Measures to control climate impact of aviation

How to reach a sustainable aviation industry

Liv Balkmar & Carola Vega Norell

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**Författare**
- Author
  - Liv Balkmar & Carola Vega Norell

**Sammanfattning**
- Abstract
  
  Aviation industry has been developing throughout the last decades and is today an important part of the global economy. This constant growth makes it important to constrain the climate impacts derived from it. The IPCC report (1999), *Aviation and the global atmosphere*, lists four measures to reduce emissions and environmental impacts of aviation; Aircraft and engine technology options, fuel options, operational options and regulatory and economic options. The study aims to discuss the efficiency and implementation level of the measures. The theoretical frame for the research is based on literature studies whereas the empirical material is based on qualitative interviews of representatives of three key sectors; the authority, the service provider and the aircraft operator.

  While analysing the theoretical and the empirical results, a certain emphasis on the regulatory and economical measures has been noticed. Moreover, following conclusions have been drawn; (1) An emission trading with carbon dioxide would be an incentive to improve aircraft technology and flying procedures; (2) The best way of having international aviation included in the European emissions trading scheme (EU ETS) would be through an initial grandfathering distribution (costless distribution of permits according to historical emission and volume of fuel use) done according to a best-practise philosophy; (3) A robust instrument to measure emissions behaviour at different levels of the atmosphere is still missing. (4) The exclusion of the international aviation from the Kyoto Protocol negotiations makes it harder to include it in the existing EU ETS. Finally, all measures are needed and should be put into practise, but a trading with emissions would be the one to start the improving cycle leading to more sustainable results regarding time, environment and economy.

**Nyckelord**
- Keywords
  - Aviation, Climate impact, Emissions, Emission trading, Measures, The Kyoto Protocol, Sustainability
Preface

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Both authors are responsible for the material in this thesis.

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Liv Balkmar and Carola Vega Norell
ABSTRACT

Aviation industry has been developing throughout the last decades and is today an important part of the global economy. This constant growth makes it important to constrain the climate impacts derived from it. The IPCC report (1999), *Aviation and the global atmosphere*, lists four measures to reduce emissions and environmental impacts of aviation; Aircraft and engine technology options, fuel options, operational options and regulatory and economic options. The study aims to discuss the efficiency and implementation level of the measures. The theoretical frame for the research is based on literature studies whereas the empirical material is based on qualitative interviews of representatives of three key sectors; the authority, the service provider and the aircraft operator.

While analysing the theoretical and the empirical results, a certain emphasis on the regulatory and economical measures has been noticed. Moreover, following conclusions have been drawn; (1) An emission trading with carbon dioxide would be an incentive to improve aircraft technology and flying procedures; (2) The best way of having international aviation included in the European emissions trading scheme (EU ETS) would be through an initial grandfathering distribution (costless distribution of permits according to historical emission and volume of fuel use) done according to a best-practise philosophy; (3) A robust instrument to measure emissions behaviour at different levels of the atmosphere is still missing. (4) The exclusion of the international aviation from the Kyoto Protocol negotiations makes it harder to include it in the existing EU ETS. Finally, all measures are needed and should be put into practise, but a trading with emissions would be the one to start the improving cycle leading to more sustainable results regarding time, environment and economy.
ACRONYMS

AAU-units Assigned Amount units
ACARE Advisory Council for Aeronautical Research in Europe
AEA Association of European Airlines
ATM Air Traffic Management
CAC Command and Control
CDA Continuous Descending Approach
CDM Clean Development Mechanism
CER Certified Emission Reductions
CNS Communication, Navigation and Surveillance
ERU Emission Reduction Units
ECAC European Civil Aviation Conference
EUA-units European Union Allowances
EUROCONTROL European Organisation for the Safety of Air Navigation
EU ETS Emissions trading scheme of the European Union
IATA International Air Transport Association
ICAO International Civil Aviation Organisation
IPCC Intergovernmental Panel on Climate Change
IVL Svenska miljöinstitutet
JI Joint Implementation
KTH Kungliga Tekniska högskolan (Royal Institute of Technology)
LFV Luftfartsverket (LFV Group Swedish Airports and Air Navigation Services) In this thesis referred to as LFV
LFS Luftfartstyrelsen (Swedish Civil Aviation Authority) In this thesis referred to as Swedish CAA
NV Naturvårdsverket - Swedish environmental protection agency
OECD Organisation for Economic Co-operation and Development
RCEP Royal Commission on Environmental Pollution
RMU Removal Units
SAS Scandinavian Airlines System
SES Singel European Sky
SFR Svenska flygföretagens riksförbund
SNF Svenska naturskyddsföringen- Swedish Society for Nature Conservation
SIKA Swedish Institute for Transport and Communication
SMHI Swedish Meteorological and Hydrological Institute
UNFCCC United Nations Framework Convention on Climate Change
Vinnova Swedish Governmental Agency for Innovation Systems
INTRODUCTION

The aviation industry has been developing throughout the last decades, and is today an important part of the global economy. It supports both commerce and private travel. Its existence affects citizens of the world, regardless whether they travel or not. With its rapid growth the industry is expected to expand further. This growth makes it important to constrain the climate impacts derived from it.

Emissions of aviation that have an impact on climate are mainly carbon dioxide, water vapour and nitrogen oxides. Aircraft is also the origin of condensation trails (contrails), which may increase cirrus cloudiness that results in a greenhouse effect. The gases that aircraft emit have an impact on the concentration of atmospheric gases with climate impact; carbon dioxide, ozone and methane. Where in the atmosphere the emissions take place is also crucial for the level of climate impact.

Greenhouse gases from international air traffic are not regulated in the Kyoto Protocol. 1944 the Chicago Convention created the International Civil Aviation Organisation (ICAO) as a specialised agency with authority to develop standards regarding international aviation including certification standards for emission and noise. This international regulatory entity is responsible for accomplishing aviation’s objectives regarding safety, performance efficiencies, economics and environment.

With the years ICAO has developed guide-documents regarding the creation of policies on fuel taxation and charging principles with relevance in the emission context. There is a constant discussion about which measures should be implemented, as well as how these should be administrated and on which bases these should be assessed.

Forecasts beyond 5-10 years are considered unreal to make, due to the several changing factors that play important role in decision-making. Among these factors, are real costs of air travel, economic activity, and new market opportunities to be found as well as world income trends, world political stability, tourism, and air transport liberalisation.

The IPCC report from 1999, Aviation and the global atmosphere, lists four measures to reduce emissions and impacts of aviation: Aircraft and engine technology options, fuel options, operational options and regulatory and economic.

There are opinions, talking in favour and against these measures. Improved aircraft technology is necessary, but not considered enough to decrease carbon dioxide emissions in the short or long run. Operational options are found effective, but difficult to implement because of lack of robust weighing instruments capable of taking into consideration the different behaviour of greenhouse gases in the atmosphere. Among economic and regulatory measures, a trading with emission permits is considered a suitable measure to incentive a limit of carbon dioxide emitted from aircraft. However, measures to limit aviation emissions do not appear to keep pace with the rapid growth of aviation.
**Aim and research questions**

The aim of the study is to investigate the potential of different measures\(^1\) to limit the climate impact caused by emissions coming from aviation. For this, the opinions of three central actors within the aviation industry will be studied. The interviewed actors are among them that are to put political decisions concerning aviation into practice, and that is why their opinions are of importance in this study. Eventually, it will be possible to discuss the efficiency and implementation level of the measures based on the opinion of the central actors and on existing documents on the subject. The result aims to present a broad overview of the current situation, and to show to what extent aviation can limit its climate impact at present development.

This study focuses on operational, technical, fuel\(^2\) and economic measures in order to control the emissions coming from aviation.

To approach the aim, the investigation will address the following questions:

- Of the four measures mentioned above, which are the most widely discussed in current European scientific literature, and within the aviation sector?
- Which measures do the chosen actors, consider applicable to obtain environmentally and economically sustainable aviation?
- What are the “difficulties” and “options” for implementing these measures according to research literature, and the actors within aviation industry?

**MATERIAL AND METHOD**

The theoretical frame of the thesis, has been based on literature in the area, whereas the empirical material has been based on qualitative interviews; the first, to have a better understanding of the different measures and so create aim-relevant questions for the interviews and the second, to get a better idea about what the authority, the service provider and aircraft operator think about the named measures. Once the results of the interviews were completed, they were interpreted through the theoretical frame, aiming to get a broader perspective and a more substantial result.

All three interviews were carried out in April 2006, and every interview lasted on average an hour. The interviews have been semi-structured and intended to be part of an explorative study, which has made it possible to cover the subject chosen for the thesis and has given space to new views. Since the respondents have talked about the same aspects but in different proportions, questions about the aspects named in the interviews and the knowledge and interest about them have been brought up in the discussion part.

**Interview method**

The interview investigation follows the seven research stages of Kvale (1996, p.87-88). Nevertheless, the named stages have been modified according to what was considered more suitable for this research. Kvale considers *thematising* as the first stage where the aim of the

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\(^1\) Measures, is a frequently used word in this study. The meaning of it, is an action taken to gain a certain goal.

\(^2\) The study does not put focus on fuel aspects. Nevertheless, being an explorative study, the importance of this has grown during the research and is named at this point.
study is formulated. The field of the topic is examined before the interviews start. The second stage would then be designing. Here the study is planned and outlined. The intended knowledge decides the design with regard to the seven stages. The next stage, interviewing, is performed with an interview guide. The knowledge gained is approached in a reflective way. The transcribing of the interviews comes afterwards and is about preparing the material for the analysing stage. The analysing method is decided depending on the purpose of the study and on the interview material. The result is then to be verified in the next stage, this means that the generalisation, reliability and the validity of the results is assessed. Reporting is the last stage of the interview research. Here the results and method used are presented in a scientific and, at the same time, understandable way.

Furthermore, the following aspects have been taken into consideration when conducting the research:

- Political: laws related to international and domestic aviation and the body responsible for their control.
- Economical/ administrative: systems to share eventual emission permits, systems and criteria for charging for emissions, and the administrative costs to implement these systems and supervise them.
- Sustainability: Short and long-term effects on the environment as well as the potential of the different measures to work as incentives for aviation industry to develop towards a decreased impact on environment.

The choice of respondents

Representatives of Swedish Airports and Air Navigation Services (LFV), Swedish Civil Aviation Authority (CAA) and Scandinavian Airlines System (SAS) were chosen since they are relevant key actors in the aviation industry, representing the different sectors that were found relevant for the study. Since the background to this thesis are measures to limit climate effects of aviation emissions, it is crucial to find out how directly related actors assess these measures. The choice of just one airline is partly due to availability. Even though there exist other airlines, which could have given a different perspective to the subject, SAS is considered a reliable and relevant airline with a long history and known for having an environmental department. However, information of some smaller and low-cost airlines was found on the Internet. Interviewing actors outside the aviation sector, like the Swedish Society for Nature Conservation (SNF), has also been taken into consideration, but finally discarded since it was not considered relevant for the aim of the thesis.

The names of the respondents have not been mentioned. Nevertheless their position and the sector they represent have been considered important to name. In order to avoid disagreements or false information, each interview-resume has been controlled and accepted by the respective respondent before being used in the thesis. All three respondents have shown willingness to answer all the questions and interest in getting the final results of the interviews as well as of the research.

Two interviews have been made in Swedish and one of them in English. The same questions were used for the three interviews and the answers have been intended to confirm, falsify or develop the information gained from earlier literature studies. The reader might find that the questions (see Appendix 1) lean towards emission trading. Since the questions have been based on issues covered in current literature and scientific articles they have dealt with
different aspects related to the study topic, including emission trading, a current and debated subject. Therefore it was relevant to try to analyse why this is so.

**Analysing method**

The interviews with the LFV and Swedish CAA have been recorded whereas the one with SAS has been documented by handwriting because of technical problems. Still, the information got from the non-recorded interview has been carefully documented and has not affected the results and the aim of the study. According to Kvale (1996, p.182) a transcript is a tool to interpret the interview, and not the goal. The recording of the interviews has been intended to support the notes taken.

As soon as the interviews had been performed, the recorded interviews were transcribed. As a following step, each interview has been translated into English as an extended text trying always to respect the content of the answers. Afterwards, each text has been thematically analysed in order to create a connected and coherent text including all the answers written under structured under clear headings. As a last step in the analysis part, the results of the interviews have been presented in a table (see Table 2), which is intended to give a resumed and clear overview of the interview results.

**Reflections on the method**

The seven research stages of Kvale (1996, p.87-88) have been a helpful tool to maintain a structured research. The interviewing step was planned to consist of recorded conversations in order to support notes. Due to technical problems the interview with the representative of the operative sector, which was a telephone interview, could not be recorded. However, the notes taken included relevant information for the purpose of the research. Still, it needs to be mentioned that face-to-face interviews are probably easier to make since the body language, eye contact and socialisation level help to give feedback to the respondent and to create a more comfortable atmosphere, which might lead to more expound answers.

The eventual level of interpretation on the respondents’ answers should not have changed the liability of the interview results since the respondents were clear and informative in their answers. Moreover, even if the respondents belong to the Swedish aviation sector, the research contains an EU-perspective. This last fact can be supported by the choice of literature, which has consisted of international reports and articles on an EU level written by relevant actors and entities. The research might have leaned towards certain aspects, but this could be seen as a natural consequence of current discussions that bring up such aspects. Finally, and according to Kvale’s verifying stage, the generalisation, reliability and the validity of the results have been assessed and finally considered to fulfil the aim of the thesis.

This research would be possible to redo. There may be a similar result using the same sources and interview questions. However, the choice of limitations, subjects and analysing method depends on the perspective and aim of the study. The validity of a study has been achieved and fulfilled when the research questions have been answered.
BACKGROUND

Presentation of the actors

Swedish Civil Aviation Authority

Swedish CAA has the regulative responsibility of Swedish civil aviation. The aim is to promote safe, cost-effective and environmentally safe air transportation in line with the Swedish transport policy objectives (Swedish CAA, 2006). The governmental instruction for Swedish CAA is to have the overall responsibility for the civil aviation sector in Sweden. Other assignments are regulations and inspections of civil air transport in Sweden. They also follow the aviation market’s development, analyse, evaluate and make prognoses. Another area is the participation in international aviation agreements. The Swedish CAA should both look after the Swedish interests and adopt international regulations in Sweden.

LFV Group Swedish Airports and Air Navigation Services

LFV is a state enterprise, which operates Swedish state owned civil airports (LFV, 2006). The enterprise is responsible for these airports’ (at the moment 18) development in a cost-effective and safe manner. One business area is the air navigation service at Swedish airports. LFV has a governmental instruction to fulfil Swedish transport policy objectives. This means they should provide for a qualitative, safe and environmentally acceptable air transport system. The air transport system should be available for citizens and industry and provide for local development in the whole country.

Since LFV are selling start and landing services to air companies it does not charge for carbon dioxide (CO$_2$), but for emissions directly related to the airports such as nitrogen oxides(NOx) because these lead to acidification, eutrophication and health aspects. These start and landing charges are differentiated and depend on the actual emissions of the aircraft.

Scandinavian Airlines System

SAS is a European airline with base in Sweden, Norway and Denmark. It was first established in 1946, which makes it one of the oldest airlines in the world. It operates both domestic and international flights. Its focus is on quality in contrast to inexpensive flights, like the so called low cost companies. SAS takes social as well as environmental responsibility, but cost-efficiency is as for most companies the primary goal.

Aviation and climate issues

The aviation industry

Matters related to safety and local air and noise pollution are not the only ones to be considered when it comes to aviation. Two global issues have now entered the environmental discussion; climate change including the change of weather patterns and UV-B radiation at the earth’s surface. Moreover, aviation fuel corresponds to 2-3 % of the total fossil fuels worldwide. Consuming 13% of the fuel used in the transport sector, aviation is the second biggest fossil fuel consuming sector after the road transportation sector. Already in 1994 the commercial aviation sector consisted of about 15,000 operating aircrafts and around 10,000 airports. More than 1.25 million passengers used airlines services for business and vacation
travel and about 24 million jobs of the world’s workforce belonged to the aviation industry (IPCC, 1999b, chapter 1).

Airbus forecasts from 2004 calculate the growth of passenger-kilometre to be 5.3% per year until 2023. Almost the same percentage is presented by Boeing (2005) as they calculate passenger traffic to grow 4.8% annually 2005-2024. Both aircraft manufacturers expect the cargo traffic to increase even more.

The Kyoto Protocol

The United Nations Framework Convention on Climate Change (UNFCCC) was signed during the Rio Conference 1992. Since then, the main objective of this international treaty has been to stabilise greenhouse gas concentrations in the atmosphere in order to prevent anthropogenic interference with the climate system, which could have dangerous effects (Kerr, 2000, p.10). The parties of UNFCCC agreed to the Kyoto Protocol in 1997 but it was not fully ratified until 2005. The Kyoto Protocol is an addition to the named treaty and the first international environmental agreement which relies on mainly market-based mechanisms (Helme, 2000, p.xvi). The Kyoto Protocol has more powerful and legally binding measures than the Framework Convention (UNFCCC, 2006a).

In the first commitment period (2008-2012), the Kyoto Protocol requires developed countries to reduce six greenhouse gases (carbon dioxide, methane, nitrous oxide, hydrofluorcarbons, perfluorocarbons and sulphur hexafluoride) by 5.2% in relation to 1990 levels (UNFCCC, 2006a).

The Kyoto Protocol has three flexible mechanisms known as joint implementation (JI), clean development mechanism (CDM) and emissions trading³(UNFCCC, 2006a). Any Annex 1⁴ party (that has ratified the Protocol) can use these mechanisms in order to meet the emissions target or invest in JI and CDM projects. It is the Annex B ⁵ countries that have the obligations to reduce emissions under the Kyoto Protocol. Annex 1 countries can only host ⁶ JI projects whereas non-Annex 1 countries can just host CDM projects. Most industrialised countries are listed in both Annex 1 and Annex B. Furthermore; JI projects may take place between two Annex 1 countries. The resulting emission reduction units (ERUs) are counted against the investing country’s targets. Annex 1 countries invest in non-Annex 1 countries CDM projects. The resulting emission reductions are called certified emission reductions (CER) and are used to help meet the invested party’s targets. The projects must contribute to a sustainable development of the host country (non-Annex 1) and must be independently certified.

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³ In the Kyoto protocol this is known as emission trading whereas in the European emission trading system this is known as EU ETS.
⁴ Industrialised countries listed in Annex 1 of the Convention (UNFCCC). These countries are the same as Annex B plus Belarus, Kazakhstan and Turkey (UNFCCC, 2006a).
⁵ Emissions- capped industrialised countries, which are listed in the Annex B of the Kyoto Protocol. These countries are the 15 member states of EU plus Australia, Bulgaria, Canada, Croatia, Czech Republic, Estonia, Hungary, Iceland, Japan, Latvia, Liechtenstein, Lithuania, Monaco, New Zealand, Norway, Poland, Romania, Russian Federation, Slovakia, Slovenia, Switzerland, Ukraine and US. The US is not willing to ratify the Kyoto Protocol at present time (UNFCCC, 2006a).
⁶ The country in which an activity or project to decrease CO₂ emissions take place. Can be an Annex 1 country for JI projects (e.g. an energy efficiency scheme) or sink activity. In a CDM project the host may be a non-Annex 1 country (UNFCCC, 2006a).
⁷ 147 countries, mostly developing ones. All countries are listed at http://unfccc.int → parties and observers
Emissions trading may take place between Annex 1 parties where assigned amount units (AAU) are transferred. Another mechanism apart from these flexible ones is greenhouse gases removed from the atmosphere through eligible sink activities such as reforestation and cropland management. The credits for such sink activities are called removal units (RMU).

Under emissions trading where surplus allowances are traded, it is not only the AAUs that can be transferred but also ERUs, CERs and RMUs earned through JI, CDM or sink activities. The penalty for a party not meeting its emissions target is to make up the difference in the second commitment period (after 2012) plus 30%. Furthermore, the party is not allowed to sell permits under emissions trading and a compliance action plan must be performed.

The Kyoto Protocol and aviation

International aviation is not included in the Kyoto Protocol. Only CO₂ emissions from domestic flights are regulated in the national targets (Williams et al., 2005, p.270). Instead the parties of the Kyoto Protocol have decided to implement the work of limiting the emissions of international aviation via International Civil aviation organization (ICAO), (Swedish government, 2006). The measures taken by ICAO so far have mainly been to improve the knowledge of the effects on climate impact originated from aviation (European Commission, 2005, p.4). Since no agreements have been made between the 188 member states of ICAO about which measures to take to diminish the climate impact of aviation, the European Commission have stated that aviation should be a part of the European emissions trading scheme (EU ETS).

European emissions trading scheme and aviation

According to the European Commission (2005, p.2) half of the global carbon dioxide (CO₂) emissions reported by industrialised countries are derived from the European Union. The European Commission has considered several alternatives to limit the emissions of greenhouse gases from aviation. Besides increasing awareness of the problem and making alternative transport modes more efficient, the main strategy is research, air traffic management and taxation of energy (European Commission, 2005, p.5).

According to bilateral agreements there is no tax on aviation fuel on international flights. However, the European Commission (2005, p.6) would prefer the same type of energy taxation on aircraft fuel as for other engine fuel. Consequently, another strategy to limit greenhouse gas emissions is needed.

The European Commission (2005, p.8) has considered different market-based instruments. Between emissions trading and emission charges, emissions trading is believed to be the most suitable to deal with aviation’s climate impact. Moreover ICAO has endorsed integration of international aviation emissions in existing emissions trading systems. The European Commission (2005, p.8) points out that the integration idea fits the climate politics of the EU.

The EU ETS started in 2005 as a mean for EU to fulfil its Kyoto obligations. EU ETS includes energy producers (power plants) and energy intense industries. Today about 12 000 entities are part of the system (Swedish EPA, 2006). The trading is made through allowances to emit CO₂. One allowance is a permit to emit one tonne of CO₂; its price varies and is set by

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8 Eligible activities: afforestation, reforestation, deforestation, forest management, cropland management, grazing land management and revegetation (UNFCCC, 2006a).
the market. The unit used in the emissions trading is called the European Union Allowance (EUA). A general cap for allowances is set and reflects the emissions goals of the EU. The allocation of the allowances is based on previous emissions and is free of charge.

The first period of EU ETS is 2005-2007 and the second period from 2008-2012 (Swedish EPA, 2006). The second period will coincide with the first Kyoto Commitment period. The member states of EU are according to the Kyoto Protocol committed to reduce their emissions by 8% year 2012 compared to 1990. A company that needs additional permits must buy these on the European carbon dioxide market.

CURRENT RESEARCH

The Intergovernmental Panel on Climate Change (IPCC) has an important role to review worldwide research on the climate area (UNFCCC, 2006b). Decisions made under the Framework Convention (UNFCCC) are and will eventually be based on IPCC reports. IPCC findings played an important role in the Kyoto Protocol negotiations.

In 1999 the IPCC wrote a special report on aviation: Aviation and the global atmosphere. Despite its publishing date, the report is still referred to when discussing the effects of aircraft on climate and atmospheric ozone. The report gives four options to reduce emissions and impacts caused by aviation: aircraft and engine technology options, fuel options, operational options and finally regulatory and economic. This section presents current research and discussions on these four areas. Aspects related to these areas are presented both generally and then more specifically in order to connect them to the aim and research questions, and are brought up in the discussion part. Table 3 presents a summary based on this section and on the interview results.

Technical aspects

Advances in aircraft design and engine technology has a great potential for emissions decreasing in the long run (Dewes et al., 2000, p.25). Large improvements have already been made, now compared to the 1960s, subsonic aircraft are about 70% more fuel efficient (per passenger-km) (IPCC, 1999a, p.10). Engine improvements stand for most of this improved efficiency and airframe design for the rest. The Advisory Council for Aeronautical Research in Europe (ACARE) co-ordinates parts of the aviation industry in Europe, which have set targets for efficiency and better environmental performance regarding airframes, engines and operations (RCEP, 2002, p.22).

Improvements of aircraft design, new materials and composites are being taken into account by the IPCC in their projections. To develop a new aircraft takes a long time and implies a large investment for an airline thus an aircraft usually has a long service life. The normal age of an aircraft is 25 to 35 years before it is taken out of service (IPCC, 1999a, p.10).

Another approach to aerotechnical development is suggested by Åkerman (2005, p.111) at KTH. The use of slower aircraft (propeller aircraft) flying at a lower altitude would lead to a 56% decrease of CO2 emissions compared to year 2000. Åkerman (2005, p.111) states that for achieving this decrease, not only a shift to propeller aircraft would be needed, but also a

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9 Scenario based on IPCC's sustainable target level for carbon dioxide concentrations by 2050. The rate of air travel in 2050 would be just a little higher than year 2000.
shift in life-styles, being less hectic and less fixed on economic growth. The growth of air travel should be performed in an environmentally sustainable way.

There is a constant improvement of aircraft and engines but both Amanatidis (2001, p.238) and Williams and Noland (2005, p.270) find that these improvements do not keep the same speed as the growth of air transportation. Amanatidis (2001, p.249) presents environmental activities within the EU and demands further research on the atmospherically impact of aircraft emissions and the appraise of these effects. According to Williams and Noland (2005, p.278-279) a policy of restricting flight altitudes would control the production of contrails and thus, limit aviation’s climate impact.

**Fuel issues**

The aviation fuel used today is kerosene. It provides a good combination of energy density, vapour pressure and combustion characteristics (RCEP, 2002, p.27). The emissions from aircraft occur at different stages of a flight and are related to the fuel burn. The emissions of carbon monoxide (CO) are greatest during taxiing\(^{10}\) and idling\(^{11}\) whereas the emissions of oxides of nitrogen (NOx) reach their greatest levels during take-off and climb-out.\(^{12}\) The carbon dioxide and water vapour production are in proportion with the fuel use. Both airframe design and efficiency of engines are significant for the fuel amount used during a flight. Take-off and landing requires a high rate of fuel burn. This makes the fuel use disproportional high for short-range flights, according to the report of RCEP (2002, p.24).\(^{13}\)

RCEP (2002, p.28) states that there is no alternative fuel for aircraft at the moment. Hydrogen used for transport instead of hydrocarbon fuels eliminates carbon dioxide emissions (at the using-point). It may lower the emissions of nitrogen oxides and lower the particulate emission appreciably but it implies also a larger production of water vapour. For air transport it would be uncertain whether hydrogen would be a way to reduce the climate impact.

Programme priority in the new seventh framework of the EU will be on climate impacts of air transport. According to the European Commission (2005, p.6), research on alternative fuel for aircraft engines may provide decreased emissions of greenhouse gases. There is a project\(^{14}\) on producing synthetic jet fuel from renewable biomass (SAS, 2005, p.99). The fuel is not certified for use in aircraft engines and it is uncertain whether it can be used for jet aircraft, as they require fuel with high energy density.

**Operational aspects**

Operational improvements may also contribute to a reduction of emissions (Dewes et al., 2000, p.25). The aim is to improve fuel efficiency by reducing the amount of consumed fuel for a certain demand of air transportation and so, automatically reduce the emissions (IPCC,

\(^{10}\) On ground aircraft moving to or from runway.  
\(^{11}\) Engine is started but the aircraft is not moving.  
\(^{12}\) Aircraft ascending to cruise altitude.  
\(^{13}\) Very long flights are not optimal regarding fuel burn either, because of the high amount of fuel that has to be carried in the beginning of the flight. The optimal flight for fuel efficiency is about 4300 km, which corresponds to a flight over the Atlantic Ocean.  
\(^{14}\) Project run by Gothenburg Company together with Chalmers University of Technology and the Lund Institute of Technology. Producing synthetic jet fuel from renewable biomass. Supported by Volvo Aero, the Swedish Energy Agency, SAS and Vinnova. The fuel is not yet certified for use in aircraft engines.
1999b, chapter 8). The decrease of fuel consumption would be reached through the improvement of the efficiency of the traffic system. Congestion problems are considered one of the aspects that need to be solved.

IPCC (1999b, chapter 8) presents new concepts for air traffic management (ATM), which includes enhanced communications, navigation, and surveillance (CNS) in support of a better air traffic system. These strategies would reduce delays, increase the capacity of existing infrastructure and improve operational efficiency such as optimisation of aircraft speed, reduction of additional weight, reduction of unnecessary amount of fuel on board, increase of the load factor, limitation of the number of extra power units and reduction of taxiing. Further optimisation would lead to reduction in fuel burn with 2-6 %.

Another method would be to adapt the cruise altitudes to limit other climate impact than carbon dioxide (CO₂) alone. At cruise level (above 900m) the emissions are of CO₂, nitrogen oxides (NOₓ), particulates and aerosols, sulphur compounds and water vapour. At ground level (underneath 900m) the emissions are NOₓ, carbon monoxide (CO) and unburned carbon hydrogen (HC). Jet engines emissions affect climate directly from carbon dioxide and water vapour (Forster et al., 2006, p.1118). The indirect effect of NOₓ affects the climate in two ways. Ozone (O₃) is produced out of NOₓ under the influence of sunlight and the methane (CH₄) concentration decreases. However, the effect of the ozone dominates leading to global warming. The contrails created by water vapour emitted at high altitude are considered to have a warming effect. The cirrus clouds (formed by contrails) also may have a climate impact, which is not fully known. However, knowledge of contrails and cirrus clouds impact on climate increases. According to Williams and Noland (2005, p.270), resent research suggest the climate effect of contrails to be smaller than the effect of CO₂, on the other hand is the effect of cirrus clouds (caused by aged contrail spreading) larger.

How other climate effects apart from CO₂ are to be assessed is a matter of having reliable weighing instruments and secondly, a question of which criteria the impacts are to be assessed with. Radiative forcing (RF) is a measure based on climate model calculations (Forster et al., 2006, p.1118). The change on global surface mean temperature, is considered to be proportional and change proportionally to RF (IPCC, 1999b, chapter 6). Climate sensitivity is in other words the increase in mean surface temperature per unit RF. Radiative imbalances can occur naturally but are also induced by human activity, which alters greenhouse gases, particles, or land albedo. A radiative imbalance leads mostly to changes in local temperatures for restoring the radiative balance within the stratosphere. However, this alters the cooling of the troposphere since warmer stratospheric temperatures increase not only the temperature of the troposphere, but also in the climate system. The IPCC sees the radiative forcing as a useful index for global climate impact, which sums and compares different atmospheric perturbations (Forster et al, 2006, p.1118). However, a Global Warming Potential index (GWP-index) is considered to be a better index, because it assesses the impact of different gases considering the time they remain in the atmosphere, which the RF index does not take into account (Forster et al, 2006, p.1118). GWP is utilised in the Kyoto protocol for

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15 The earth intercepts in average 340 W m⁻² of solar radiation over the surface. Of this quantity, 100 W m⁻² radiative balance between the solar heating and the terrestrial cooling when radiation is reflected to space. Any radiative imbalance would be restored by the adjustment of the climate system, in the first place temperature and clouds of the lower atmosphere (IPCC, 1999, Chapter 6).

16 The proportion of the incident light that is reflected by a surface (Word wizard, 2006).

17 From ca 10- 50 km above global surface.

18 From 0- ca 10 km above global surface.
calculation of equivalence between different green-house gases (Wit et al, 2005). It is useful in calculating long-lived gases, but has been criticised for not being able to calculate all aviation emission effects. The newly introduced Global Temperature Potential (GTP) seems to lack some of the disadvantages of GWP but is not yet used as a policy metric (Wit et al, 2005).

**Regulatory and economic aspects**

According to Carlsson and Hammar (2002, p.365) the interest in incentive-based environmental regulations in aviation has grown. The traditional regulations such as command and control (CAC) have been for example engine standards and flight movements. Examples of incentive-based regulations are: fuel charges, tradable emission permits and emission charges. Carlsson and Hammar (2002, p.366) discuss the costs of incentive-based instruments (here emission charge and emission permits) and of CAC regulation to limit emissions. The incentive-based instruments would in theory mean a lower total cost to attain a given emission limit. A company would decrease emissions to the level of equality between marginal cost of decreasing emissions and the cost of the permit or charge. To reach the same reduction with a CAC regulation would cost the companies more. Thus incentive-based instruments give a higher incentive for investment in more environmentally friendly technology.

According to the Kyoto protocol, an emission trading aims to decrease the greenhouse gases at the lowest possible cost. It is also considered an incentive for innovating technology and so reducing emission beyond standard requirements (IPCC, 1999b, chapter 10). The emission trading is based on setting an overall level (cap) of emissions, which would then lead to a permit dealing/exchanging market. This is considered to provide geographic and temporary flexibility, flexible trading across industry boundaries (all sectors) and to be an incentive to meet environmental goals of sustainable development.

Environmental levies include taxes and charges, and cover infrastructure costs and services at the airports. Landing charges and route facility charges are paid by the airlines (IPCC, 1999b, chapter 10). Taxes, often included in the ticket price, are paid by passengers for different services at the airport. Internalising the external costs (environmental effects) into the ticket price would act as an incentive to develop and purchase low emission technology, improve operational efficiency and reduce demand via higher fares (IPCC, 1999b, chapter 10).

The ICAO report of 1998, *Focal Point on Charges* (IPCC, 1999b, chapter 10) cites as the best alternative for reducing emissions, the introduction of a fuel levy and en-route-charge. This implies passing the resulting cost increase to consumers, which would lead to lower traffic demand and a reduction of emissions.

Carlsson and Hammar (2002, p.366) states that between taxes and charges, the last one is more accepted in aviation industry. The advantage of including aviation in an emission trading system would be that the reduction of emissions would be known, according to them. The article discusses the design of such a system and means that a free distribution of permits to airlines (grandfathering) is not a stringent regulation, but a likely political decision. Grandfathering, which is about dealing out permits based on past emissions, is considered a barrier for new airlines, and a disadvantage to airlines that have already made investments in environmentally adapted technology (Wit et al, 2005, p.86)

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19 Charge for the emissions produced during a whole flying route.
INTERVIEW RESULTS

The first part of this section presents the representatives for the chosen sectors, their role within each of them respectively, as well as their academic and working background. Afterwards, the answers are to be found arranged under certain titles, which stand for the content of the text underneath them. These titles do not directly relate to every question in the questionnaire but to the main aspects brought up in the respondents statements. Moreover, the titles are connected to and considered to deal with the research questions of the thesis. Finally, Table 2 gives an overall view about the respondents’ opinion regarding commonly named aspects.

The attentive reader may notice that there was no question about the interaction between the Kyoto Protocol and the EU ETS in the interview guide. This is due to the fact that the authors were not aware of the significance of this interaction before the interviews. Still, this issue is brought up both in the interview results and in the discussion part. Being an explorative study this is considered relevant for the thesis.

The respondents

Service provider

At the LFV Group Swedish Airports and Air Navigation Services (LFV) the interviewee is the environment strategy manager who deals with current environmental questions at state owned Swedish airports run by LFV. The respondent coordinates environmental issues concerning air traffic and air traffic control. This person is also in charge of environmental regulations and policies for the airports making sure their environmental work has the same alignment. Another task is to present proposals for the business directive, appointed by the directors, and setting annual environmental goals for LFV. With one year of experience as environmental consultant at a private entity she now also an environmental consultant and reviser who helps the airports to do what is economically possible for them. Before LFV she worked for ten years with environmental research at the Swedish Environmental Research Institute (IVL), with focus on water research and eco-toxicity assessments.

Authority

The senior advisor for Air Transport and Environment at the Swedish Civil Aviation Authority (CAA) has been working there since 1986 with a break during the period 1998-2001 where he worked at the Nordic representation as Alternate Council Member at the ICAO in Montreal. Having a degree in economics he notes that many issues he is dealing with have also significant legal implications. At the beginning he was working with aviation regulation and participated also in the European Civil Aviation Conference (ECAC) working groups. Now he is the chairman of ICAO’s Emissions trading task force. The chairmanship is shared with a representative of the International Air Transport Association (IATA). He is also part of the European Commission’s Aviation working group.

As an additional participant in the interview at the Swedish CAA, was also a specialist in environmental issues, in particular aviation emissions in the atmosphere. Her tasks include emissions calculations and reporting to other authorities. She co-operates with Swedish Institute for Transport and Communication (SIKA) regarding data for emissions forecasts. These data are communicated with stakeholders.
Aircraft operator

The respondent is the manager of Environment and Sustainability at SAS Group placed in the department of Corporate Communication and Public Affairs. One of the main tasks are to maintain an open and proactive dialogue between stakeholders and employees. Earlier he was manager in the independent SAS internal organisation Health, Environment and Safety. He has a social technological degree. Together with another person he runs the Sustainability Network in SAS Group and co-ordinates the work and the development of the environment and sustainability aspects of the SAS Group annual report.

Environmental impacts caused by aviation

The representatives of LFV and SAS mention emissions of carbon dioxide (CO2) and nitrogen oxides (NOx). Moreover, the SAS representative talks about 90 % of the impact deriving from fuel combustion includes not only CO2 and NOx but also water vapour. Besides climate impact the representative of the Swedish CAA also brings up acidification and local problems like de-icing liquid leakage, and both LFV and Swedish CAA representatives talk about noise problems mainly associated with people living near the airport areas. Finally, carbon hydrogen (HC) is named by the LFV as a problematic emission.

Existing measures for decreasing climate impacts caused by aviation

The following table shows the answers to the question of which measures there are to decrease effects of greenhouse gas emissions from air transportation.

Table 1. Measures to decrease climate impact from aviation brought up by the respondents.

<table>
<thead>
<tr>
<th>Service provider</th>
<th>措施</th>
</tr>
</thead>
<tbody>
<tr>
<td>(LFV)</td>
<td></td>
</tr>
</tbody>
</table>
| ❖ Technical aspects: fuel effective motors and well maintained aircraft  
| ❖ Flying procedures: a continued descending approach (CDA) as well as correct flying altitude, optimisation of flying routes and avoiding wide holding.  
| ❖ Introduction of bio fuels  
| ❖ Emission trading |

<table>
<thead>
<tr>
<th>Authority</th>
<th>措施</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Swedish CAA)</td>
<td></td>
</tr>
</tbody>
</table>
| ❖ Internalisation of external costs  
| ❖ Levies (taxes and charges)  
| ❖ Emissions trading  
| ❖ Technical improvements  
| ❖ Alternative fuel  
| ❖ Air traffic management (ATM)  
| ❖ Differentiated landing/starting fees on for example NOx  
| ❖ Improved knowledge of NOx and cirrus clouds significance and the management to avoid its climate impact |

<table>
<thead>
<tr>
<th>Aircraft operator</th>
<th>措施</th>
</tr>
</thead>
<tbody>
<tr>
<td>(SAS)</td>
<td></td>
</tr>
</tbody>
</table>
| ❖ Renewal of the fleet, new environmentally adapted aircraft  
| ❖ Research and development of alternative fuels  
| ❖ Being offensive in the emissions trading issue (lobby for aviation to be included)  
| ❖ Fuel saving by a higher cabin factor which leads to less fuel per passenger. This also includes using the most proper aircraft for a specific destination/route.  
| ❖ Flying more economic (eco-flying). A fuel saving program with a task to reduce the fuel use by 5 % in 2006/2007.  
| ❖ Air traffic management (Single European Sky) |
Measures to reach an economically and environmentally sustainable aviation

The representative of LFV thinks that for reaching an economically effective and environmentally friendly aviation industry, an emission trading system could be a start. Nevertheless an ETS should exist together with continued research about how to treat all possible emissions coming from aviation independently.

The representative of Swedish CAA is of the opinion that it is not cost efficient to impose the same reductions of CO₂ on each individual sector of economic activity. That is why emissions trading is a way forward to achieve a more sustainable air transport. The reductions would be made where they are cheapest for the society to make. It would be very expensive to society to make the reductions in the aviation sector only, and it would lead to a significant cut down on flight frequency. According to him the flexible mechanisms of the Kyoto Protocol could be an option. This means that measures to make the aviation sector sustainable would have to be taken outside the aviation industry to a certain extent.

The SAS representative thinks that it is all measures together that make a difference. He states that for the last 30 years environmental improvements have been made in the aviation industry; however the sector is not sustainable. The industry is growing 5% per year and the technical improvements only compensates for 3%.

The LFV representative considers it important to optimise the flying procedures and flying routes. Therefore, air traffic controllers play an important roll in considering environmental aspects when changing the flying routes and procedures. A new project called Grönt Flyg (Green Flight) is focusing on improving the landing procedures. By avoiding unnecessary holding time and by knowing exactly when an aircraft is going to land, working-craft on ground would be prepared in the right place at the right time. This would also be intended to lead to more satisfied customers and to the optimisation of the economy of the air company. LFV stimulates airlines to reduce their greenhouse gases. According to the respondent, one of the highest costs airlines have to deal with is related to fuel. It is therefore important to them to have more effective motors. Furthermore and aiming to develop the knowledge about the existence of alternative fuels, LFV puts some pressure on fuel companies and airlines by asking them why they do not sell/use bio-fuel.

Comparing measures to limit climate impact

The representative for LFV says that their entity would not be directly affected by an eventual emission trading system. It would imply increased costs for the airlines though. LFV’s role would then be trying to maintain their prices for “on ground” services in order to avoid airlines going out of business. Still, LFV supports the proposals of having an emission trading system because airlines have little possibilities to decrease their amount of CO₂

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20 An efficient aircraft today is considered to consume around 0, 3 litre per person and kilometre. Charges on greenhouse gases are directly steered by fuel prices (LFV interview, 2006-04-21).
21 According to LFV it is nowadays possible to produce bio-fuel out of biogas. Moreover, the technology for redoing biogas into kerosene exists. Because of the oil trade barrier, South Africa began to produce a synthetic kerosene several years ago. Producing a synthetic kerosene might be more expensive but since the oil price will continue to race it will soon be necessary to produce kerosene in another way for economical reasons. Air traffic increases worldwide with 5% per year whereas motors get 1% better within the same period of time. According to LFV environmental strategy manager it could be a possibility to produce bio-fuel and afterwards mix all to a 5% in the same way as it is done with fuel and ethanol for cars. By mixing 5% bio-fuel each year, the increase of air traffic with its negative impacts would be counteracted.
emissions. Therefore it is a good aspect being able to buy reductions from some other place in the world such as land energy constructions. It is not permitted to emit more than allowed, but if the airlines wanted to expand anyway, they would have to reduce emissions of other sectors.

The representative for Swedish CAA thinks emission trading has the biggest potential among the measures presented in this study. It would work in the medium long run, about 30 years, as a stimulant to technical development and is considered to be cost effective. It would also give incentives to technical development apart from only “keeping one’s nose above the water” of aviation’s climate impacts. After that, emissions trading might be too expensive or unnecessary because of an attained balance. On the other hand, levies are not considered to be appropriate incentives to limit CO₂ emissions enough, and are not considered cost efficient whereas air traffic management is thought to have an important role to play.

Except from new technology, the representative for SAS finds it hard to distinguish which one of the measures has the highest potential. If one must choose, new technologies, emission trading and proper alternative fuel have the best potential.

When comparing a taxation system and an emission trading system the representative for LFV thinks that taxes do not improve the condition of the environment. Taxes may be used for infrastructural means such as road construction, and not for research on fuel alternatives, motor improvement or CO₂ reduction in other sectors. She states that a tax on fuel or passengers would not directly lead to decreasing CO₂ emissions anywhere; in other words, it would imply less people flying but not decreased environmental impact. Aviation is charged for the airport services and infrastructure as well as for covering fees for noise and nitrogen oxides (NOx). An emission trading system means that a reduction is bought from somewhere else where in fact something has been made to reduce CO₂ emissions.

The Swedish CAA representative considers that external costs caused by aviation are already included in aviation’s own costs. The infrastructure and operating costs are financed by the aviation sector itself via charges/fees instead of taxes. Thus the level of internalisation of aviation is high and covers its external effects to a large extent.

**Distribution and allocation of EU ETS**

According to Swedish CAA’s representative there is general agreement in the EU that the emissions cap of the international emissions for the aviation sector is set at the European level. This is good from the competition aspect and avoids allocation of international emissions to individual states. Monitoring and the surrender of emissions allowances should be based on real consumption of jet fuel. Systems for reporting the real consumption are in use already due to safety reasons.

When it comes to the aviation industry, LFV thinks that the EU ETS permits should be distributed at the EU-level so that every company gets its permits directly from the European Union. The way of distribution should then be grandfathering because it is the system implemented in the rest of the trading industry. Nevertheless, in the long run permits should be auctioned to avoid buying more permits than those actually needed. A grandfathering system should be done under a “best-practise” philosophy if the impact from aviation industry is meant to be decreased. This would benefit low-cost carriers as well as traditional airlines.

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22 Costless distribution of permits according to historical emission and volume of fuel use.
The LFV representative states that the emission trading should be done on a downstream trading system, in other words, it is the airlines owning the permits and the trading would happen between the airlines even if they belonged to the same partner group. Still, if other transport modes are included in the EU ETS, an upstream trading system should be implemented, where the distributors should be the ones owning the permits and trading with them. That the permits should be owned by the airlines, is also the opinion of Swedish CAA. An upstream system is considered to be difficult to deal with on an international level. A downstream system would be easier to regulate, as the airlines are the ones regulated today. The allocation of the permits should be carrier based and the distribution should be made either by grandfathering or benchmarking, this would benefit the sector most according to the representative of Swedish CAA. Auctioning of the permits would cost the airlines more since it would be expensive to buy starting permits leading to fewer permits in the starting market. According to SAS a downstream system where the airlines own the permits would give incentives for airlines to be more sustainable. If the airlines did not have the permits there would be no competition. Grandfathering would be the best distribution system for airline companies, both economically and environmentally.

It is talked about the risk of having companies not selling their unused permits. The LFV representative agrees with the idea that it might create a trading barrier, but at the same time considers it a way to stop CO₂ releases. She mentions that it is possible nowadays to go into the emission trading system and buy permits in order to take them out of the market and so influence amounts of emissions. Seen from an environmental perspective she finds this something good, and mentions that this is practised by the Swedish Society for Nature Conservation (SNF). Still, regardless if it is done for economical or environmental purposes or for both, it is possible for anybody to register for 500 SEK at the Swedish Energy Agency (Energimyndigheten) and start trading with emission permits.

About the EU ETS, the representative for Swedish CAA as well as SAS and LFV thinks there should be the same rules for international and domestic flights. It is important to have a system with a clear definition of responsible entity so it is easy to know which airline is responsible for the emissions of a certain flight. The airlines should be able to internally solve the administration with the emissions allowances regarding code-shared flights with alliance partners. There should be equal conditions so that airlines can take suitable measures according to SAS.

**Emissions to be considered in the EU ETS**

The representative for the Swedish CAA finds that the climate impact to be primarily considered in the emissions trading should be CO₂. Other greenhouse gases would be too hard to calculate or even estimate. Furthermore he thinks that there should be a trading of CO₂ against CO₂ and NOx against NOx, if NOx would be included in a system. To use an equivalent calculation for different emissions is not possible at this time. However, other effects than from CO₂ on climate change from aviation should not be ignored in the long run.

The representative of LFV finds the stringency in the emission trading system between sectors important and since the existing emission trading system includes just CO₂, it should not be

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23 The distribution of permits would be under control of an international body e.g. ICAO.
24 A measurement or standard that serves as a point of reference by which process performance is measured. (Investor dictionary, 2006) In this case, the distribution is based on a set standard.
different when it comes to the aviation industry. If so, it might create a negative impact in other sectors and that would not be fair.

The Kyoto protocol, the EU ETS and the international aviation

The representative of the Swedish CAA states that when talking about climate impact of aviation, the international aspect is very important. A key issue is how to involve international aviation in emissions trading since international flights are not included in the Kyoto Protocol emission trading system. The allocation question has not been solved. Today it is possible for international aviation to buy permits from sectors included in the Kyoto Protocol but not to sell permits to these sectors. The European Union is trying to solve this issue alone in the shorter time scale since the USA left the negotiations even though it first came with the proposal of using the emissions trading in the Kyoto Protocol.

The Swedish CAA representative notes that the EU ETS merges with the Kyoto Protocol by using two labels on the same allowances; EAU is the trading unit of EU ETS and AAU is the one used for emission trading in the Kyoto Protocol. However, one tradable unit in EU ETS is also a unit in the Kyoto system. Swedish CAA representative mentions that according to the European Commission and the European Council, the aviation is to be part of the EU ETS. One problem is that international aviation can not be a net seller into EU ETS/Kyoto. He states that an important goal is to enlarge the system with emissions trading for aviation to the rest of the world but how it is going to work is not settled yet.

Swedish CAA does not consider it realistic having aviation included in the EU ETS by 2008, but probably by 2010-2011. If not then, a new period of preparation would be needed as the rules may have changed.

By late 2006, the European Commission is expected to be ready with the proposals about how aviation is going to be included in the emission trading system. According to LFV this is considered to be a reality maybe not before 2008 but not later than 2013. Moreover, LFV calculates that it can take a few years till operational measures such as the adjustment of flying routes or eco-driving with its Continuous Descending Approach (CDA) are fully implemented in Sweden whereas it might take a shorter time, 2-5 years, to implement an emission trading system.

According to the representative of SAS most of the airlines and other entities in the aviation industry are positive to involving aviation in the EU ETS, but are not all are as forward as SAS. Within AEA some policy agreements have been made among the airlines involved.
**Interview overview**

The following table presents a clarifying overview of the interview results, and consists of the common aspects that have been brought up by all respondents or emphasised by some of them. It works as a starting point for the following discussion.

Table 2. Overview of opinions on main topics brought up in the interviews.

<table>
<thead>
<tr>
<th>Main topics</th>
<th>Service provider (LFV)</th>
<th>Authority (Swedish CAA)</th>
<th>Aircraft operator (SAS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental impacts from aviation industry</td>
<td>Carbon dioxide, carbon hydrogen and nitrogen oxide. Emissions to water and noise levels.</td>
<td>Climate change, noise, health problems caused mainly by NOx and particles, acidification, and local problems like de-icing liquid leakage and noise levels.</td>
<td>Carbon dioxide, water vapour and oxides of nitrogen.</td>
</tr>
<tr>
<td>Measures to limit climate impact of aviation</td>
<td>Fuel effective motors, well maintained aircraft. Minimise holding time and a continuous descending approach, correct flying altitude and optimisation of flight routes. Introduction of bio fuels and emission trading.</td>
<td>Internalisation of external costs, levies, emissions trading, technical improvement, alternative fuel, air traffic management. Differentiated landing/starting fees on for example NOx. Further knowledge of climate impact of NOx and cirrus clouds and dealing with its effect.</td>
<td>Renewal of the fleet, new environmentally adapted aircraft. Being offensive in the emissions trading issue. Fuel saving by a higher cabin factor. Proper aircraft for a specific destination/route. Eco-flying.</td>
</tr>
<tr>
<td>Measures for reaching an environmentally and economically sustainable aviation industry</td>
<td>Mainly, emission trading together with technical and operative measures.</td>
<td>Regarding climate change: Emission trading in the medium long run. Good incentive which would lead to better operative strategies and technical development.</td>
<td>New technology and emission trading. All measures together make a difference.</td>
</tr>
<tr>
<td>Allocation and distribution of permits in the EU ETS</td>
<td>EU-level, same rules for domestic and international flights. First, distribution by grandfathering following a “best-practice” philosophy, later auctioning. Downstream permit system.</td>
<td>EU-level, same rules for domestic and international flights. Distribution based on real emissions (based on real fuel consumption) and made by benchmarking or grandfathering. Downstream permit system.</td>
<td>Same rules for domestic and international flights. Distribution by grandfathering. Downstream permit system.</td>
</tr>
<tr>
<td>Considered emissions in EU ETS</td>
<td>CO₂</td>
<td>CO₂</td>
<td>CO₂</td>
</tr>
<tr>
<td>Aviation industry included in EU ETS</td>
<td>Not before 2008 but not as late as after 2013</td>
<td>Not by 2008 but probably by 2010-2011</td>
<td></td>
</tr>
<tr>
<td>The Kyoto Protocol</td>
<td>A key issue is how to involve international aviation in the emissions trading since this part of the aviation sector is outside Kyoto emissions trading.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
POTENTIAL OF VARIOUS MEASURES

This table is based on the chosen literature and the empirical studies, and is a concluding summary of the discussed measures. The table is attempted to briefly present which potential the discussed measures have to limit the climate impact of aviation. The time aspect is used to assess the implementation level. The authors use the content as a foundation for the following conclusions, answering the overall aim of the thesis.

Table 3. Overall comments of the authors about the main aspects based on discussed subjects in the literature and the interviews.

<table>
<thead>
<tr>
<th>Measure/option</th>
<th>Current status</th>
<th>Time aspect</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Technical aspects</strong></td>
<td>Large improvements have already been made in terms of engine emissions. Other improvements like airframe design require large investments in research.</td>
<td>Major technical improvements are considered a necessary but long-term and expensive measure.</td>
</tr>
<tr>
<td><strong>Operational aspects</strong></td>
<td>There are already projects like SES (Single European Sky) to adjust air traffic management to future demands. These improvements would prevent congestion, which would lead to less queuing, holding time as well as less taxiing and idling.</td>
<td>Medium long-term measure. Takes time until fully implemented.</td>
</tr>
<tr>
<td>Adapting cruise altitude, which</td>
<td>Adapting cruise altitude, which would affect emission at high altitude such as NOx, contrails and cirrus clouds, needs more research although some knowledge exists. There is research and suggestions on how to handle these emissions.</td>
<td>Decision making and full implementation of technique and methods take time and are therefore considered a long-term measure.</td>
</tr>
<tr>
<td><strong>Marked- based regulations</strong></td>
<td>Aviation emission in EU can be regulated in an already existing system, EU ETS. The obstacles consist of formalities about how the system should involve the aviation sector. Actors inside and outside the aviation sector in EU agree upon the introduction of aviation in the EU ETS and work to find a solution.</td>
<td>EU ETS is considered as a relatively short-term measure as it may be implemented within 5 years.</td>
</tr>
<tr>
<td><strong>Alternative aviation fuel</strong></td>
<td>Fuel projects are still on the prototype stage. It is uncertain whether alternative fuel will be energy intensive enough to be used as aircraft fuel. On the other hand, the technique to make bio fuel does already exist.</td>
<td>Fuel improvements are considered a medium long-term to long-term measure.</td>
</tr>
</tbody>
</table>
DISCUSSION

The subjects for discussion have been based on the respondents’ answers, compared and developed with facts and examples from the theoretical frame. The main discussed aspects are related to the research questions, and aim of the thesis.

Since all three respondents come from the aviation sector, there are expected similarities in their answers on environmental impacts of aviation and the existing measures to limit them. It was possible to recognise a so-called ground perspective; however, different levels of emphasis were put on certain measures. SAS puts most emphasis on investing in new, more environmentally adapted aircraft since fuel costs and maintenance cost is dependent on the aircraft fleet. Investing in technological improvements would then imply saving money for fuel consumption and having more effective and modern aircraft, which would be positive for their economy, image and the environmental demands they have to fulfil. On the other hand and being in charge of the air traffic control in Sweden, and capable of influencing this area, LFV puts more emphasis on operational measures to decrease climate impact. However, the Swedish CAA underlines regulatory/economic strategies such as levies, charges and fuel taxes, which would help to improve the technological aspects and internalise environmental cost. Why do the three of them finally support an emission trading? It seems that there is hope and trust for a working emission trading system, which would help to decrease emissions now and in the future, but at the same time, there seems to be a doubt about its successful implementation within aviation. Apparently this is not based on the idea of an emission trading system as such, but on the process of designing it and the inclusion criteria to be followed. Either way, it seems that an emission trading is considered cost-effective and something to support regardless all the expressed uncertainties.

Measures for reaching an environmentally and economically sustainable aviation

The respondents consider emission trading a good measure to start with in order to reach an environmentally and economically sustainable aviation. They all agree that the aviation sector is not likely to be environmentally sustainable on its own, but are still positive to a growth in aviation industry. It is part of their occupational role to promote aviation. Better technology and improved operating can however only partly compensate for the growing air transportation (Amanatidis, 2001, p.238). Even so, emission trading might be a way to compensate for unsustainable and constantly growing aviation industry. According to the representative of the Swedish CAA, emission trading would be an economically favourable measure to take since reductions will be made where it is most economical for society. In other words, unused permits in a certain sector could be bought by the aviation sector for a reasonable price.

The authors have recognised a willingness from the respondents to make aviation industry more sustainable with the help of the IPCC measures. However, the three respondents, just like Åkerman, consider aviation a non-sustainable industry. Nevertheless, aviation is an important part of the world’s economy and therefore its growth and expansion is supported. Taking into consideration the aim of the study, which tries to investigate the potential of the four measures to limit the climate impact caused by emission coming from aviation, it can be concluded there is a conflict between controlling emissions, but at the same time letting the source of these emissions grow. An emission trading would then be a way of controlling emission increase and at the same time maintaining a certain economic level in a constant growing market. Still, there is the question about this being possible to achieve.
The idea that emission trading is considered an incentive for investing in environmentally optimal technology, is expressed by the representative of Swedish CAA as well as Carlsson and Hammar (2002, p.365). The latter discusses the advantage of emission trading over an emission charge meaning that an emission trading system and its defined emissions cap would make it possible to know its effect in terms of emissions reduction. The SAS representative supports the idea of emission trading but underlines the need of technical improvement as a better possibility.

If emission trading was implemented in all sectors (e.g. other transport modes and industries), and everyone was able to go into the trading system as the representative of LFV mentions, it would then be a question of how long the trading would last until a balance is reached and there is no longer a market for emissions trading. The representative of the Swedish CAA expected therefore, that the emission trading would be effective in the medium-long run (about 30 years). After that, a new measure would need to be created. Furthermore, and this is a reasoning of the authors, if the permits were bought just to take them out of the market, it would then be a question of how beneficial it would be for the newly introduced emission trading system and its function. On the one hand it would be better for the environment; on the other hand, there would be the risk of interference with a system created to improve the environmental situation in the long run.

Other economical measures such as revenues from taxes and charges could be used as a mean to limit environmental impacts from aviation (IPCC, 1999b, chapter 10). On the one hand, revenues would help to reach future technological improvement. On the other hand, re-channelling these revenues would imply administrative complexities.25 LFV considers that taxes do not directly improve environmental conditions. Taxes, often included in the ticket price, are only used for infrastructural means. A tax on fuel or passengers would not directly lead to decreasing CO₂ emissions anywhere; in other words, it would imply less people flying but not decreased environmental impact from aviation. Still, both LFV and Swedish CAA consider that external costs are already included in aviation’s own costs. The infrastructure and operating costs are financed by the aviation sector itself via charges and fees.

According to the report *Focal Point on Charges* of the ICAO 1998 (IPCC 1999b, chapter 10) a fuel levy and en-route-charge would lead to a lower traffic demand, which would lead to fewer emissions. However, the representative of LFV states that it is decreased emissions from aviation, and not a lower traffic demand that is wanted. If the air traffic demand were not meant to decrease but to grow; would it be possible to develop a green technology at the same speed, so that the consequences of an increased flight demand do not affect the climate stability even more? SAS representative states that even though environmental improvements have been made in the aviation industry for the last 30 years the sector is not sustainable. The technical improvements only partly compensates for the growth of air transportation.

As seen above, there is a connection between economical and technical measures. If for example fuel efficiency were to be improved by reducing the amount of consumed fuel for a

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25 The airport of Zurich has introduced an emissions charge to the landing fee, which is based on engine certification information contained in the ICAO Engine Exhaust Emissions Data Bank (IPCC,1999b, chapter 10). This charge is seen as an incentive to encourage operators to use their lowest emissions aircraft when Zurich is a destination, “forcing” air companies to use best available technology. Revenues are used to finance emissions reduction measures at the airport. In 1998, a similar emissions-related charge was applied at ten Swedish airports. These charges were also revenue neutral and did not affect consumer demand. They were considered an incentive to airlines to purchase and operate aircraft with lower engine emissions.
certain demand of air transportation, emissions would automatically be reduced. Congestions and delays would then also be an issue to consider because of its connection to fuel consumption. The suggestion of Åkerman (2005, p.111) to use slower aircraft flying at lower altitude to decrease emissions from aviation, would support the idea behind fuel levy/ en-route-charges, which would lead to a lower traffic demand. But as said before, instead of limiting the growth of aviation, the representatives of the aviation sector prefer taking measures to compensate for the climate impact caused. According to them this can be made using the flexible mechanisms of the Kyoto protocol.

**Interaction between aviation, EU ETS and the Kyoto Protocol**

The interaction between the Kyoto Protocol and the EU ETS raises some questions that need to be solved. The years 2008-2012 is the second EU ETS period and the first period of the Kyoto Protocol where the 15 member states of the EU agreed upon aiming towards certain emission targets. Domestic aviation is included in the targets under the Kyoto Protocol and hence gets an assigned amount of emission (AAUs) to cover its emissions (Wit et al, 2005, p.75). As international flights are not included in the Kyoto targets they are not covered by AAUs, but the EU member states have shown their wish to include these flights in the already exiting EU ETS. Trying to solve this issue, EAUs for international aviation are expected to co-validate missing AAUs for this part of the sector. According to Swedish CAA representative, two labels will be used on the same allowance, one AAU and one EAU. Nevertheless, since the international aviation was not included in the Kyoto negotiations from the beginning, there are not enough AAU permits for the member states to distribute on international aviation. As the LFV representative says, an inclusion of aviation in the EU ETS would probably lead to airlines needing to buy allowances (if they expand), which is a way to make airlines pay for their emissions. The representative of Swedish CAA mentions, having aviation included in the EU ETS would be a matter of political willingness. The authors conclude that if the actors concerned are positive to this action, an implementation would probably be easier.

**How to include aviation in the EU ETS**

According to all respondents the system should be a downstream system where the airlines would own the emission permits. According to the representative of SAS, a downstream system would be more competitive and an incentive to be more sustainable. This would be easiest to implement, according to the Swedish CAA representative, as the airlines are already paying regulating fees. Still, if other transport sectors were to be included in the EU ETS, there should be an upstream system where the fuel distributors owned the permits and put a price on the fuel according to the CO₂ emission potential. If the aviation sector were included in a downstream system whereas the other transport modes traded in an upstream system, effects on competition between different transportation sectors would be a problem (Carlsson and Hammar, 2002, p.368).

In the same way, the initial distribution of permits is an important subject because it could mean competitive disadvantages for some airlines (Carlsson and Hammar, 2002, p.368). A country-based system would mean that individual countries distributed (or auctioned) the permits to the airlines. This could lead to one country distributing permits for free and another country auctioning them. In a carrier-based system the permits would be allocated on EU 26 The unit used in the emissions trading is called European Union Allowances (EAU).
level and this is what both representatives of Swedish CAA and LFV suggest to be the most suitable system.

The allocation of permits among the airlines can either be for free and based on real emissions, grandfathering, or by auctioning. The SAS representative would prefer grandfathering, which due to political reasons, is most likely to be implemented (Carlsson and Hammar, 2002, p.368). The authors of this thesis conclude that for an established airline like SAS, grandfathering would probably be favourable. Besides, an airline with an “old fleet” should be gaining on a system based on historical emissions.

Swedish CAA believes that a benchmarking system or alternatively a grandfathering system would be most suitable for aviation. LFV speaks for the grandfathering system based on a “best-practise” philosophy, which would benefit low cost carriers as well as traditional airlines. Still, a grandfathering might imply a trading barrier for those airlines that come into the market for the first time. This could be avoided by leaving a share of permits for auctioning (Carlsson and Hammar, 2002, p.371). The LFV representative supports a future auctioning system, with the idea that it would avoid airlines from buying more permits than those actually needed. Another disadvantage about a grandfathering distribution system would be a weaker incentive for investing in cleaner technology (Carlsson and Hammar, 2002, p.368). In addition, according to Wit et al (2005, p.86) grandfathering is not in line with the polluter pays principle.

**Weighing instruments for assessing aviation emissions**

Whereas the Kyoto protocol requires the reduction of six greenhouse gases, the actors within aviation industry find CO2 as the main greenhouse gas to deal with. The respondents consider emission trading a measure to focus on, and since the existing EU ETS includes just CO2, it should not be different when it comes to the aviation industry. The conclusion of Forster et al (2005, p.1121) is that effects other than CO2 from aviation, are not yet to be included in the EU ETS. However, when the knowledge is sufficient, the effects on climate other than CO2 should not be ignored in the long run, the Swedish CAA representative adds.

IPCC (1999, chapter 6) considers radiative forcing (RF) a useful index of aviation-induced atmospheric perturbation. Nevertheless, the RFI index fails to account for the resident timescales of emissions (Forster et al, 2005, p.1118). According to LFV a well-defined timescale is needed, if RFI were to be used. A GWP-index considers the time different gases remain in the atmosphere (and is used in the Kyoto Protocol) but is not optimal for calculation of all aviation emission effects (Wit et al., 2005). The results of an RFI could be misleading because they are sensitive to cruising altitudes. For example, aircraft flying at lower altitudes produce fewer contrails, which would lead to a lower RFI. Nevertheless this implies a higher production of CO2 because of an increased fuel burning (Forster et al., 2005, p.1118). Adapting cruise altitude could be helpful to limit the climate impact from other gases than CO2. However, there is not a sufficient knowledge about how to appoint the best flight routings or cruising altitudes in order to minimise climate effects of emissions of nitrogen oxides and water vapour. This is, according to the environmental specialist of Swedish CAA, dependant on the local climate, weather conditions and substance concentrations in the atmosphere. Williams and Noland (2005, p.279) conclude that if an emissions trading scheme would address not only CO2 emissions it would need a measure of actual contrail production. Only then would the polluter pays principle be fully applied.
CONCLUSIONS

The following section shows conclusions which answer the aim of the study and which the authors have drawn based on the research questions.

*Of the four measures brought up in this study, which are the most widely discussed in current European scientific literature, and within the aviation sector?*

All measures to control climate impact of aviation are needed and should be put into practise, but emission trading would be the one to start the initial improvements, leading to more sustainable results in terms of time, environment and economy. Airlines’ need to expand will create an increased demand for emission permits and since these are limited, technological, operational and even fuel aspects will have to be improved.

*Which measures do the chosen actors, consider applicable to obtain environmentally and economically sustainable aviation?*

All measures discussed in this thesis are applicable but the time aspect differs. There is a large agreement both inside and outside the aviation sector about including aviation in the EU ETS. By putting a cap on emissions it would be possible to achieve the emission targets and the commitments of the Kyoto protocol.

In case aviation is included in the EU ETS, an initial grandfathering system based on a “best-practise” philosophy could be a good solution since it also would work as an incentive for existing airlines to improve their technology and flying strategy. Still, a share of permits for auctioning should also exist for opening market barriers for newer airlines or those who not yet have managed to improve their technology or implement better flying strategies. In this way, a future emission trading between airlines fulfilling certain environmental standards might be reached.

*What are the “difficulties” and “options” for implementing these measures according to research literature, and the actors within aviation industry?*

The aviation sector is not likely to be a sustainable sector using the discussed measures only, but the flexible mechanisms of the Kyoto Protocol give possibilities to compensate aviation for its unsustainability.

One of the difficulties in operational measures is that there seems to be a lack of robust instruments to measure the impacts of different greenhouse gases. If measures and laws are to be chosen depending how serious the impact of different greenhouse gases is, different weighing methods seem to be needed. Emission trading should probably focus on carbon dioxide and other measures should be created for other greenhouse gases.

If overall carbon dioxide emissions are to be decreased, all sectors need to be included in the question. The proposal of letting international aviation be a part of the Kyoto Protocol was not accepted in the initial negotiations. Had it been so, time demanding compatibility problems would have been avoided and all energy would have been focused on implementing the system as effectively as possible. Such a well functioning system would probably have implied an overall and more effective emission reduction.
Further studies

If aviation was to be included in the EU ETS, it would be interesting to find out how the system would work. One approach for a study could be how different airlines are affected by the scheme. Interesting research questions would be: Have the design of the scheme favoured certain types of airlines? And of course: Does the EU ETS actually work as an incentive to reduce emissions of aviation?
**SOURCES**


APPENDIX I

INTERVIEW GUIDE

Background details

1. What is your title or position in the organisation?

2. What are your main tasks in the organisation? What have you been working with earlier?

Measures to decrease emissions from aviation

3. Which environmental problems are associated with aviation? Which are the most important?

4. Which different measures are there to decrease (climate impact) emissions derived from aviation?

For every measure the following questions will be asked:

5. Which are the significant factors for airlines/administration/authority to implement this measure? How do you assess these factors?

6. How viable is the implementation of this measure? (economically, administrative, politically, effects on other actors in the sector etc.)

Measures in relation to each other

7. Among these measures which one do you consider the one to have the highest, second highest etc. (rank if possible) potential to reduce the climate impact of aviation? Which criteria do you use for assessing the potential?

8. What measures would be the most appropriate to implement towards an economically and environmentally sustainable aviation industry?

9. Which instructions do you have from the governments when assessing different measures to limit emission from aircraft to atmosphere?

Detailed questions

10. Should different emissions trading policies be created for domestic and international flights separately? Which consequences could this mean?

11. How would laws for emissions trading work in practice when it comes to the air alliances?

12. About the European emissions trading scheme (EU-ETS) it is said that aviation industry could have an upstream (permits owned by fuel distributor /importer)or a downstream (permits owned by airlines) system. What system do you think would work best in the aviation industry? Why?
13. How would the permits be distributed and allocated (country-based/carrier-based, grandfathering/auction) to gain the aviation industry most?

14. How would the permits be distributed and allocated to limit the greenhouse gases derived from the aviation industry?

15. What kind of climate impact should be considered in the emissions trading and how should it be calculated (in which unit of measurement)?

16. Is there a co-operation between the airlines, administrators and authorities on decreasing climate impact of aviation? How does it work?

Other questions

17. Do you think we are disregarding any facts? Is there something else you want to bring up?