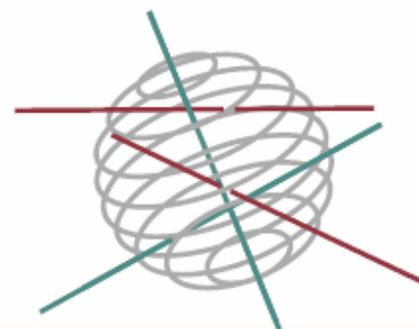


# SSD

SCIENCE FOR A SUSTAINABLE DEVELOPMENT



## AVIATION AND THE BELGIAN CLIMATE POLICY : INTEGRATION OPTIONS AND IMPACTS

«ABC-IMPACTS»

SD/CP/01A

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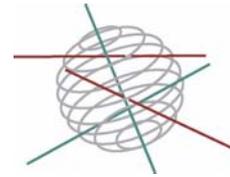
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CLIMATE 

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ATMOSPHERE AND TERRESTRIAL AND MARINE ECOSYSTEMS 

TRANSVERSAL ACTIONS 



*Climate*

FINAL REPORT PHASE 1  
SUMMARY

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W. Hecq, J. Van Mierlo, C. Macharis, J. P. van Ypersele, S. Meyer, J. Matheys, T. Festraets, B. Matthews, P. Marbaix, A. Ferrone. ***Aviation and the Belgian Climate Policy : Integration Options and Impacts «ABC-Impacts»*** Final Report Phase 1 Summary. Brussels : Belgian Science Policy 2009 – 7 p. (Research Programme Science for a Sustainable Development)

## 1. Introduction

Since the publication of the Intergovernmental Panel on Climate Change (IPCC) special report on aviation (1999), the international scientific community has become aware of the importance of the impacts of emissions from the aviation sector on global warming. The report indeed shows that not only CO<sub>2</sub>, but also NO<sub>x</sub>, condensation trails ([contrails](#)) and enhanced [cirrus](#) cloud formation, have a significant impact on [climate change](#). Yet, emissions from international air transport are not targeted by the [Kyoto Protocol](#) commitments, and are not integrated in any international climate policy, despite considerable growth in aviation since more than 10 years.

The possibility of integrating this sector is increasingly considered both at the European level and in the context of the United Nations Framework Convention on Climate Change (UNFCCC). The European Union is planning on including aviation in its [emission trading](#) scheme in 2011-2012, and it is very likely that part of the post-Kyoto international negotiations will be dedicated to accounting for emissions from [international air transport](#).

On the 20<sup>th</sup> of December 2006, the European Commission has officially published its proposal to include the aviation sector in the [EU-ETS](#). Adding the current negotiations on the review of the existing [EU-ETS](#) at the European level and on the post-2012 scheme and commitments at the [UNFCCC](#) level to the picture provides an overview of how climate impacts of the aviation sector have become an important "hot" topic but also how tricky and interdependent policy options to include aviation in climate policy are.

Concerning scientific progress related to climate impacts of non-CO<sub>2</sub> emissions from the aviation sector, major scientific advances have been included in the [IPCC](#) AR4 report (as well as projects such as TRADEOFF), compared to the TAR and SRAGA. These include that the estimated impact of NO<sub>x</sub> and [contrails](#) has been reduced but the impact of [cirrus](#) cloud formation seems to be greater than expected although there is still a large uncertainty. This implies that the total impact of aviation is dominated by the non-CO<sub>2</sub> impacts, particularly as far as Belgium is concerned.

In this context, the *ABC impacts* project intends to analyse these different climate policy options (as well as their consequences) and to provide an in-depth study of the technical, economic and environmental characteristics of the aviation sector.

## 2. Climate, climate policy and the aviation sector

The influence of human activities on climate has been demonstrated by the [IPCC](#) and it is well known that the main anthropogenic [greenhouse gasses](#) are generated by [combustion](#) processes, such as those related to the transport sector.

Climate policy aims at limiting climate impacts either by adapting ecosystems and human societies to those climate changes ([adaptation](#)) or by trying to reduce emissions causing climate change ([mitigation](#)).

The transport sector is not only responsible for an important share of the total [GHG](#) emissions, especially in industrialised countries (more than 20% of the total GHG emissions of those countries are due to transport), but it grows strongly and continuously while other sectors succeed in stabilising, or even in reducing, the total quantity of their GHG emissions. Among the different transport segments, aviation plays a particular role for two main reasons:

1. aviation induces greater climate impacts than those due to [Kyoto greenhouse gasses](#) emitted by aircrafts (e.g. perturbation of the high cloud cover, which induces a strong regional [forcing](#)) ;
2. aviation registers one of the highest growth rates within the transport sector during the last years, and market forecasts seem to confirm this trend for the following years.

Different policy instruments are available for the climate policy to mitigate climate impacts from the transport sector:

1. instruments with a direct link on the global warming issue (raising public awareness, voluntary/negotiated agreements or actions, financial and economic tools such as taxes / fees / subsidies / market mechanisms, R&D, command-and-control regulation) ;
2. instruments not aiming specifically at global warming but having an indirect influence on it (planning, financial and economic tools to set up a level playing field between all transport modes such as VAT or duty free sales, infrastructure management such as slot allocation at airports, the environmental legislation focusing on other air pollutants than GHGs or related

annoyances such as noise, R&D to support more environmentally friendly transport solutions or alternatives to transport).

The analysis of those instruments results in the realization that the environmental effectiveness of a policy mix is often better than the environmental effectiveness of a sole instrument. No isolated instrument offers simultaneously a real limitation on the total climate impact and a satisfactory level of flexibility to minimize the related costs as much as possible. In other respects, raising public awareness seems to be a basic element for a good comprehension and acceptance of other climate policy instruments. Moreover, ensuring a level playing field between all transport modes by applying a harmonized rate of VAT on the tickets and fuel tax is necessary to avoid competition distortion, as well as harmonizing the duty free practices.

Moreover, the adoption of any policy measure should be done with the assessment of all its global consequences, seeing that even measures not focused on tackling climate change could have a substantial indirect influence on the efficacy and efficiency of other climate policy instruments.

The world-wide extent of global warming and transports such as aviation generally implies that international agreements could have a better environmental efficiency and a lower risk of market distortion than measures adopted at the local level (e.g. tax on [kerosene](#) or on CO<sub>2</sub> emissions; emission standards; airport taxes or fees; etc.). On the other hand, this kind of agreements may take a long time to be implemented and are often limited to the adoption of the lowest common denominator between the parties.

The adoption of the [Montreal Protocol](#), the [UNFCCC](#), the [Kyoto Protocol](#) and the [EU-ETS](#) falls within this scope. The two last ones are aiming at increasing the flexibility of the policy measure and at reducing the compliance costs by combining a strict emission ceiling with market mechanisms.

In this framework, the European Commission has officially launched in December 2006 a directive proposal to include the aviation in the [EU-ETS](#). Diverging views between the European Parliament and the European Council Environment require a procedure of second reading that is expected to begin in May 2008.

### 3. Emissions from aircraft

Due to the continuous growth of transport, related CO<sub>2</sub> emissions have continuously increased during the last years, and are expected to reach 25% of world-wide CO<sub>2</sub> emissions by 2030.

Aviation is one of prime drivers of this growth, and yet its total climate impact is by far more important than only its CO<sub>2</sub> emission climate impact. The concerned atmospheric pollutants are generated through [kerosene combustion](#) in aircraft [engines](#) and their respective total quantity of emissions depends either on the fuel composition (NO<sub>x</sub>, SO<sub>x</sub>), or on combustion conditions. These last ones vary according to the flight phase, so that more CO, NO<sub>x</sub> and unburnt hydrocarbons (HC) are emitted during the [LTO](#) phase than during the [cruise](#) phase and that the energy efficiency per kilometre flown is lower for short-distance flights than for long-distance flights. [LTO emissions](#) are more worrying for health and ecosystems (air quality), while [cruise](#) emissions are particularly more sensible for [climate change](#).

In order to realise an aviation emission inventory for Belgium based on the calculation of aircraft emissions and related energy consumption, the following parameters have to be taken into account:

- activity data of Belgian airports, as well as of overflights ;
- aircraft types (and as far as possible the used [engine technologies](#)) ;
- distances flown ;
- the different flight phases.

CO<sub>2</sub> emissions and energy consumption related to flights departing from or arriving at a Belgian airport almost reach the same level as in 2001, before the SABENA bankruptcy and the New York attacks, while those related to overflights have steadily increased period to attain practically twice the emission level of Belgian airport activities. A similar trend exists for NO<sub>x</sub> emissions, as opposite to CO and HC emissions that are typically generated in higher quantities during the [LTO](#) phases (in this case, on Belgian airports) rather than during the [cruise](#) phase of overflights.

There are different solutions to [mitigate](#) aviation emissions on a short to middle term either at the aircraft level ([engine technology](#) improvement, higher [load factor](#), small modifications of the aircraft design, etc.), or at the level of the global aviation sector (alternative fuels, improvement of the navigation system, better emission management at airports, etc.). However, reduction potentials face

many obstacles to be really efficient (time delay for the adoption and market penetration of new R&D solutions, huge increase of the total forecasted emission volume due to the market growth compared to the emission reduction potential, etc.).

#### 4. Aviation sector prospect and Belgian characteristics

After 2001, the aviation sector almost recovered its former activity level partly thanks to the strong growth in the freight segment. Another general trend in the [passenger](#) transport consists in the use of larger aircrafts which increase the number of available seats.

In contrast, the number of flights at the European level has risen sharply since 1985 (with a little drop in 2001-2002) but overflights represent a minor part of the total flights contrarily to the Belgian situation.

Considering air traffic forecasts, [passenger](#) flights are expected to grow by 4% per year, leading to a doubling of the current frequencies by 2023, and cargo flights could reach an even stronger growth level between 4,4% and 5,9% per year.

More specifically, European air traffic is expected to increase on average by 3,3% annually in the mid term and from 2,3% to 3,4% in the longer term (until 2023), while Belgian/Luxembourgian air traffic should grow annually by 2,8% on average in the mid term, with an increased proportion of overflights in the total, and by 2,3%-3,4% in the longer term.

As regards the characteristics of the Belgian aviation sector, 15 companies registered their licence in Belgium in 2007, from which 2 helicopter businesses. At the airports level, Brussels National Airport still registers the most important activity but suffered the Sabena bankruptcy in 2001, while passenger numbers have grown substantially at regional airports, especially Brussels South Charleroi Airport. Concerning cargo flights, which grew faster than passenger flights in Belgium, Brussels Airport is still the major Belgian cargo airport but the market share of regional airports, mainly Liège Airport, has increased sharply these last years with a stronger trend than for passenger transport.

Since Belgium is situated in the middle of the main European air knots, overflights above the Belgian territory are especially important (more than 750.000 in 2006 compared to more or less 200.000 [LTO](#) cycles at Belgian airports).

From the financial point of view, the situation of the Belgian aviation sector has improved since 2001 and the staff number hired and paid in Belgium has strongly declined (decrease in the sector employment + growth in staff hired following another country rules), but the Belgian aviation sector has never been profitable as a whole during the last ten years.

#### 5. Interactions between the climate and the aviation sector

As mentioned earlier, aviation has a greater climate impact than that only induced by CO<sub>2</sub> emissions.

Emissions at high altitude play an important role:

- in the interactions with the atmospheric chemistry (methane destruction, ozone formation, aerosols formation), modifying the [radiative forcing](#) balance of the atmosphere,
- and in clouds induction ([contrails](#), [cirrus](#)), which is mainly a local phenomenon along the main air corridors.

Therefore, the total climate impact of an aircraft at 12 km, taking into account global and regional impacts, is on average twice as large as its impact at 8 km.

On global average, the total climate impact from the aviation sector ranges from 2,5 (IPCC, 1999) times to more 5 times (TRADEOFF, 2003) the climate impact from aviation CO<sub>2</sub> emissions only.

Whereas in Europe as a whole, overflights (without [landing or taking off](#) in any European airport) represent only a tiny portion of all flights (less than 1%), they represent the majority of the flights over the Belgian territory (~70%). This is reflected in the [radiative forcing](#) of [contrails](#) and aircraft induced cloudiness (AIC) produced by these flights.

Seeing that Belgium is right in the middle of the main European air knots, it will suffer from one of the most important [contrail](#) covers.

In Belgium the impact of [LTO](#) flights represent only ~4% of [RF](#) due to [contrails](#) or AIC as most of the flights taking off or landing in Belgium do not reach an altitude where contrails can be produced before leaving the Belgian airspace.

Belgium is thus submitted to important climate impacts (imbalance in [radiative forcings](#) inducing local temperature changes, enhanced cloudiness) from these flights that do not or barely contribute to the economy of the country (It is important to note that although the [RF](#) from AIC in Belgium is of the same order of magnitude than that of all anthropogenic CO<sub>2</sub>, this does not imply that the temperature increase generated by these [radiative forcing](#) imbalances will be the same, as the climate system will be able to disperse the impact of such a strong local forcing).

One implication of this result is that it would be in the interest of Belgian policymakers to propose a strong mechanism to include the non-CO<sub>2</sub> gases, either within the [Emissions Trading System](#) or some parallel process.

In order to assess climate impacts from the aviation sector, two new modules have been added to the interactive Java Climate Model JCM5. This version of JCM5 is already available online, and can be launched easily with one click from a web browser, assuming that Java 5+ is installed. {see point 5.2}

To make it easier to find the new plots and parameters, a system has recently been developed to automatically set up the model settings and layout to illustrate a specific topic such as aviation. The aviation setup includes a documentation page linking to other examples, illustrating the changing mixture of [radiative forcing](#) from different aviation gases and also a variety of scenarios, both unmitigated within the context of the EU 2°C limit.

During the second phase of the ABC Impacts project, further work will be done on the assessment of regional climate impacts generated by the aviation sector. First tests to model regional climate changes have already been carried out with the CCLM model.

## 6. The MAMCA analysis

Among several evaluation methods on transport related projects, the multi stakeholders multi criteria analysis (MAMCA) has been chosen by the ABC Impacts project.

The methodology consists of seven steps.

The first step is the definition of the problem and the identification of the alternatives (step 1). Secondly, the various relevant stakeholders are identified as well as their key objectives (step 2). Then, these objectives are translated into criteria and then given a relative importance (weights) (step 3). For each criterion, one or more indicators are constructed (e.g., direct quantitative indicators such as money spent, number of lives saved, reductions in CO<sub>2</sub> emissions achieved, etc. or scores on an ordinal indicator such as high/medium/low for criteria with values that are difficult to express in quantitative terms, etc.) (step 4). The measurement method for each indicator is also made explicit (e.g. willingness to pay, quantitative scores based on macroscopic computer simulation, etc.). This enables the measurement of each alternative performance in terms of its contribution to the objectives of specific stakeholder groups.

Steps 1 to 4 can be considered as mainly analytical, and they precede the "overall analysis", which takes into account the objectives of all stakeholder groups simultaneously and is more "synthetic" in nature. Here, an evaluation matrix is constructed aggregating each alternative contribution to the objectives of all stakeholders (step 5). The MCDA yields a ranking of the various alternatives and gives the strong and weak points of the proposed alternatives (step 6). The stability of this ranking can be assessed through a sensitivity analysis. The last stage of the methodology (step 7) includes the actual implementation.

## 7. Main conclusions and recommendations

Based on the former chapters, the following conclusions and intermediary recommendations have been drawn by the ABC Impacts project:

- 7.1 Through important innovative adaptations the aviation sector succeeded in implementing an important reduction of the emissions (CO<sub>2</sub>, H<sub>2</sub>O, Soot, CO, SO<sub>x</sub>, NO<sub>x</sub>, etc.) and fuel consumption of individual aircraft. However, the **reductions of the emissions (fuel consumption decreases by 0,5% - 2% per year) are less than the high growth rate of the sector** (average of 6,4% per year between 1991 to 2005, European Commission).

In the future several improvements are to be expected. In the long term some radical changes (like the use of hydrogen as a fuel for aircraft) might occur. In the meantime some other technological evolutions are to be expected (implementation of synthetic fuels, biofuels, etc.) all of which present some specific strengths and weaknesses. Some other innovative concepts have recently been presented (adapted rear turboprop mounting, adapted empennage and air frame, improved aerodynamics...) and form promising options for the future.

- 7.2 On the other hand, some **sector management changes** (improved ATM, implementation of the Single European Sky, Reduced Vertical Separation Minimum (which is already largely implemented), Continuous Descent Approach...) might reduce the impact of aviation on climate by more than 10% without the need for new technologies to be implemented onboard and without the delay that is necessary for fleet renewal when new technologies are implemented.
- 7.3 The Belgian aviation market has a very specific position within Europe due to its geographical situation; in the middle of the so-called FLAP area which is demarcated by the four main airports of Europe: Frankfurt, London, Amsterdam and Paris. This also implies that the **number of overflights is already considerable through Belgian airspace and could become even more important due to the sectoral growth and potential route adaptations** (according to Statfor-Eurocontrol, the adoption of shorter routes could increase overflights above the Belgian territory by 10%).
- 7.4 The **role of ozone and cirrus clouds**, especially for regional climate, is fundamental and so operational measures to reduce them should be considered, despite remaining uncertainties. This is especially important as tradeoffs are to be found between the different impacts. In general a reduction of CO<sub>2</sub> emissions for an engine induces an increase in NO<sub>x</sub> emissions, thus producing more ozone. Also it is a general trend that more fuel efficient engines produce more [contrails](#) at higher temperature (i.e lower altitudes).
- 7.5 It is important to note that on the one hand the impacts of the Belgian aviation sector on global [climate change](#) is relatively small compared to other sectors or other countries (Belgium's contribution to aviation **emissions** is not particularly remarkable), but that on the other hand regional climate impacts due to [contrails](#), [cirrus](#) formation and change in the ozone concentration could have a large influence on the country because of the concentration of flights over the Belgian territory. **One focus for Belgian policy makers could be to reduce the impacts from transit aviation**, especially via operational measures targeting non-CO<sub>2</sub> gases, as well as shift to other transport modes.