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Giving wings to emission trading

Inclusion of aviation under the European emission trading system (ETS): design and impacts

Executive Summary

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Executive summary

1 Background

Air transport performs many important functions in modern societies. Aviation facilitates economic growth and cultural exchanges and in many regions the industry provides direct employment. However, aviation also contributes to global climate change, and its contribution is increasing. While the EU's total greenhouse gas emissions fell by 5.5% from 1990 to 2003, carbon dioxide emissions alone from the international aviation of the 25 Member States of the European Union increased by 73% in the same period. Even though there have been significant improvements to aircraft technology and operational efficiency this has not been enough to neutralise the effect of increased traffic. Without due policy intervention, the growth in emissions is expected to continue in the coming decades.

The full climate impact of aviation goes beyond the effects of CO_2 emissions, though. Apart from emitting CO_2, aircraft contribute to climate change through the emission of nitrogen oxides (NO_x), which are particularly effective in forming the greenhouse gas ozone when emitted at cruise altitudes. Aircraft also trigger formation of condensation trails, or contrails, and are suspected of enhancing formation of cirrus clouds, both of which add to the overall global warming effect. In 1999 the Intergovernmental Panel on Climate Change (IPCC), examining the total climate impact of aviation, estimated these effects to be about 2 to 4 times greater than those of CO_2 alone, even without considering the potential impact of cirrus cloud enhancement. This means the environmental effectiveness of any mitigation policy will depend on the extent to which these non-CO_2 effects are also taken into account.

A variety of economic instruments such as fuel taxation, emission charges and emissions trading have been proposed to mitigate the climate impacts of aviation. At the European level there have already been studies on an aviation fuel tax and en-route emission charges. In order to complete the existing knowledge base, the European Commission has now taken the initiative of investigating the detailed modalities and impacts of inclusion of aviation in the EU's emissions trading scheme.

2 Objective of the study

The overarching objective of the present project is:

> *To develop concepts for amending Directive 2003/87/EC to address the full climate change impact of aviation through emissions trading.*

This overarching objective has been achieved by securing the following specific goals:

1 To examine the means by which non-CO_2 effects of aviation impact on climate change and the ways in which the 'full climate change impact' of aviation might be captured within the EU emissions trading scheme without undermining the scheme's environmental integrity.
2 To design viable policy options for including aviation in the existing EU Emissions Trading Scheme (EUETS), in particular to propose viable options for:
   a Scope in terms of geographical coverage and types of flights included.
   b Allocation and surrendering of allowances.
   c Monitoring, reporting and verification of data.
3 To assess the qualitative impact of policy options developed for including aviation in the EU ETS.

3 Design of policy options

The study identifies seven key design elements to be addressed if the climate impacts of the international aviation sector are to be included in the EU ETS:

- **Coverage of climate impacts** – besides CO_2 emissions, this refers to whether and by what metrics or instruments the non-CO_2 effects of aviation are to be addressed.
- **Geographical scope** – refers to the geographical coverage of aviation emissions under the trading scheme, i.e. specification of the countries, routes and type of flights/aircraft to be included.
- **Trading entity** – refers to the entities that would be obliged to surrender allowances for emissions generated and be allowed to trade.
- **Decision on allocation rules** – refers to the institutional level (EU or Member State) at which emission targets and methodologies for the distribution of allowances are to be set, i.e. the degree of subsidiarity granted to Member States with regard to the method used for allocating allowances.
- **Interplay with Kyoto Protocol** – refers to the question how aviation can be integrated in the EU ETS, given the separate treatment of this sector under the Kyoto Protocol.
- **Allocation method** – refers to the method to be used for initial distribution of allowances among entities.
- **Monitoring method** – refers to the emission measurement or calculation method to be used and the agency responsible for monitoring and reporting emissions.

Table 1 reviews the main choices to be made with respect to each of these key design elements.

Table 1 Key design elements and associated choices

Key design element	Choices (options)
Coverage of climate impacts	– CO_2 x multiplier to capture full climate impacts – CO_2 plus effect-by-effect approach to account for non-CO_2 impacts – CO_2 only, with flanking instruments (flight procedures, NO_x landing charge and NO_x en-route charge)
Geographical scope	– Intra-EU – Intra-EU routes and 50% of routes to and from EU airports – Emission of all flights departing from EU airports – All emissions in EU airspace – Emission of all flights departing from EU airports plus remaining emissions in EU airspace – Intra-EU and routes to and from third countries that have ratified the Kyoto Protocol
Trading entity	– Aircraft operator – Airport operator – Fuel supplier – Providers of air traffic management – Aircraft manufacturers
Decision on allocation rules	– Amount of aviation allowances defined at EU level and a uniform allocation approach – Amount of allowances set at Member State level and common allocation criteria
Interplay with the Kyoto Protocol	– Extension of the scope of the Kyoto Protocol – Borrowing of AAUs from sectors not covered by the EU ETS – No allocation of allowances to the aviation sector – Obligation to buy allowances for emissions growth above a baseline – Semi-open trading for aviation – Gateway (trade restrictions)
Allocation method (allowance distributing mechanism)	– Grandfathering – Benchmarking – Auctioning – Baseline – No allocation
Monitoring method	– Measured trip fuel by aircraft operators – Calculated emissions by e.g. EUROCONTROL

In order to develop coherent policy options for including aviation in the EU ETS, first the potential advantages and disadvantages of the choices associated with each of the above key design elements were evaluated. Below, the findings and conclusions are presented for each element.

Coverage of climate impacts

This study examined three scenarios by which the 'full climate change impact' of aviation might be captured under the EU ETS without undermining the scheme's environmental integrity:

1 CO_2 × multiplier to capture full climate impacts.
2 CO_2 plus effect-by-effect approach to account for non-CO_2 impacts.
3 CO_2 only, with flanking instruments for non-CO_2 effects.

The main findings and conclusions with regard to these three scenarios are presented below.

Scenario 1: CO_2 × multiplier to capture full climate impacts

The Kyoto Protocol and the EU ETS are based on the principle of emissions being a tradable commodity, so that some measure or 'metric' is required to calculate the degree of equivalence between different gases. In the Kyoto Protocol the Global Warming Potential (GWP) is used for this 'equivalency' and this aspect is mirrored in the EU ETS. The key question is then which metric is a suitable candidate for incorporating the non-CO_2 climate impacts of aviation in a single metric that can be used as a multiplier.

This study shows that it is not feasible to calculate GWPs for the complete suite of aviation impacts, particularly contrails and aerosols, and that there are conceptual difficulties associated with calculating GWPs for aircraft NO_x induced ozone. Because of this, there is no direct equivalency between GWPs and *all* radiative forcings due to aviation. The use of the radiative forcing index (RFI) in the EU emissions trading scheme as a multiplier for *emissions* is shown to be unsuitable, as it does not take future effects into account the way a GWP does. A newer metric, the Global Temperature Potential (GTP), has been shown to be closer to GWP. The GTP was examined in more detail and a derivative metric demonstrated here – an analogue of the RFI, coined the Global Temperature Index (GTI) – was shown to be a potentially suitable future candidate for a metric compatible with GWP. Instead of the individual forcings being summed and calculated as a ratio to CO_2 forcing, as in the RFI, in the GTI the resultant temperatures are calculated. The result was a GTI of approximately 2 with a range from 1.5 to 3. Overall, it is felt that the GTI will require more work before this approach has sufficiently matured. However, using the GTI metric to reflect non-CO_2 effects may be feasible within the next few years. It should be borne in mind that it is inherent in a multiplier scenario that CO_2 optimisation will be strengthened, with no specific incentives to address individual non-CO_2 climate impacts. Overall, a multiplier approach could not yet at present be based on an accurate scientific methodology but would have to be justified on the basis of the precautionary principle.

Scenario 2: separate climate effects on an individual flight basis

The aim of this scenario was to examine whether the individual non-CO_2 effects of aviation could be addressed using different metrics that might be compatible with the GWP under an emissions trading scheme. In general, the approach taken was to consider individual flights. It is shown that a flight-based approach to account for non-CO_2 effects requires sophisticated atmospheric modelling to account for ozone/methane changes due to NO_x emissions and contrails/cirrus. Models able to compute ozone/methane are still in the research domain and it is not possible to recommend one over another. Different models also yield different results, introducing another source of uncertainty into this approach. There is the added difficulty, moreover, that aircraft impact depends on background conditions and these conditions – and the ultimate effect – are time- and space-dependent. If it were hypothetically possible to agree on a model and it was accepted that globally aggregated emissions lead to a certain global ozone production rate, then under such broad assumptions it might be reasonable to disaggregate an ozone (mass) production rate per unit mass NO_x. However, to take such disaggregation to the next level of radiative forcing and disaggregate to individual flights, additional assumptions would have to be made that are hard to justify. Moreover, the coupling of NO_x with methane and ozone chemistry makes this very complicated. For contrails, similar difficulties arise in that the models are still in the research domain and there are uncertainties in the calculation of both contrail coverage and radiative effect. Again, to attribute an effect down to the level of individual flights is not currently feasible in any robust manner. It is in principle possible to formulate a GWP for ozone from NO_x but this is a contentious issue, debated vigorously in the literature; for contrails, it is not possible to derive a GWP, since a contrail cannot readily be related to a mass emission. Therefore, this scenario cannot be recommended.

Scenario 3: CO_2 only, with flanking instruments for non-CO_2 effects
Basically, the main question to be investigated here is whether flanking instruments could mitigate the non-CO_2 impacts of aviation effectively and possibly more efficiently if these are not covered by an emissions trading scheme. Possible flanking instruments that might be considered are:
- Flight procedures to prevent contrail and enhanced cirrus formation.
- Continued NO_x LTO stringency through ICAO.
- An NO_x cruise certification regime under ICAO.
- NO_x-based landing charges at all EU airports.
- An NO_x en-route charge.

The following conclusions were drawn. In general, flanking instruments may be an attractive way of mitigating non-CO_2 climate impacts, as they need not be explicitly compatible with the EU emissions trading scheme.
The science of contrail and enhanced cirrus cloud formation was considered to be currently too immature for implementation in a regulatory/control regime, i.e. for a flight routing mechanism incorporated in air traffic management. Of the various NO_x options, reliance alone on continued ICAO LTO NO_x certification was deemed unsuitable because of its inherent allowance for higher NO_x emission indices with higher OPR engines and because the process of agreeing LTO NO_x certification standards has complex international dependencies. ICAO cruise certification was also rejected, as it has similar international dependencies and may be a decade or so away from agreement and implementation, moreover. Alternatively, a NO_x-based landing charge was assessed to be a suitable flanking instrument, the general expectation within the sector being that a reduction of NO_x LTO emissions will also reduce NO_x cruise emissions. Furthermore, NO_x-based landing charges can be based on a straightforward metric: kg NO_x/LTO. As an added benefit, NO_x landing charges might have a positive effect on local air quality. NO_x en route charges are also considered to be feasible and probably effective to reduce overall NO_x emissions of aircraft operations. However, the sensitive issue is then: who is to receive the money generated by a NO_x en-route charge?

Geographical scope

In relation to geographical coverage several scenarios were considered in the study, specifying different sets of countries and routes for inclusion in the scheme, as follows:

- Scenario 1: Intra-EU routes.
- Scenario 2a: Intra-EU and 50% of emissions on routes to and from EU airports.
- Scenario 2b: Emissions of all flights departing from EU airports.
- Scenario 3: All emissions in EU airspace[1].
- Scenario 4: Emissions of all flights departing from EU airports plus remaining emissions in EU airspace.
- Scenario 5: Intra-EU and routes to and from third countries that have ratified the Kyoto Protocol.

Scenario 1 (intra-EU) can essentially be considered as a base-case option. Scenario 4 is a combination of the route-based scenario 2b and the airspace-based scenario 3. Table 2 shows the aviation CO_2 emissions addressed under the five scenarios for geographical scope in the year 2004. For comparison, the overall quantity of allowances allocated under the present EU ETS of the 25 EU Member States in the period 2005-2007 are also given. For the first trading period (2005-2007) the 25 Member States have been allocated approximately 2,200 Megatonne CO_2 emissions per year. As Table 2 shows, for the year 2004 the CO_2 emissions covered under the various aviation scenarios are between 2.4% and 7.7% of this amount. It should be noted that the climate impacts of aviation as a share of the total impact of all sectors under the geographical scope would increase significantly if non-CO_2 climate effects from all sectors were also taken into account.

Table 2 Comparison of CO_2 emissions under present EU Emission Trading Scheme and aviation CO_2 emissions covered by various geographical scenarios

	CO_2 emissions in million kg in 2004	% of present CO_2 emissions in ETS
CO_2 emissions under present Emission Trading Scheme (2005-2007)		
Allocated CO_2 emissions	2.200.000	100.0%
Geographical scenarios for aviation emissions (2004)		
1 Intra-EU	51,875	*2.4%*
2a Intra-EU +50% routes to/from EU	130,287	*5.9%*
2b Departing from EU	130,403	*5.9%*
3 Emission in EU airspace	114,337	*5.2%*
4 Departing from EU + EU airspace	161,988	*7.4%*
5 Intra-EU and routes to/from other KP states	72,449	*3.3%*

[1] In this study the EU airspace is defined on the basis of the Flight Information Regions (FIR) of the EU Member States as employed by EUROCONTROL and officially agreed on with ICAO. The FIRs employed by EUROCONTROL encompass not only the national territories of individual countries, but may also include particular areas of seas and oceans. For all intra-EU routes it is assumed that the full route length is covered, also if the airspace of non-EU States is used.

This study examined whether there are any legal obstacles to the geographical scenarios considered. As was soon apparent, emissions trading is not addressed by the instruments of current international aviation law. Therefore, the main conclusion with regard to legal feasibility is that international provisions such as the Chicago Convention and bilateral agreements contain no obstacles to including aviation's climate change impact in the EU ETS. This conclusion is in respect of the inclusion of all aircraft, irrespective of ownership or country of registration, within the scope of the options that are considered in this study.

Trading entity
Aircraft operators appear to be the most suitable entity for surrendering allowances in the EU ETS. This option provides the best guarantee of achieving the most effective and efficient incentives for emissions reduction, as it is aircraft operators that have greatest control over abatement measures and have easy access to detailed monitoring data.
All the other options for trading entities have one or more decisive disadvantages that led them to be rejected as inferior.

Decision on allocation rules
One of the pivotal issues of an emissions trading scheme is the level – EU or Member State – at which the total amount of allowances is to be decided and the rules according to which allowances are to be allocated among the entities covered. In essence, this task comprises decisions on whether and eventually how to distribute allowances.
As in the case of emissions trading for stationary sources, central decisions should be taken at the EU level. For example, Annex III of the emissions trading Directive (2003/87/EC) sets out 11 criteria which Member States must adhere to when drawing up their national allocation plan. Exactly how allowances are to be distributed among the emissions trading sector can then be decided by Member States under their own plan, which are then scrutinised by the Commission against these 11 allocation criteria. Accordingly, Member States have some scope for subsidiarity in their allocation decisions. This degree of subsidiarity may be considered an advantage. Member States can duly consider any specifics regarding the situation of the aviation sector within their country and alter their allocation formula accordingly, to the extent that an unfair advantage is not granted to the aviation sector vis-à-vis other sectors of that economy.

The present study, however, identified two convincing arguments for defining the amount of allowances at the EU level and employing identical allowance distribution rules for all regulated entities in the aviation sector:
- *International aviation is not included in the EU's Burden Sharing agreement*
  An important reason for allowing a degree of subsidiarity as to the quantity of allowances to be distributed to stationary sources was the Burden Sharing agreement, which established different emission reduction targets for each Member State. As international aviation is not covered by this agreement, no such barrier to harmonised allocation exists for this sector.
- *Prevention of competitive distortions and administrative costs*
  A uniform EU allocation method would prevent competitive distortions, as all the entities covered would be allocated allowances according to exactly the

same rules. For Member States it might also reduce the administrative costs associated with allocation decisions.

Interplay with the Kyoto Protocol

In contrast to domestic aviation emissions, greenhouse gas emissions from fuel consumption in international aviation are not assigned under the Kyoto Protocol and are consequently not the subject of so-called Assigned Amount Units (AAUs) – at least not during the first commitment period from 2008 to 2012. In addition, the non-CO_2 climate effects, which are not related to fuel burn, from both domestic and international aviation are not covered under the Kyoto Protocol and therefore not covered by AAUs. The quantity of AAUs is based on the commitments laid down in Annex B of the Protocol and specifies a country's permitted greenhouse gas emissions during the first commitment period. These are measured in tonnes of CO_2 equivalent (tCO_2e).

Including international aviation in the EU ETS may create accounting problems in the system and under the Kyoto Protocol unless specific design features are introduced to counteract any disparities between the quantity of emissions covered by the Kyoto Protocol which is in fact emitted and the quantity of Kyoto units which are retired for compliance purposes to cover these emissions. These accounting problems arise because the emissions of international aviation are not underpinned by the AAUs used for compliance control under the Kyoto Protocol, as explained above[2]. The most obvious problem case is where there is a net flow of tradable units from the aviation sector to sectors covered both by the EU ETS and by AAUs under the Kyoto Protocol.

This study identified and assessed several options for avoiding these problems:

1 *Extension of the scope of the Kyoto Protocol*
Repeal of the exemption of aviation from quantitative obligations.

2 *Borrowing of AAUs from sectors not covered by the EU ETS*
AAUs from sectors not covered by the EU ETS will be used temporarily to underpin any allowances issued for international aviation emissions under the geographical scope with AAUs. Correspondingly, aviation entities are allocated allowances that are fully fungible, i.e. the aviation sector can buy and sell allowances from and to other sectors under the EU ETS without any trade restrictions. Since all allowances will be surrendered at the end of the commitment period, the attached AAUs are only “loaned” to the aviation sector.

3 *No allocation of allowances to the aviation sector*
The aviation sector must buy all the allowances required for compliance from other sectors, with no additional allowances being granted to aviation. Emissions trading in aviation is based on allowances from the EU ETS and Kyoto units only.

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[2] EU Allowances (EUAs) can be used for compliance under the EU ETS (Directive 2003/87/EC). AAUs are for compliance under the Kyoto Protocol. The registries for the EU ETS serve at the same time as registries under the Kyoto Protocol. Correspondingly, they contain all AAUs allocated to a country under the protocol, some of them earmarked as EUAs.

4 *Obligation to buy allowances for emissions growth above a baseline*
This option is similar to the previous one, but limits the obligation to surrender allowances to those for emissions growth relative to a base year or base period (baseline).

5 *Semi-open trading for aviation*
Aviation entities are allocated allowances. They can buy additional allowances from non-aviation sectors, but cannot not sell surplus allowances to these entities.

6 *Gateway (trade restrictions)*
Aviation entities are allocated allowances. They can buy additional allowances from non-aviation sectors, but can only sell to other sectors as many allowances as they, as a sector as a whole, have already bought from non-aviation sectors during the trading period.

The first option would avoid any trade restrictions, as AAUs would be created for international aviation as well. However, it is unlikely that international agreement on the incorporation of international aviation into the quantitative targets of the Kyoto Protocol would be realised in advance of the first commitment period of from 2008 to 2012. Consequently, at least up until 2013, this option is regarded as unfeasible for including aviation in the EU ETS.

Option two would also avoid any trade restrictions as AAUs are used from sectors not participating under the EU ETS. However, this option requires a clearing house mechanism for optimal registry purposes and a mechanism should be agreed on with all Member States for the event that not all borrowed AAUs are given back at the end of the commitment period. This situation may occur if there is a net flow of tradable units from the aviation sector to other sectors covered by the EU ETS.

As most of the emissions and effects of aviation are not underpinned by AAUs, all other options are designed to ensure continued integrity of the EU ETS. This implies either that no EU allowances are allocated to the aviation sector (options 3 and 4) or that trade restrictions are set (option 5 and 6).

If the aviation sector has high marginal abatement costs compared to other sectors, as is generally assumed, and in the absence of over-generous allocation of allowances, aviation would be a net buyer of allowances. Correspondingly, on these assumptions, bringing aviation into the EU ETS would result in additional demand for allowances on the EU ETS market. This implies that it is to be expected that the special design features under options 2 to 6 (e.g. closing of the Gateway), required in the case of net selling by the aviation sector, may not be ‘switched on’.

Allocation method

Auctioning appears to be the most attractive option for allocation. From an economic angle it is to be considered the most efficient option. Other important advantages are the achievement of simplicity regarding the equal treatment of new entrants compared with existing operators and crediting for early action, and the lower administrative burden associated with data requirements. There is also a significant degree of flexibility regarding the extent to which auction revenues are recycled.

A second-best option would be to start off with benchmarked initial allocation. In general, it is felt that benchmarking is to be preferred over a grandfathering approach, the latter being less favourable to new entrants and those companies that already operated relatively energy-efficient aircraft in the baseline year.

Monitoring method

To establish monitoring and reporting protocols, emission inventory activities could rely either on self-reporting by participants or on third parties such as EUROCONTROL. The most accurate monitoring option for CO_2 is for aircraft operators to measure the actual fuel used on each trip flown within the chosen geographical scope of the emission trading system. CO_2 emissions can then be calculated from the carbon content of that fuel. Under current international regulations, the amount of fuel used on each flight must already be registered by airlines.

The environmental effectiveness of the emissions trading system would certainly benefit if actual trip fuel were used, as would its economic efficiency, for operational measures to reduce emissions would be duly rewarded. The European airline industry and their association have expressed their preference for a monitoring and reporting method based on actual trip fuel, reported by aircraft operators. They regard this as feasible and fairly straightforward to implement.

Selection of three policy options

Based on the assessment of the pros and cons of the individual key design elements cited above, three policy options were selected for further examination (see Table 3). The configuration of the options was based on the wish for coverage of each of the main feasible choices per key design element, for consistent combinations of the design variables and for comparable environmental impacts. Note, however, that none of these is necessarily 'the optimum', even though the results of the evaluation below may show one option to be less attractive than another because of a sub-optimum combination of key design elements.

Table 3 Overview of the three selected policy options for including aviation in the EU ETS

Design element	Option 1	Option 2	Option 3
Coverage of climate impacts	CO_2 and multiplier for non-CO_2 climate impacts	CO_2 only (with flanking instruments for other impacts)	CO_2 only (with flanking instruments for other impacts)
Geographical scope	Intra-EU	Emissions of departing flights from EU airports	EU airspace
Trading entity	Aircraft operator	Aircraft operator	Aircraft operator
Decision on allocation rules	Uniform approach set at EU level	Uniform approach set at EU level	Uniform approach set at EU level
Interplay with Kyoto Protocol	Aviation buys allowances from other sectors above a historic baseline	Unrestricted trading based on AAUs borrowed from other sectors	Trading with other sectors based on a gateway mechanism
Allocation method	Baseline	Benchmarked allocation	Auctioning
Monitoring method	Actual trip fuel reported by aircraft operator	Actual trip fuel reported by aircraft operator	EUROCONTROL data (*ex ante* and radar)

4 Impacts on operating costs and ticket prices

As the future price of allowances cannot be forecast with any great precision, a range of € 10 to € 30 per tonne CO_2 equivalent was assumed to gain an idea of the potential impact on operational costs and ticket prices. This range was assumed for both the price of allowances on the EU ETS market and the auction price under Option 3. The impacts are calculated for the year 2012. The impacts are shown by comparing the Business as Usual (BaU) situation in 2012 with a situation where one of the 3 policy options is implemented[3].

[3] A quantitative impact analysis has been carried out for 2012, using 2008 emission levels as a historical baseline. Under Option 1, aviation has to buy allowances for all emissions above this baseline. Under Options 2 and 3, the total amount of emissions grandfathered or auctioned, respectively, to aircraft operators is assumed equal to the 2008 emissions level.

Table 4 Initial impact on aircraft operating costs and ticket prices in 2012 (in € per return flight) assuming an allowance price range of € 10 to € 30 per tonne CO_2

Aircraft operating costs	Option 1	Option 2	Option 3
Short haul	47 – 140	23 – 70	160 – 481
Medium haul	92 – 275	46 – 138	316 – 948
Long haul	0	228 - 684	546 – 1,638
Ticket prices	Option 1	Option 2	Option 3
Short haul	0.4 - 1.3	0.2 - 0.7	1.5 - 4.6
Medium haul	0.9 - 2.6	0.4 - 1.3	3.0 - 9.0
Long haul	0	1.0 - 2.9	2.3 – 6.9

Note: Figures indicate expected increase in aircraft operating costs and ticket prices in 2012, based on a load factor of 70% for a round trip. Costs due to inclusion of the multiplier in Option 1 are included, additional costs of flanking instruments are not. It is assumed that opportunity costs of 'grandfathered allowances' are not passed on in the ticket prices under Options 1 and 2. The first figure is the increase at an allowance price of € 10 per tonne CO_2, the second at an allowance price of € 30 per tonne.

Under Option 2, *ticket price* increases range from about € 0.20 (for a short-haul flight and an allowance price of € 10 per tonne) to € 2.9 (for a long-haul flight and an allowance price of € 30). Owing to the multiplier, price increases under Option 1 are twice as large for short- and medium-haul flights. The long-haul flight is not intra-EU and does not fall under the scheme in Option 1. Ticket price increases under Option 3 range from € 1.5 to € 9.0 for a round trip.

The impact on ticket prices is relatively small, for several reasons. In the first place, under Options 1 and 2 the only financial costs borne by aircraft operators are those associated with emissions growth. These costs are expected to be spread out over all tickets for flights falling under the scheme, however. Increases under Option 3 are generally greater because of the auctioning of allowances. As Option 3 is based on EU airspace, however, only a small portion of long-haul flights is subject to the scheme.

Furthermore, calculations are based on the assumption that the opportunity costs of allowances issued free of charge are not passed on to customers. If these opportunity costs were passed on *in toto*, the ticket prices increases under Options 1 and 2 would be about 7 times greater[4]. It should be borne in mind that passing on opportunity costs to customers would raise ticket prices, but it would also generate so-called windfall profits for aircraft operators by the same amount per ticket. I.e. inclusion of opportunity costs will not increase total costs of aircraft operators, since such an increase in ticket prices would not reflect a rise in actual operational costs for aircraft operators.

Since opportunity costs play no role in Option 3, the results for this option are not influenced by this assumption.

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4 Assuming a reference scenario of 4% growth of air transport CO_2 emissions annually, emissions in 2012 will be about 17% higher than baseline emissions in 2008. This growth amounts to 14.5% of 2012 aviation emissions. Consequently, under Options 1 and 2, financial costs are related to about 14.5% of emissions in 2012. Relating costs to the other 85.5% would lead to 1/0.145 = about 7 times higher costs.

5 Environmental impacts

Table 5 below summarises the total absolute CO_2 emission reduction impacts of the three policy options compared with emissions in the Business as Usual (BaU) scenario in 2012. It should be borne in mind that each policy option is based on different scenarios of geographical scope. For example, assuming an allowance price of € 10 per tonne, Option 1 would reduce CO_2 emissions by about 20 Mt of total intra-EU CO_2 aviation emissions in the BaU scenario (71 Mt), while Options 2 and 3 would reduce CO_2 emissions by 25.9 Mt of all emissions of flights departing from the EU (178.5 Mt) and 22.7 Mt of all emissions in EU airspace (156.5 Mt), respectively.

Table 5 Absolute and proportional CO_2 emission reduction of the three policy options in 2012 compared to BaU scenario in 2012 based on AERO-MS

	Option 1	Option 2	Option 3
BaU emissions in 2012	71 Mt	178.5 Mt	156.5 Mt
Baseline emissions 2008	60.7 Mt	152.6 Mt	133.8 Mt
Allowance price: €10 per tonne CO_2 eq.[5]			
Total reduction of CO_2 eq., *of which*:	20.3 Mt[6]	25.9 Mt	22.7 Mt
– Reduced within the aviation sector – Purchased from other sectors	0.3 Mt 19.9 Mt	1.1 Mt 24.8 Mt	2.0 Mt 20.7 Mt
Allowance price: €30 per tonne CO_2 eq.			
Total reduction of CO_2 eq., *of which:*	20 Mt	25.9 Mt	22.7 Mt
– Reduced within the aviation sector – Purchased from other sectors	0.7 Mt 19.3 Mt	3.2 Mt 22.7 Mt	5.6 Mt 17.1 Mt

The estimated CO_2 emission reduction impacts of all three Options up to 2012 assume that most of the cheapest emission reductions are available from non-aviation sectors covered by the EU ETS, who then sell their surplus allowances to the aviation sector.

In the medium term (about 5 years), the bulk of reductions *in* the aviation sector is due to reduced demand for air transport compared to the BaU scenario. In the longer run, about half the reductions *within* the aviation sector may be attributable to supply-side responses by airlines (technical and operational measures), mirrored through the purchase of somewhat fewer allowances from other sectors. Obviously, at an allowance price of € 30 supply-side responses may increase significantly as more of the abatement measures available to the aviation sector become cost-effective.

5 The term CO_2 *equivalent* applies here because some of the allowances bought from other sectors may be based on emission reductions of other gases covered by the Kyoto Protocol (e.g. methane, F-gases) which are achieved under the EU ETS in other sectors.

6 The total reduction of CO_2 equivalents under Option 1 is not equal to the growth of emissions in the aviation sector between 2008 and 2012. This is due to the multiplier of 2, assumed to capture the full climate impact of aviation. Because of the multiplier, for each additional emission unit two allowances will have to be purchased from other sectors. The amounts of reduction within the aviation sector are presented without the multiplication factor. If the allowance price is higher, the reduction within the sector will be larger and the overall reduction smaller, because the multiplier affects less allowances.

The three Options do differ significantly in their environmental effectiveness. This depends on the incentive 'at the margin' (i.e. the change in an aircraft operator's marginal costs associated with production of one extra tonne of CO_2) and on the amount of emissions for which allowances must be surrendered. This amount influences the financial incentive for the aviation sector, since it is these emissions that are associated with costs, either effective or opportunity. It depends on the choices made regarding three key design elements.

- **Coverage of climate impacts**. If a multiplier were applied to CO_2 emissions to account for non-CO_2 impacts, the strength of the incentive would be proportional to the multiplier. With a multiplier of two, for example, the incentive created in Option 1 would be twice as great as in Option 2. Clearly, flanking instruments would provide incentives of their own, possibly reinforcing the incentives provided by the EU ETS for CO_2 emissions.
- **Geographical scope**. The strength of the incentive to the aviation sector depends on the geographical scope of the option. If more routes are included, environmental effectiveness will increase. Moreover, the greater the share of a route, the stronger the incentive, which will rise in direct proportion to the CO_2 emissions falling under the scheme. In addition, options with a limited scope, such as Intra-EU (Option 1) and to a lesser extent EU airspace (Option 3), benefit long-haul more than short-haul flights, as only the latter are (fully) covered by the scheme.
- **Allocation method**. Although the strength of the incentive for operators does not depend on whether allowances are grandfathered or auctioned[7], it does depend on the amount of emissions for which allowances must be surrendered. Option 1 differs from a standard baseline and credit system, because aircraft operators are accountable only for emissions above their historic baseline. The scheme therefore provides no incentives for reductions beyond this baseline.

Potential trade-offs of CO_2 optimisation

The crucial question with a CO_2-only scheme is whether it will lead to any *negative* trade-offs. This is an extremely difficult issue to evaluate, because of its speculative nature and also for lack of technological documentation in the public domain.

CO_2 - NO_x

This study indicates that emission trading based on CO_2 only (with potentially a multiplier covering the non-CO_2 effects) would not adversely impact NO_x emissions overall. In the medium term, at constant engine technology level, overall fleet reductions in CO_2 that might arise from emissions trading go more or less hand in hand with NO_x emissions reductions. This is because in the short and medium term, the total amount of fuel used by all air traffic in Europe can to a large extent only be reduced by fuel efficiency measures that also reduce NO_x, such as operational measures (network, load factor, speed, climb angle, etc.) and any reduced demand for air transport.

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7 In either case it pays to reduce emissions, either by being able to sell allowances or by having to purchase fewer allowances.

In the longer term, it is more uncertain whether CO_2 optimisation would also reduce overall NO_x. The NO_x emissions index (NO_x emissions per unit fuel) might increase *faster* if aviation were incorporated in the European Emissions Trading Scheme on a CO_2-only basis. In other words, the EI NO_x of the aircraft fleet might increase compared with a Business as Usual scenario owing to the higher combustor temperatures and pressures resulting from technological innovations to increase the fuel efficiency of gas turbine engines. However, although it is uncertain, an *additional* EI NO_x increase is expected to be offset by other measures aimed at increased fuel efficiency such as operational measures, demand effects and airframe innovations (e.g. weight reduction). Moreover, there is a European commitment (ACARE) to improve NO_x performance (bearing in mind that not all aircraft flying in Europe have European-manufactured engines/airframes).
Based on the above findings, we conclude that a CO_2-only based scheme will most probably reduce both CO_2 and NO_x emissions in the shorter term and longer term, but that the uncertainties of the impact in the longer term suggest that a precautionary approach to NO_x emissions is appropriate.

CO_2 - contrails
Whilst environmental conditions of ice supersaturation and temperature are the primary determinants of whether a persistent contrail is formed, it has been reported that more modern technology has a higher propensity to cause contrails because of a cooler exhaust, causing contrails over a greater depth of the atmosphere than was the case with older technology. Based on assumptions regarding the likely increase in propulsive efficiency (η), this trend is expected to continue in the future. This effect and whether it will increase over a BAU situation (like NO_x) is rather speculative. However, that there is an effect of more modern engines has been shown from observations and theoretical calculations. If the pressure on fuel efficiency increases as a result of incorporating aviation in the ETS, then η will also increase, with a consequent impact on contrail production. As an indication of the potential of this effect, sensitivity calculations from the literature suggest that an η of 0.5 in 2050 will result in 20% greater contrail coverage than an approximate estimate of the 1990's η of 0.3. It is uncertain, however, whether this trend will increase faster if aviation were incorporated in the EU ETS.

6 Economic impacts

Impacts on the competitive position of EU carriers
Besides examining general economic impacts, this study also looked specifically at potential economic distortions. Of particular concern in this respect would be effects on competition between EU and non-EU carriers. The main conclusion is that none of the policy options considered in this study will significantly damage the competitive position of EU airlines relative to non-EU airlines. This conclusion is based on the following arguments:

– Foremost, none of the options considered differentiate with respect to nationality of the aircraft operator or type of operation. All commercial aircraft flying on a route falling under the scheme are subject to it. This means that

European and non-European airlines receive equal treatment under all the proposed policy options for including aviation in the EU ETS. This is not the case for other sectors already covered by the EU ETS. Most of their competitors based outside the EU do not face similar cost increases. as they are obviously not covered by the EU emissions trading scheme.

- Furthermore, this study shows that the impact on the size of the home market is too small to have substantial effects on the operating efficiency of EU carriers. It is sometimes argued that the competitive position of carriers might also be affected by changes in the size of their home market. Obviously, one second-order effect of including aviation in the ETS might be somewhat lower growth of the European air transport market due to increased air fares. meaning that over time there might be an effect on European carriers' economies of scale. However, this study shows that an allowance price range from € 10 to € 30 per tonne CO_2 would decrease air transport volume in the short term on the EU market by 0.1% to 0.2% under Option 1, by 0.1% to 0.4% under Option 2 and by 0.5% to 1.4% under Option 3. Based on this relatively small impact on market size, we conclude with regard to the home market argument that introduction of none of the three policy options would affect the operating efficiency of EU carriers significantly compared with non-EU carriers. These figures are average impacts for the sector as a whole and may differ for individual aircraft operators.
- Most non-EU carriers will be affected by inclusion of aviation in the EU ETS on a relatively small proportion of their flights compared to EU aircraft operators. The response of non-EU carriers might be to deploy their newest and cleanest aircraft on routes falling under the scheme, diverting older and less fuel efficient aircraft to other routes. This may give non-EU carriers a competitive advantage over EU carriers. However, this effect may in practice be limited by other constraints and commercial considerations that play into fleet management and deployment strategies.

To bring things into perspective, although aviation is an international business, it is less vulnerable to economic distortions than other sectors of the EU economy. This is for two reasons. First, the 'product' in the aviation industry, transportation, is by definition geographically bounded (to a major extent), with passengers and freight having relatively fixed origins and in many situations also relatively fixed destinations. An increase in the cost of European flights will not make a Frenchman with business in Denmark buy a ticket to America instead, and any air carrier operating between e.g. Paris and Copenhagen will be subject to exactly the same competitive conditions. In comparison, many other products would appear to be more vulnerable, as the only relevant aspect here regarding their purchase and use anywhere in the world is the cost associated with production of the product and transportation to its place of use. A second reason is that the air transport market is highly regulated by bilateral air service agreements that limit competition from airlines outside the EU.

Marginal impact on the EU ETS and the allowance price

Table 6 shows that under all three policy options aviation would buy about 1% of the allowances available under the present EU Emissions Trading Scheme in the year 2012. It should be stressed that this percentage would be even lower if markets for emission reduction credits (JI and CDM) were also taken into account. A certain additional supply of CERs from a few big additional CDM projects may easily absorb the relatively small additional demand from aviation. In all three Options we therefore expect no significant rise in the allowance price in the short term if aviation were included in the EU ETS.

Table 6 Absolute and relative amount of allowances bought by the aviation sector from the EU ETS in 2012

	Allowances (in million tonne)	% of present allowances in ETS
Allowances for CO_2 emissions under present Emission Trading System (2005-2007)		
Allocated CO_2 emissions	2,200 Mt	100.0%
Allowances bought by aviation from other sectors (2012)		
Allowance price: € 10 per tonne		
Option 1	20.0 Mt	0.9%
Option 2	24.8 Mt	1.1%
Option 3	20.7 Mt	0.9%
Allowance price: € 30 per tonne		
Option 1	19.3 Mt	0.9%
Option 2	22.7 Mt	1.0%
Option 3	17.1 Mt	0.8%

In the long run, if any option is introduced for more than one commitment period, continued growth of aviation might cause the allowance price to rise. The extent to which including international aviation in the EU ETS could, in the long term, cause the allowance price to rise faster than would have otherwise been the case depends on many factors influencing the demand and supply side of the international carbon markets, not least the marginal abatement cost curves of other sectors of the economy.

7 Overall conclusion

This study examined the feasibility of including international aviation in the EU Emissions Trading Scheme in order to mitigate the climate impacts of this sector by encouraging airlines to integrate reduction of those climate impacts into their business objectives. The introduction of emissions trading for the aviation sector, most immediately in respect of its CO_2 emissions, while keeping the structure open for including non-CO_2 impacts in the future, does not appear to pose many challenges that have not already arisen in the context of the existing EU Emissions Trading Scheme. This suggests that emissions trading is a policy option that can be considered alongside other policy instruments to tackle the climate impact of aviation.