry should pay for its environmental costs. This is set out in Section 1 of this document.

2.3 Second, the Government needs to assess the rationale for Government intervention. Section 3, with accompanying annexes, presents analysis which demonstrates the extent of aviation's environmental impact. It is possible to express much of this impact, albeit tentatively, in monetary terms. The analysis provides evidence of market failure because full environmental costs are not currently factored into the prices paid by those who benefit from aviation. Hence there is a case for the Government to intervene.

2.4 Third, the Government evaluates the benefits and costs of intervention. Potential environmental benefits need to be considered in relation to the costs of achieving them. When considering any economic instruments, the Government will take into account, in particular the:

(i) Environmental impact, including, for example, the effectiveness at internalising external costs.

(ii) Economic impact, including any impacts on fares and demand for air travel and wider impacts across the economy.

(iii) Distributional impact, including any impact on regional services, effects on social exclusion, and on the developing world.

(iv) Competitiveness impact, including the impact on the aviation industry.

(v) Value for money, including consideration of potential administrative compliance costs.

Box 1: **The role of economic instruments**

Different instruments available to Government include regulation, economic instruments such as taxes, charges or trading schemes, the provision of information and voluntary agreements.

Regulation, for instance, is an important tool for delivering the Government's environmental objectives for aviation. Regulation may be needed where it is necessary to avoid certain environmental impacts altogether, or in cases where the cost of environmental impacts is or may be extremely high.

The Government's discussions with stakeholders will focus on the role that *economic instruments* could play in meeting the Government's environmental objectives for aviation, including how they might complement the regulatory framework, for example by ensuring that the EU limit values for local air quality are respected, and in achieving targets such as those established in the Kyoto Protocol. Economic instruments have only been applied to the aviation sector in a limited way in the past. The Government believes that, in general, economic instruments can help to:

- give market signals to industries to adapt their behaviour to reflect environmental costs;
- encourage, in a cost-effective way, new technology and innovation;
- send long-term signals to the market, and orient decision-makers towards the long-term goals of sustainable development.

The choice of economic instrument will also depend on the policy objectives. When weighing up the advantages and disadvantages between taxes and tradable permits, the Government considers a number of questions:

- Is it essential to bring pollution down to a set quantity or is the aim to internalise a known externality?
- What is the relationship between the marginal benefits of reducing emissions and the marginal costs of abatement? Where emissions above a certain level are associated with very high damage, there is a higher risk of a large welfare loss with a tax, as the outcome cannot be guaranteed.
- Could a trading scheme be implemented at reasonable cost and would there be a well-functioning market in permits?

2.5 Fourth, the Government needs to determine the most efficient instruments for achieving the objective. The most efficient approach will be the one that provides the greatest overall economic benefits. In some cases, a combination of economic and other instruments (e.g. regulation) may be needed to achieve the objective.

2.6 Fifth, it is important that the Government considers the extent to which potential instruments have synergies or trade-offs with other economic and social objectives, and the extent to which these are acceptable.

2.7 Finally, the Government takes forward the process of policy development and implementation. Having identified an environmental problem, the Government engages in a process of evidence gathering, consultation and analysis before deciding on the most effective policy response. Given the long-term nature of many environmental problems, including many of aviation's environmental impacts, the Government believes that policies should be developed in close consultation with stakeholders. To this end, the Government has published a number of documents in recent years:

- *The Future Development of Air Transport in the United Kingdom* – a series of regional consultation documents – discussed a wide range of airport development options in the face of the forecast rise in demand for air travel over the next 30 years. Specific responses were invited as to what controls should be put in place to manage the adverse effects of any additional development. This consultation period has been extended due to the addition of options for Gatwick in the South East regional consultation.

- *The Future of Aviation*[3] asked questions on a wide range of policy issues relating to aviation. In particular, responses were sought as to whether greater emphasis should be placed on regulation, economic instruments or voluntary agreements in order to mitigate the environmental effects of aviation. A summary report of the responses to this consultation may be found on the DfT website.

- *Valuing the External Costs of Aviation*[4] – published in parallel with *The Future of Aviation* – reviewed the valuation of external costs and considered the implications on airline costs, fares and demand of aviation meeting these costs. The analysis presented in Section 3 of this document updates this information, where appropriate.

2.8 Finally, the Government is now engaging in a series of discussions with stakeholders to gain further information and views at first hand. This document is intended to provide background and support for those discussions.

2.9 The Government will present its views in the Air Transport White Paper at the end of 2003. Where appropriate, the Government will then consult on the design of any measures proposed and the shape of the overall package.

3 *The Future of Aviation*, December 2000, DETR available online at www.aviation.dft.gov.uk/index.htm

4 *Valuing the External Costs of Aviation*, December 2000, DETR available online at www.aviation.dft.gov.uk/atwp/exvalue/index.htm

Box 2: **Legal issues**

In addition to the issues outlined above, the Government would need to consider the legal permissibility of particular policy instruments. There are a number of provisions in both international and European Union law which need to be taken into account.

The Chicago Convention and bilateral air service agreements

The Chicago Convention is the fundamental treaty on international civil aviation. It provides the framework for the operation of international air services. Most of the nations of the world, including the 15 EU member states, are parties to this treaty. Its provisions form binding international law.

Bilateral air service agreements regulate the operation of air services between pairs of countries. They supersede national regulations. One of the best known agreements is the Bermuda 2 agreement concluded in 1977 between the US and the UK.

The convention prohibits the imposition of taxes or charges on fuel *kept on board* aircraft and consumed on international flights. Restrictions under bilateral air service agreements go further.

European Union law

Any measures considered would also need to comply with various EU legal provisions. These include Directive 92/81/EEC, which exempts air carriers from payment of excise duties on fuel consumption within the EU. However, it should be noted that the provisions in this directive reflect *international* legal agreements, and the EU is committed to removing them should the international agreements be altered.

Section 3
Aviation's Environmental Impact

Introduction

3.1 This section summarises the Government's knowledge of aviation's external costs, now and in the future, and translates these costs into monetary values where estimates are available. However, this document focuses specifically on the external costs relating to:

- Climate Change
- Noise
- Local Air Quality

3.2 The Government recognises that there are a wide variety of other environmental effects particularly associated with the development of airport capacity. These include impact on land use and properties, heritage and ecology; they are addressed in the consultation documents seeking views on *The Future of Air Transport in the United Kingdom*.

Climate Change

3.3 The impact of aviation on climate change is the large environmental cost that can be quantified in monetary terms. Aircraft engines (and other ground sources) emit carbon dioxide (CO_2) and nitrogen oxides (NO_x). CO_2 is a greenhouse gas; NO_x results in ozone (a greenhouse gas) both of which contribute to global warming and climate change. The aviation emission for which external costs can be most easily calculated is CO_2; the monetary cost of the climate change caused by CO_2 is evaluated by calculating the amount of carbon produced and multiplying this by an estimate of the cost per tonne of carbon released. **ANNEX A** explains how the Government estimates a cost for carbon emissions.

3.4 The impact of aviation on climate change is increased over that of CO_2 alone by the range of secondary emissions released and their specific effects at altitude. These effects include increased tropospheric ozone, contrail formation and stratospheric ozone depletion. The environmental impacts of aircraft have been assessed by the Intergovernmental Panel on Climate Change (IPCC, 1999)[5] and more recently by the Royal Commission on Environmental Pollution (RCEP, 2002)[6].

3.5 The total impact of all aviation emissions on climate change is attained by multiplying the volume of CO_2 released by 2.7. This is known as the 'radiative forcing index', and is the ratio of total radiative forcing to that from CO_2 emissions alone and is a measure of the importance of aircraft induced climate change other than from the release of CO_2. **ANNEX A** contains further information on the cost of carbon and **ANNEX B** gives a brief description of radiative forcing.

3.6 The cost of aviation's impact on global warming is calculated by using an illustrative value for the cost of

[5] *Aviation and the Global Atmosphere*, Intergovernmental Panel on Climate Change, (1999) available online at www.ipcc.ch

[6] *The Environmental Effect of Civil Aircraft in Flight*, November 2002, Royal Commission on Environmental Pollution available online at www.rcep.org.uk

carbon such as £70 per tonne (rising by £1 per tonne per annum in real terms). The details of the calculations are in **ANNEX C** followed by example calculations for climate change costs for typical long and short-haul flights.

3.7 Meeting the cost of climate change would have the effect of reducing demand by around 10%, with the outcome dependent on the scale of demand responses and technological improvements or supply side effects. Supply side effects range from part of the increase in costs being absorbed by airlines, the accelerated purchase of more fuel-efficient aircraft and, in the longer term, the development of new aircraft and engine types embodying new technology. Supply side effects can have the desirable property of leading to environmental benefits while minimising wider negative impacts.

3.8 **ANNEX C** reports the national cost of global warming using published estimates of aviation CO_2 from passenger aircraft in 2000 at £1.4 billion, increasing to £4.8 billion in 2030, assuming no demand or supply side responses for economic instruments. The 2030 figure reflects more air traffic and a higher cost of carbon. The national CO_2 forecasts assume that no new economic instruments are in place, and therefore they represent unconstrained forecasts. Economic instruments may lead to lower demand, and have supply side effects (see paragraph D18 in **ANNEX D**). The net effect of this on the national air passenger forecasts is discussed in *The Future Development of Air Transport in the United Kingdom: South East* (see in particular paragraphs 5.5 to 5.12 which places this in context).

Aviation's Share of CO_2 Emissions

3.9 For 2000, estimates[7] show that UK civil passenger aviation produced 30 million tonnes of CO_2, which corresponds to 18% of all UK transport CO_2 emissions and 5% of UK CO_2 emissions from all sectors.

3.10 Estimates reported in *The Future Development of Air Transport in the United Kingdom: South East* (**ANNEX E**, Table E.2) suggest that passenger aviation will be responsible for c. 70 million tonnes of CO_2 in 2030 in a scenario with high growth of airport capacity. **ANNEX D** explains the basis of this calculation, which includes conservative assumptions such as that existing plane types do not get more fuel efficient engines, as newly built planes of those types enter service in coming decades.

3.11 The 2030 carbon dioxide forecast implies an increase of 2.3 times the year 2000 total of 30 million tonnes of CO_2. On the basis of current policies, including the full impact of the Climate Change Programme, overall UK carbon dioxide emissions might amount to some 135 million tonnes of carbon in 2020. While there is no specific aviation forecast for the same year, interpolation suggests that aviation might produce some 14 – 16 million tonnes of carbon in 2020[8], about 10 – 12% of total UK CO_2 emissions from all sectors. For the reasons given in the section on radiative forcing (**ANNEX B**) aviation's share of total climate change effects is higher than its share of CO_2 alone.

Year	Aviation CO_2 million tonnes	Share of total UK CO_2 emissions/ %
2000	30	5
2020	55	10-12

[7] National Environmental Technology Centre

[8] See page 72 of *Our energy future – creating a low carbon economy*, February 2003, DTI

Noise

3.12 Aircraft noise is an important public concern because it causes a direct impact on people in the vicinity of airports. Monetary valuations of noise attempt to place a value on annoyance and on the impact on quality of life.

3.13 Estimates in *The Future Development of Air Transport in the United Kingdom: South East*, of the cost of noise were made by estimating the effect of a sustained increase in noise on house prices, using so-called '*hedonic pricing*' techniques. A technical note giving hedonic price estimates for all major UK airports where there might be substantial development can be found on the DfT website at www.aviation.dft.gov.uk

3.14 Of all UK airports, Heathrow has the highest number of people affected by noise. The study estimates were based on households exposed to an equivalent continuous daytime sound level of 57dBA Leq and above, to which was applied the consensus finding from research that a sustained 1dBA rise in the quantity of noise was likely to reduce house prices by between 0.5 and 1%. The results as shown in *The Future Development of Air Transport in the United Kingdom: South East* (page 174) suggest that monetary values for the effect of aircraft noise ranged between 36 and 40 pence per passenger. At other airports in the South East, on the same basis of calculation, values do not exceed 5 pence per passenger. This work shows the costs for all residents living around each of the airports where major expansion may take place, who would be affected by noise levels greater or equal to 57dBA. The total cost of noise impacts for all airports has been estimated at around £25 million for 2000. (It is, of course, recognised that aircraft noise is annoying outdoors as well as indoors, to visitors as well as those living near airports and to some people living beyond the 57dBA Leq daytime contour. It is also true that the hedonic valuation method encompasses night as well as daytime noise).

3.15 **ANNEX E** contains further information relating to night noise (the subject of a separate consultation), the SERAS study and background information on World Health Organisation guidelines.

Local Air Quality (LAQ)

3.16 Aviation affects local air quality through emissions produced by fuel combustion during take-off and landing and the operation of ground auxiliary vehicles and associated surface access movements. The main aviation emissions affecting LAQ are NO_2 and PM_{10}; other air pollutants emitted by aviation included sulphur dioxide and VOCs (volatile organic compounds). Mandatory EU limits will come into force for NO_2 and PM_{10} in 2010 and 2005/2010 respectively. The SERAS report considers that these two emissions are sufficiently indicative of the scale of LAQ impacts.

3.17 *The Future Development of Air Transport in the United Kingdom: South East* reports that exceedence of the EU levels for NO_2 is likely to occur at Heathrow. Levels currently include emissions from all sources, including aviation and road use (for instance from the M4 and M25). Monitoring data at Heathrow and Gatwick over the last few years does not indicate any major airport-related excess in concentrations of PM_{10}.

3.18 Page 174 of *The Future Development of Air Transport in the United Kingdom: South East*, reports that estimates of the NHS costs of respiratory illnesses indicate that the total amount would be too low to be expressly represented in any economic instrument. An alternative approach, based on total external costs of air pollution from aviation was taken in a study by CE Delft in 2002 on the *External Costs of*

Aviation[9]. This report set out all the emissions of importance from a LAQ perspective and the range of health and environmental impacts. This study estimates that the external LAQ costs of aviation vary between €1-2 per passenger (equivalent to £119–236 million for all UK passengers). Further details on LAQ may be found in **ANNEX F.**

Congestion

3.19 Aviation causes two main types of congestion: congestion in the skies, and congestion around airports (surface access). The costs of congestion in the skies are largely borne by other air users who pay higher air fares than otherwise would be the case and are to some extent within the control of the regulatory regime for airports and slot allocation. Hence, unlike road transport, where there are large congestion external costs imposed on other road users, the *external* costs to the sector as a whole are likely to be minimal.

3.20 Where additional surface traffic is encouraged around airports, others are likely to be affected. There may be a range of tools available to airport operators and local authorities ranging from traffic management schemes such as local congestion charging, to free buses and park and ride facilities.

3.21 Due to the lack of market mechanisms in the current slot allocation system, there is no guarantee that those airlines who value the scarce capacity highest are able to obtain the slots, resulting in an inefficient use of airport capacity. The Government is pressing at an EU level to reform slot allocation regulations, but in the meantime there may be other measures the Government could deploy to encourage more efficient use of capacity. Such measures, however, fall outside the scope of this discussion paper, which focuses on aviation's environmental costs.

Conclusions

3.22 Aviation's principal externality, which can be translated into monetary terms, arises from the effect of greenhouse gases and the impact that they have on climate change. Calculations indicate that the external costs of climate change could increase from £1.4 billion in 2000 to an estimated £4.8 billion in 2030. Noise and LAQ impacts are less certain, although it is possible to obtain estimates for the external cost of noise. However, unlike the position for climate change, there are mandatory local limits for LAQ.

[9] 02.7700.03 *External Costs of Aviation*, February 2002, CE Delft available online at www.cedelft.nl

Section 4
Questions for Discussion

4.1 There are a number of issues that it would be helpful to discuss in more detail with stakeholders relating to each of the environmental impacts identified in Section 3.

Climate change

- What economic instruments could be used to tackle climate change? Which of these would be most desirable in terms of:
  - Providing the best incentives for the aviation industry to take account of its environmental impact?
  - Administrative feasibility?
  - Minimising undesirable economic impacts?

- Should there be a priority to reduce one particular aspect of aviation's contribution to climate change, such as CO_2 emissions, or should a broad approach be adopted to tackle other contributions as well, such as NO_x and contrail formation?

- Emissions from domestic aviation are currently included within the national targets agreed under the Kyoto Protocol, but emissions from international aviation are subject to separate commitments under the auspices of ICAO. The second Kyoto commitment period will run from 2012. What would be the advantages and disadvantages in including international aviation in national totals for this commitment period?

- What measures could be introduced to encourage airlines to purchase assets which are less environmentally-damaging?

- What other measures might be effective at tackling climate change?

- Would it be preferable to aim for long-term international agreement, which would have the greatest environmental benefits; or should domestic measures be pursued in the short term, even if they may have a more limited impact and have other effects on, for example, competitiveness? Would action at EU level be preferable?

Local air quality and noise

- What economic instruments could be used to tackle impacts on local air quality and noise? Which of these would be most desirable in terms of:
  - Providing the best incentives for the aviation industry to take account of its environmental impact?
  - Administrative feasibility?
  - Minimising undesirable economic impacts?

- Should economic instruments be varied by emissions, or by noise, or both?
- On which types of emission would it make most sense to base economic instruments?
- Should economic instruments based on local environmental impacts be varied by aircraft or by airport/location? Is there a role for economic instruments to help meet mandatory EU limits for NO_2 and PM_{10}?
- Should economic instruments be based on estimates of external costs?

Section 5
Next Steps

5.1 This document is intended to form the basis for the discussions with stakeholders announced in the Pre-Budget Report.

5.2 The Government welcomes contributions on a wide range of options to tackle the environmental impacts outlined in this document. The Government will set out its views in the Air Transport White Paper.

5.3 The Government will send out invitations to all key representative stakeholders to attend discussion sessions. The stakeholders will include umbrella organisations covering the following broad areas:

- Industry and business (including airlines, airport operators, manufacturers, tourism bodies and union representatives)
- National environmental groups
- Public bodies
- Expert community

5.4 Organisations wishing to contribute to these discussions should contact groups which represent them. For more information, please contact the Department for Transport enquiry line on 0845 100 5554.

Annex A
The Cost of Carbon

A.1 The *'cost of carbon'* accounts for the cost to society resulting from climate change effects caused by releasing carbon into the atmosphere as carbon dioxide. The cost of global environmental damage caused by climate change is estimated and then related to the amount of carbon released as carbon dioxide, giving a damage cost per tonne of carbon.

A.2 This section describes the analysis underlying DEFRA's 'cost of carbon'. DEFRA Guidance on the monetary valuation of the cost of carbon is based on the Government Economic Service (GES) Working Paper 140: *Estimating the Social Cost of Carbon Emissions* (2002). The Working Paper concludes that the most sophisticated study of the existing literature is Eyre et al (1999): *Global Warming Damages*, Final Report of the ExternE Global Warming Sub-Task. This study's cost of carbon estimates have been adopted by DEFRA in its guidance on valuing the cost of carbon emissions. This section provides a brief overview of these two important studies.

ESTIMATING THE SOCIAL COST OF CARBON EMISSIONS (2002)

A.3 The Working Paper concludes that *'a value of approximately £70/tC (2000 prices, with equity weighting)*[10]*, seems like a defensible illustrative value for carbon emissions in 2000. This figure should then be raised by £1/tC in real terms for each subsequent year'*[11].

A.4 The £70 per tonne of carbon value takes no account of uncertainties including the probability of:

- so-called 'climate catastrophe' (e.g. melting of the West Antarctic ice sheet, Gulf Stream suppression etc);
- the 'socially contingent impacts' of climate change (e.g. famine, mass migration etc); or
- the costs of impacts post 2100.

The paper also recommends the use of £35 and £140 (half and double the central estimate) as a sensitivity range pointing out that this does not cover the full uncertainty involved in the estimation of the social cost of carbon.

A.5 The Working Paper suggests that there are three main areas of inconsistency between the studies it reviewed that can help to explain the differences in damage estimates arising from various studies:

- the climate impacts associated with a doubling in the atmospheric concentration in carbon,
- the identification and valuation of the physical impacts associated with climate change; and
- the choice of discount rate.

A.6 The GES paper also recommended periodic reviews of its recommendations on social cost of carbon figures for policy decision-making as new evidence become available. There have been recent advances in the 'family of models' on which the GES figures were largely based. There have also been

[10] Equity weighting is used to take account of differences in income between geographical regions of the world

[11] Note, these values were originally in dollars, so have been converted using an exchange rate of £1=$0.56

developments in the climate change impacts literature and general developments in the UK Government economic appraisal guidance (e.g. the new Green Book *Appraisal and Evaluation in Central Government*, January 2003, and in particular the proposal to look at decreasing discount rates when assessing policies over long time horizons). To reflect these advances and to address the partial coverage of the costs of climate impacts, the Government has decided to review the recommended social cost of carbon figures.

GLOBAL WARMING DAMAGES: EYRE ET AL (1999)

A.7 Eyre et al consider a wide range of impact categories and geographical regions, use sophisticated modelling techniques, and use the marginal damages cost approach to estimate the social costs of carbon emissions. A value of 3% is used for the social rate of time preference (SRTP), i.e. the discount rate.

A.8 This study assumes that the physical damage costs per tonne of carbon will fall in the future, due to reductions in emissions, leading to a slower rate of climate change and due to reduced vulnerability to climate change through adaptation. However, this is more than offset by the assumption that the valuation of impacts will increase over time, largely due to increases in income. Overall, the study suggests an increase in damage values over time of approximately £1/tC in real terms per year.

A.9 Eyre et al calculate damage estimates by way of a series of disaggregated functions linking damages in individual impact categories (i.e. agriculture, human mortality etc.) to mean temperatures and/or other secondary climate impacts. A separate damage function is employed for each of a number of impact categories. This allows them to link damages to the rate, and level, of temperature change for each individual category of impact.

A.10 The study uses two different models to produce damage estimates; the Framework for Uncertainty, Negotiation and Distribution (FUND) model and the Open Framework for Climate Change Assessment (OF) model. The FUND model identifies the dynamic effects of climate change, incorporating sensitivity to both the level and rate of climate change. The OF model concentrates on the first order impacts associated with temperature changes. Climate change induced mortality is valued at the value of a statistical life, using a value of $3 million (1990 prices).

A.11 Equity weighting is applied to the values because, as the Working Paper says, 'it is utility that we want to maximise and we feel that equity weighting gives us a way of getting a handle on the effect of utility more accurately'. Placing equity weights on regional damage valuations 'results in marginal damage estimates a factor in excess of two times higher than if regional damages are not equity weighted'.

A.12 The income elasticity of marginal utility measures how responsive marginal utility is to changes in income. In the literature ε is an index of 'inequality aversion' so that the higher it is, the more weight is put on low-income areas. Eyre et al use $\varepsilon = -1$. (The IPCC (1996) state that standard rates are between –1 and –2).

A.13 Eyre et al use social rates of time preference of 1%, 3% and 5%, and report sensitivity analysis assuming rates of 0% and 10%. They state that "…there is… a strong case for a low positive rate of discount". The damage estimates increase by a factor of between two and three when the assumed social rate of time preference decreases from 5% to 3%, and by a further factor of between two and three, when the SRTP falls from 3% to 1%.

Annex B
Radiative Forcing

B.1 Aircraft emit gases and particles directly into the atmosphere altering its composition. These gases and particles alter the concentrations of atmospheric greenhouse gases, including carbon dioxide (CO_2), ozone (O_3), and methane (CH_4); trigger formation of condensation trails (contrails) and may increase cirrus cloudiness, all of which contribute to climate change. When a particular human activity alters greenhouse gases, particles or land status, such activity results in radiative imbalance. Such an imbalance cannot be maintained for long, and the climate system – primarily the temperature and clouds of the lower atmosphere – adjusts to restore the radiative balance. The IPCC uses a single measure of climate change: radiative forcing (RF), which is calculated directly from changes in greenhouse gases, aerosols, and clouds.

B.2 The radiative forcing index (RFI) is defined as the ratio of total radiative forcing to that from CO_2 emissions alone. For CO_2 radiative forcing, it makes no difference whether the fossil fuel is burned by aircraft or by other transportation/energy sectors. Total radiative forcing induced by aircraft is the sum of all forcings, including direct emissions (e.g. CO_2, soot) and indirect atmospheric responses (e.g. CH_4, O_3, sulphate, contrails). RFI is a measure of the importance of aircraft-induced climate change caused by all emissions, not just the contribution from the release of fossil carbon alone. According to the 1999 IPCC report *Aviation and the Global Atmosphere*, in 1992, the RFI for aircraft is 2.7, within an uncertainty range as described on page 211 of this report.

B.3 The cost of carbon values therefore needs to be scaled up to reflect the impact of radiative forcing from emissions at altitude. Professor David Lee of Manchester Metropolitan University and QinetiQ (the consultants who produced the CO_2 estimates in SERAS) says that:

'Excluding the landing and take-off (LTO) cycle, the average Radiative Forcing of aviation is 2.7 times that of CO_2 alone. Radiative forcing effects arise from CO_2 plus other emissions that result in ozone (arising from NO_x emissions) and contrail formation. 2.7 times is, of course, the reciprocal of 37%, which is CO_2's share of total radiative forcing from aviation at altitude.'

B.4 Therefore, the original cost of carbon estimated in the Eyre et al study, and subsequently adopted by DEFRA, has been scaled up by 2.7.

Annex C
Calculating Climate Change Costs

C.1 This section shows the derivation of the calculations of climate change costs in 2000 and 2030 given in **Table C1.**

C.2 In 2000, the amount of carbon emitted by passenger flights was 8.2 million tonnes[12]. In 2030, the amount of carbon emitted by passenger flights is forecast to be 19 million tonnes (from *The Future Development of Air Transport in the United Kingdom: South East*, **ANNEX E**). The following steps are then taken in calculating the cost of climate change.

- *The UK contribution from international trips is obtained by taking half of the effect of the whole trip.*
- *Emissions are separated into cruise and LTO contributions (different for long-haul and short-haul flights)[13].*
- *The proportion of carbon emitted at altitude is then multiplied by the radiative forcing index to account for the effect of other emissions at altitude and adjusted to account for the relative proportions of LTO and cruise emissions.*
- *This total is then multiplied by an illustrative cost of carbon of £70 per tonne of carbon for 2000 and rising by £1 p.a. to £100 per tonne of carbon in 2030; giving a total cost of £1.4 billion in 2000 and £4.8 billion in 2030.*

Table C1: **Climate change costs in 2000 and 2030**

Year	Carbon emitted million tonnes	Radiative Forcing Factor	Effective Carbon million tonnes	Cost of carbon £ per tonne	UK cost £ billion
2000	8.2	2.4	20	70	1.4
2030	19	2.5	48	100	4.8

Calculating Climate Change Costs

C.3 This section sets out a method of calculating costs when aviation pays for its external costs due to climate change, with illustrative examples for specific short-haul and long-haul flights.

ASSUMPTIONS

C.4 As explained earlier, the calculations use an illustrative cost of carbon of £70 per tonne, rising at £1 per tonne per annum. The average climate change impact of aviation emissions is 2.7 times that of CO_2 alone.

C.5 We take QinetiQ's fuel burn at altitude figures to get CO_2 emissions (QinetiQ were the sub-consultants in SERAS used for climate change analyses in the regional consultation documents). Aircraft load factors are implicitly included in these calculations.

[12] National Environment Technology Centre

[13] Estimated on a pro-rata basis for 2030 from 2000 LTO/Cruise weightings

CALCULATIONS

C.6 The specific details and emissions estimated for the two illustrative flight types are shown in **Table C2** below.

Table C2: **Climate change costs for long and short-haul flight examples**

Specific flight example	Distance/ nautical miles	Fuel consumed/ tonnes	CO_2 emitted/ tonnes[1]	Including Radiative forcing/ tonnes[2]	As carbon/ tonnes[3]	Total cost of climate change/£[4]
Long-haul B747	3,724	74.1	233.4	630	171.7	12,021
Short-haul B737	600	3.5	11	29.7	8.1	566

Notes.

1. One tonne of aviation fuel used is equivalent to 3.15 tonnes of CO_2 emissions.
2. The quantity of CO_2 is scaled up by 2.7 times to take account of all emissions at altitude (IPCC 1999). For simplicity, total CO_2 (LTO and Cruise) is uplifted.
3. Using 3.67 tonnes of CO_2 =1 tonne carbon (IPCC).
4. Illustrative cost of carbon of £70 per tonne for 2000.

C.7 Taking the figure for the amount of carbon released, we then calculate the total cost of emissions using an illustrative cost of carbon. This can be expressed as a cost per aircraft movement. In practice, charges are more likely to be applied per air traffic movement (ATM), thus giving an incentive to use planes at a higher load factor and to bring forward potential supply side improvements.

Annex D

CO_2 Forecasts for 2000 and 2030

D.1 This section describes the national estimates of aviation CO_2 produced by QinetiQ/Halcrow in SERAS and reprinted for *The Future Development of Air Transport in the United Kingdom: South East* consultation document (**ANNEX E**). This work is based on the assumption that the UK's share of international flights is one-half of the total so as to ensure that, at the global level, aviation is not double-charged. The same approach is used for the 2000 CO_2 forecasts as for the 2030 forecasts and can be summarised as follows:

- *Passenger and freight aircraft movement forecasts are split by six seat band classes and aggregated into 15 destination regions (10 international and 5 domestic).*
- *Representative aircraft chosen for each seat band class.*
- *Fuel burn data (in kg) estimated for each representative aircraft for each destination region, based on average load, flight distance and flight altitude assumptions.*
- *Ground emissions estimated for each representative aircraft.*
- *Fuel burn and ground emission data is multiplied by aircraft movements to give estimates of total fuel usage.*
- *Aircraft fuel usage in tonnes is multiplied by 3.15 to give CO_2 emissions.*
- *Surface access CO_2 emissions to airports are calculated by multiplying road surface access trips by the average trip distance and by an assumed emission rate of 147 grams of CO_2 per vehicle km.*

D.2 Passenger aircraft movement forecasts were taken from the DfT Air Passenger Forecasting Model, SPASM, with freight movement forecasts taken from the SERAS Freight Forecasting Model. Further details of the approach can be found in the SERAS documentation (available online at www.airconsult.gov.uk).

D.3 The two principal differences between the 2000 and 2030 CO_2 forecasts are:

i) The use of passenger and freight movement forecasts appropriate for each year.
ii) The use of representative aircraft reflecting the fleet in the two years.

D.4 The six seat band classes used in the CO_2 forecasts are taken from SPASM. The seat band classes for passenger aircraft are shown in **Table D1.** Freight aircraft were separated into four classes based on freight carrying capacity.

Table D1: **Seat band classes for passenger aircraft**

Class	Size
1	< 70 seats
2	71 – 150 seats
3	151 – 250 seats
4	251 – 350 seats
5	351 – 500 seats
6	> 500 seats

D.5 A comparison of the 'representative aircraft' in 2000 and 2030 is shown below in **Tables D2 and D3** for passenger and freight aircraft. Each representative aircraft type aggregates a range of aircraft.

Table D2: **Representative passenger aircraft in 2000 and 2030**

Seat band	2000		2030	
	Aircraft	Proportion of aircraft in seat band	Aircraft	Proportion of aircraft in seat band
1	Fokker 50	75%	Falcon 2000	67%
	Falcon 2000	14%	Embraer 170	33%
	Embraer 145	11%		
2	B 737-400	50%	A320	71%
	A320	26%	BAe146	29%
	BAe 146	14%		
	MD 80	10%		
3	B757-200	55%	B767-300ER	56%
	B767-300	27%	B757-200	44%
	A306	18%		
4	DC10	44%	B777-200	46%
	B777-200	35%	A340	37%
	A340	13%	A330	17%
	A330	9%		
5	B747-400	68%	B747-400	74%
	B747-200	32%	B777-300	26%
6	A3XX	100%	A3XX	100%

Table D3: **Representative freight aircraft in 2000 and 2030**

Seat band	2000		2030	
	Aircraft	Proportion of aircraft in seat band	Aircraft	Proportion of aircraft in seat band
1	A320-200	100%	A320-200	100%
2	B757-200	100%	B757-200	100%
3	B767-300	57%	B767-300	60%
	DC10	43%	MD11	40%
4	B747-400	100%	B747-400	100%

D.6 Specialist aircraft emissions consultants at QinetiQ calculated fuel burn data and ground emissions for each representative aircraft for the year 2000 using their aircraft emissions databank. Where 'representative aircraft' are the same in 2000 and 2030, fuel burn data was recalculated to reflect differences in average aircraft age and engine technology. A cautious approach has been followed and only known aircraft types and performance data have been included.

D.7 More disaggregated fuel burn data was multiplied by ATM data by destination and aircraft size to give forecasts of total aviation fuel usage in 2000, which was then converted to CO_2 emissions. Surface access related CO_2 emissions were calculated by multiplying total vehicle km by an average emission rate of 147 grams per km. Resulting CO_2 forecasts for 2000 are shown in **Table D4.**

Table D4: **Aviation-related CO_2 estimates for 2000**	
Description	**Tonnes of CO_2 in 2000**
Surface Access	
South East	533,269
Rest of UK	730,718
Airport Sources ('South East')	
International passenger traffic	19,221,678
Domestic passenger traffic	622,144
International freight traffic	508,398
Domestic freight traffic	34,789
Airport Sources ('Rest of UK')	
International passenger traffic	4,084,447
Domestic passenger traffic	757,662
International freight traffic	825,384
Domestic freight traffic	52,394
Total South East related	
Surface access	533,269
Aircraft CO_2	20,387,009
Grand total	20,902,278
Total CO_2	
Total surface access	1,263,987
Total aircraft	26,106,896
Grand total	27,370,883

D.8 The South East (London, the South East and Eastern regions) is estimated to account for 76% of total air transport related emissions in 2000. This reflects the dominance of the South East airports in air transport in 2000, with the seven main South East airports (Heathrow, Gatwick, Stansted, Luton, London City, Southampton and Norwich) handling two thirds of all passengers (and nearly all long-haul passengers) and half the freight tonnage through UK airports.

CO_2 Forecasts

D.9 The most widely used aviation related CO_2 estimates for 2000 are those by the National Environmental Technology Centre (NETCEN). NETCEN provide forecasts of aviation CO_2 emissions at cruise altitudes based on aviation fuel sales data. For the year 2000, NETCEN estimated that UK aviation (including flights by freighter aircraft) accounted for 31.4 million tonnes of CO_2 emissions. A comparison of the NETCEN and SERAS CO_2 forecasts (both passenger and freight planes) is shown in **Table D5.**

Table D5: **Aviation-related CO_2 forecasts (million tonnes)**			
Type of traffic	**SERAS**	**NETCEN**	**Difference**
Domestic	1.5	2.9	-55%
International	24.6	28.5	-14%
Total	26.1	31.4	-18%
Note: Excludes passenger trips by surface modes to airports			

D.10 A principal difference in the table above lies in the estimates of CO_2 emissions from domestic aviation; SERAS estimates around less than half of those of NETCEN. The SERAS estimates only cover the 29 airports in the SPASM passenger allocation model. These airports accounted for 86% of total domestic movements in 2000 but the planes in question are small with little effect on the total. The discrepancies between the two approaches are being investigated.

D.11 The current NETCEN methodology is similar to IPCC Tier 2 (CORINAIR 'Simple') in that it uses fleet-averaged emission factors based on fuel uplifted at all UK airports for the non-LTO flight stages but more detailed information for the LTO cycle. It bases the LTO calculation on past airport emission inventories for 9 major UK airports. Emissions are assumed to scale as the ratio of total movements in the year of interest to the total in the year the inventory was generated. For airports where an inventory is not already available, the emissions-per-movement values are taken to be similar to those for an airports on the list with a similar activity level.

D.12 National CO_2 forecasts for 2030 (e.g. see *The Future Development of Air Transport in the United Kingdom: South East* – ANNEX E) were carried out for two scenarios:

- A low capacity scenario, with no new runways assumed in the UK (415 mppa).
- A high capacity scenario, with new runways at Heathrow, Gatwick, Stansted, Birmingham, Manchester and Edinburgh (giving a national throughput of 480 mppa).

D.13 A comparison of the CO_2 forecasts for 2000 and 2030 is shown in **Table D6.**

Table D6: **Aviation-related CO_2 forecasts for 2000 and 2030 (million tonnes of CO_2)**

Description	2000	2030		Change on 2000	
		Low capacity	High capacity	Low capacity	High capacity
Surface Access					
South East	0.53	1.46	1.36	+173%	+155%
Rest of UK	0.73	1.72	1.92	+135%	+162%
Airport Sources ('South East')					
International passenger traffic	19.22	34.95	48.75	+82%	+154%
Domestic passenger traffic	0.62	0.61	0.75	-2%	+21%
International freight traffic	0.51	2.35	2.21	+362%	+334%
Domestic freight traffic	0.03	0.13	0.12	+274%	+252%
Airport Sources ('Rest of UK')					
International passenger traffic	4.08	23.51	19.03	+476%	+366%
Domestic passenger traffic	0.76	1.04	1.22	+37%	+61%
International freight traffic	0.83	4.19	4.19	+407%	+408%
Domestic freight traffic	0.05	0.22	0.23	+323%	+339%
Total South East related					
Surface access	0.53	1.46	1.36	+173%	+155%
Aircraft CO_2	20.39	38.04	51.83	+87%	+154%
Grand total	20.92	39.49	53.19	+89%	+154%
Total CO_2					
Total surface access	1.26	3.17	3.27	+151%	+159%
Total aircraft	26.11	66.99	76.50	+157%	+193%
Grand total	27.37	70.16	79.77	+156%	+191%

D.14 Passengers and CO_2 at South East and regional airports are shown in **Table D7**.

Table D7: **Change in CO_2 forecasts per passenger between 2000 and 2030**

Type of traffic	Pax (mppa)			Change in CO_2 per pax 2000-30 (%)	
	2000	**2030 Low**	**2030 High**	**Low**	**High**
South East					
International	107.0	181.9	266.9	+7%	+2%
Domestic	10.8	17.5	19.4	-39%	-32%
Rest of the UK					
International	45.1	184.1	161.0	+41%	+30%
Domestic	16.4	31.3	33.5	-28%	-21%
Total UK					
International	152.1	366.1	427.9	+4%	+3%
Domestic	27.2	48.8	53.0	-33%	-26%
Grand Total	179.3	414.8	480.9	+5%	+5%

D.15 Changes in total emissions per passenger will be a complex interaction between improvements in fuel efficiency, increases in average plane size and increases in average trip lengths. Any comparison of the 2000/2030 CO_2 emissions estimates with the increase in ATMs or total passenger numbers over this period is potentially misleading, as it is predicted that there will be an increase in the proportion of passengers flying on long-haul routes. This suggests that more passengers will be accommodated on fewer ATM's, as the aircraft used for long-haul flights are typically larger.

D.16 There is a change in the operating mix of aircraft types by route between 2000 and 2030 but no introduction of new aircraft types. For a given 'representative aircraft' type, there is minimal material change in engine technology and hence in fuel efficiency (see **Table D8,** below). Some older current aircraft types are omitted from the 2030 fleet (such as the B747-200) but no new aircraft types (other than the A380) are allowed for. Fuel burn rates per ATM km for existing aircraft types are assumed to increase somewhat to allow for higher load factors.

D.17 The estimates used are conservative, IPCC (*Aviation and the Global Atmosphere*, 1999) cite in Table 9.2 (page 302) future trends in fuel efficiency of the future aircraft fleet. These projections (made in the early 1990s) assume an annual improvement to the forecast fleet (encompassing planes still in the fleet and all planes delivered since 2000) of 1.3% pa from 2000 to 2010, dropping back to 1% pa from 2010 to 2015.

D.18 In general, if supply side or technological improvements are encouraged, then it is likely that some of the costs of economic instruments will be reduced over the longer-term, leading to smaller reductions in demand. Historically, technological improvements have meant that new aircraft tend to perform better on all fronts with lower emissions and noise than older aircraft. However, there may be trade-offs between different sorts of technological improvement. For instance, there is some evidence to suggest that aircraft engines can become more fuel and CO_2 efficient by burning fuel at a higher temperature – which can lead to higher NO_x emissions. There is also the possibility that penalties for CO_2 would encourage aircraft to fly at higher altitude, at which NO_x emissions and contrail formation have greater climatic impact.

Table D8: **Changes in fuel burn for representative aircraft**

Class	Typical length of haul	Aircraft	Proportion	Number of seats	2000 fuel burn	Aircraft	Proportion	Number of seats	2030 fuel burn	Change in Average load	Change in Fuel burn
1	Short haul	Fokker 50	75%	50	1,189	Falcon 2000	33%	19	1,050		
1	Short haul	Falcon 2000	14%	19	1,205	Embraer 170	67%	70	2,383		
1	Short haul	Embraer 145	11%	50	1,615						
1	Short haul	Average		46	1,240			53	1,943	16%	57%
2	Short haul	B 737-400	50%	146	3,487	A320-200	70%	149	3,517		
2	Short haul	A320	26%	149	3,451	BAE146	30%	100	3,459		
2	Short haul	BAe 146	14%	100	3,053						
2	Short haul	MD 80	10%	149	4,156						
2	Short haul	Average		141	3,488			134	3,500	-5%	0%
3	Short haul	B757-200	56%	169	4,781	B767-300ER	60%	227	6,301		
3	Short haul	B767-300	27%	227	6,245	B757-200	40%	159	4,813		
3	Short haul	A306	18%	200	7,104						
3	Short haul	Average		190	5,583			200	5,706	5%	2%
4	Long haul	DC10	44%	276	48,923	B777-200	45%	305	51,563		
4	Long haul	B777-200	35%	305	49,775	A340-300	15%	305	49,774		
4	Long haul	A340-300	13%	305	48,229	A330-200	40%	267	43,692		
4	Long haul	A330-200	9%	267	43,834						
4	Long haul	Average		289	48,690			290	48,146	0%	-1%
5	Long haul	B747-200	32%	386	83,268	B747-400	80%	421	71,571		
5	Long haul	B747-400	68%	421	69,855	B777-300	20%	375	59,122		
5	Long haul	Average		410	74,108			412	69,081	0%	-7%
6	Long haul	n/a				A3XXX-100	100%	555	86,090		

Note: Short-haul – France, Iberia (599 nautical miles),
Long-haul – North America (3,724 nautical miles),
Load factors are assumed to increase from 70% in 2000 to 74% in 2030.

Annex E
Noise

E.1 The methodology underlying the noise cost estimates in SERAS is described in *Setting Environmental Taxes for Aircraft: A Case Study of the UK*[14] by D. Pearce and B. Pearce (2000). Surveys in the 1990s of the hedonic pricing literature tried to identify 'consensus' values for a so-called Noise Sensitivity Depreciation Index (NSDI) calibrated in relation to aircraft noise. The figures they found largely ranged between 0.5% and 1% per dBA. In other words, this means that a sustained 1dBA rise in the quantity of noise is likely to reduce house prices by between 0.5 and 1%. Pearce and Pearce derived the marginal willingness to pay (MWTP) for an aircraft 'event' (landing and take-off) for each aircraft type considered, using a *typical* NSDI value of around 0.6% per dBA. By applying this NSDI value to the average house price within the Heathrow 57dBA daytime contour and by multiplying by the number of resident households, they estimated overall MWTP for a 1dBA reduction.

E.2 The equivalent continuous sound level to 57dBA over 16 hours daytime has been considered, on the basis of the the Civil Aviation Authority's (CAA) 1985 work on *The United Kingdom Aircraft Noise Index Study*, an approximate marker of the threshold for the onset of significant community annoyance due to aircraft noise. Although 57dBA corresponds to relatively low annoyance, 54dBA contours were also produced for SERAS as a sensitivity indicator.

E.3 The study estimates were based on households exposed to an equivalent continuous daytime sound level of 57dBA and above in 3dBA bands, and attributing to these marginal noise valuation equivalent to a pro-rating of the valuations based on the hedonic studies mentioned above. Monetary values for the effect of aircraft noise at Heathrow ranged between 36 and 40 pence per passenger. At other airports in the South East, on the same basis of calculation, values never exceeded 5 pence per passenger. The total cost of impacts for all airports has been estimated at around £25 million for 2000.

E.4 To provide a benchmark for night-time aircraft noise impacts, an indicator that predicts sleep disturbance is most useful. In a 1992 study, *Report of a Field Study of Aircraft Noise and Sleep Disturbance*[15], CAA showed that, below 90dBA sound exposure level (SEL), aircraft noise events were unlikely to produce disturbance in the average subject during the period asleep. For events between 90 and 100dBA SEL, one person in 75 on average was disturbed[16]. Therefore SERAS generated 90dBA SEL footprints generated by the loudest aircraft operating at night time.

E.5 DfT commissioned a 3-year research project in December 2001, which is to examine attitudes to aircraft noise and the valuation of its annoyance. This will inform the policy that the aviation industry should, in broad terms, meets its external costs. The objectives of this study includes providing evidence on the external costs of aircraft noise based on stated preference survey work.

[14] CSERGE Working Paper GEC 2000–26, available at www.uea.ac.uk/env/cserge

[15] Available at www.aviation.dft.gov.uk/sleepdisturbance

[16] On a measure of transient disturbance whereby the average subject experiences 18 comparable disturbances per night, most not being remembered the following day

World Health Organisation (WHO) Guideline Values

E.6 The World Health Organisation (WHO) guideline values for community noise in specific environments are largely derived as levels above which the effect in question begins to be reported. Most of the guideline values do not relate to any demonstrable physical health effect, and include:

- a night guideline figure of 60dBA Lmax for noise measured outside bedrooms derived on the basis of assuming absolute protection from even infrequent and/or transient sleep disturbance while sleeping with the windows open.
- daytime guideline figures including 55dBA Leq outdoors for 'serious annoyance' and 50dBA Leq outdoors/35dBA Leq indoors for 'speech intelligibility and moderate annoyance', so as to protect the majority of people.

E.7 In a great many geographic areas, including the vicinity of major airports, the guideline values – however desirable in an ideal world – are not a realistic aspiration in the short to medium term. The Government is committed, as a signatory to the WHO Charter on Transport, the Environment and Health, to take account of the WHO recommendations, alongside other material considerations, when setting targets and regulations in this area.

Annex F

Local Air Quality

F.1 The impact of aviation on local air quality (LAQ) occurs primarily through emissions produced by fuel combustion as aircraft accelerate during take-off and landing, the operation of ground auxiliary vehicles and associated surface access movements. The main aviation emissions affecting LAQ are NO_2 and PM_{10}; other air pollutants emitted by aviation include sulphur dioxide and VOCs (volatile organic compounds). The consultants' work reported in *The Future Development of Air Transport in the United Kingdom: South East* (page 169) took the view that NO_2 and PM_{10} are sufficiently indicative of the scale of LAQ impacts. The objectives and limits for these two impacts are the most difficult to meet around a major airport.

F.2 The combustion process in aircraft (as in cars) mainly emits nitrogen oxide (NO) with only a small amount of NO_2 (typically 5%). However, much of the NO emitted is rapidly transformed in the atmosphere into NO_2 by reaction with ambient ground-level ozone, so that the NO_x emitted generates much more 'secondary' NO_2 than the small amount of 'primary' NO_2 initially emitted.

F.3 The *SERAS Stage Two: Appraisal Findings Report* says (in paragraph 7.9.3), with regard to Heathrow, that "the figures clearly show the highest annual mean NO_2 contours fall directly on the runways, and particularly the ends of the runways, associated with acceleration during take-off. The figures also show the major roads of the M25 and M4 with areas of exceedance", i.e. due to road vehicle emissions. The consultants calculated the total NO_2 concentrations resulting from NO_x emissions. *The Future Development of Air Transport in the United Kingdom: South East* and the parallel documents for the other regions report on exceedances under alternative airport development scenarios.

F.4 It is NO_2 rather than NO which has known health effects at ambient levels of concentration. Robust values of the effects of local air quality changes on health are not available, although the Department of Health's (DH) Committee on the Medical Effects of Air Pollutants (COMEAP) recommended that estimates could be made as 'sensitivity' calculations. Evidence from DH suggests that respiratory hospital admissions might increase by 0.5% for each 10ug/m^3 of NO_2. This implies an increased admission rate of approximately 5 per 100,000 people at a NHS cost of £1500 – £2700 per respiratory hospital admission. These values give a total cost of around £10,000 for every 100,000 people subject to an increase of 10ug/m^3 of NO_2 arising from respiratory illnesses. These figures only indicate the NHS costs of a respiratory hospital admission; to this should be added human costs (through applying suitable willingness to pay estimates) and loss in output where appropriate. This analysis does not include any deaths brought forward for which there is no evidence at present.

F.5 There are greater uncertainties in estimating the PM_{10} emissions from aircraft than for NO_x or CO because PM_{10} is not certificated. Scientific research has established that particulate air pollution is associated with a range of effects on health including effects on the respiratory and cardiovascular systems, asthma and mortality. The objectives in the National Air Quality Strategy are a statement of policy intentions for air quality for the medium term, taking account of the costs and benefits and the feasibility and practicability of moving towards the standards. These latter are concentrations below which significant risks to public health are unlikely to occur. EU Limit Values on the other hand, represent mandatory limits that the UK will have to meet, according to the requirements of the directives, throughout its territory.

F.6 SERAS modelled PM_{10} emissions from all sources, not just aviation, and found exceedances of EU standards only at the ends of runways, but not where people live. Also, the Air Quality Strategy objective (equivalent to the EU Stage 1 limit value) was met in residential areas around the options, with the relevant concentrations only being exceeded very close to the runways or roads. The Government has now brought in revised PM_{10} limits, similar to the EU Stage II regulations, which are much tighter than the ones that were current at the time of SERAS. The SERAS results suggest that in 2015 even these more stringent limits will not create any PM_{10} exceedance for any option including an additional Heathrow runway.

F.7 An alternative approach based on total external costs of air pollution from aviation was taken in a study by CE Delft in 2002 on the *External Costs of Aviation*[17]. This report set out all the emissions of importance from a local air quality perspective and the range of health and environmental impacts. This study estimates that the external LAQ costs of aviation vary between €1-2 per passenger (equivalent to £119–236 million for all UK passengers).

F.8 Although odour is recognised as a 'nuisance', there is no ambient air quality standard for 'odour' nor for kerosene vapour. It is difficult to correlate the detection of odour with absolute concentrations, anyway, because of the characteristics of the human nose and the complex mix of compounds in aviation fuel. Unlike the situation for NO_x, modern engines are getting better (per passenger) in terms of total hydrocarbon emissions from exhaust, but much of the odour may come from unburned fuel on engine start-up (fugitive emissions from fuel handling also contribute but are not very large), and it is not clear if start-up emissions are increasing or decreasing per passenger. There is no evidence of health effects from kerosene vapour at the 'ambient' concentrations at issue here, but there may be occupational health issues for handlers of aviation fuel.

[17] 02.7700.03 *External Costs of Aviation*, February 2002, CE Delft available online at www.cedelft.nl

The Government announced in the 2002 Pre-Budget Report that it would discuss with stakeholders the most effective economic instruments for ensuring that the aviation industry is encouraged to take account of, and where appropriate reduce, its contribution to global warming, local air and noise pollution. This report forms the basis for those discussions with stakeholders. It provides estimates of aviation's external costs and outlines the Government's approach to using economic instruments. It also presents a range of questions concerning the effectiveness and desirability of economic instruments in this area.

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