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Critical Issues of Inclusion of Aviation in EU Emissions Trading System

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***Abstract*—**This paper dissertates about issues which may occur after next year will be major part of civil aviation in EU included into system of Emission trading. This system should help to fight against global warming and to fulfill Kyoto Protocol commitments of European countries. Main issues mentioned in this paper are connected with problem of radiative forcing from emissions and lack of their monitoring and charging in EU legislative. There are mentioned main differences between industrial emissions and *emissions* form aviation with notification about possible negative impacts of neglecting these differences. Special attention is dedicated to risk of possible reverse effect of inclusion aviation in EU ETS, which may theoretically occur.

***Keywords*—**EU ETS, radiative forcing, aviation, emission trading.

I. INTRODUCTION

CRITICAL Critical issues of inclusion of aviation in EU Emission Trading System (EU ETS)The inclusion of aviation in EU ETS is the first diffident step in an effort to reach a sustainable growth of air transport. Reduction of emissions of greenhouse gases is one of the goals of the WHITE PAPER Roadmap to a Single European Transport Area [1]. Air transport is the first transport area which is included in CO_2 allowance trading scheme. Aviation is a pioneer in an effort to have economically accessible but environmentally more friendly transport in EU countries. As aviation is the first transport mode which is the subject of direct greenhouse gas emission regulation it is an opportunity to remove all possibly unsuitable processes to make the inclusion of other transport modes smoother. However, in fact the inclusion of aviation in EU ETS brings along many issues which must be solved before this system earns a real benefit.

II. EU ETS

EU ETS is a trading scheme based on cap and trade basis. The EU ETS is one of the policies introduced across the European Union (EU) to help it meet its greenhouse gas emissions reduction target under the Kyoto Protocol. Very simply introduced, EU ETS allows to emit only as much greenhouse gas as the producer has allowances for. Allowances are partially distributed free of charge according to emission background and are partially accessible on the free market where they can be sold and purchased by anyone. This market instrument allows the contributors who spare some of their allowances to sell them for profit. Theoretically, this system should be used for every greenhouse gas. In practice, only the emissions of CO_2 are taken into account. More about EU ETS can be found in EU Directive 87/2003 [2].

EU ETS has been working since 2005 and covers more than 10 000 industry installations. Starting from 1 January 2012 all aircraft operators, reaching limits of transport performance, performing flights arriving at or departing from any airport situated in the territory of the European Union or an EEA-EFTA[1] country (Iceland, Liechtenstein and Norway) will be included in the EU Emissions Trading System. Aviation is going to be included in the system by EU Directive 101/2008 [3]. It is going to be made in several gradual steps to help the business to become established within EU ETS. For first year there will be allowances for 97% of historical aviation emissions. historical emissions represents the average of the estimated annual emissions for the years 2004, 2005 and 2006. For each next year there will be allowances only for 95% of historical emissions. But only 15% of all allowances is auctioned. Rest more than 80 % is allocated freely to airlines according their historical emissions. The number of needed allowances is counted according to equation(1), where fuel consumption is in tonnes, and emission factor should be taken from 2006 IPCC Inventory Guidelines or subsequent updates of these Guidelines, for each type of fuel, for most common used aviation fuel is used emission factor 3,15.

$$\text{Fuel consumption} \times \text{emission factor} \quad (1)$$

Emission factor 3,15 covers only production of carbon dioxide, for inclusion of emission of other greenhouse gases which are produced during combustion of aviation fuel, we would have to rise emission factor.

The inclusion of aviation in EU ETS gives rise to a few issues which have been obvious even before aviation really starts to works in EU ETS. During our research of this problem, we found some issues connected with inclusion of aviation in EU ETS which need to be solved. Some of these problems are unavoidable and they will negatively impact air traffic operators but some issues are elemental problems and they may cast doubt about the whole inclusion of aviation in EU ETS.

III. ISSUE 1 : CARBON LEAKAGE

Carbon leakage commonly means an increase in carbon dioxide emissions in one country as a result of an emissions reduction by a second country with a strict climate policy [4]. However, we can look at carbon leakage from a wider perspective as the leakage between transport modes and even between carriers in one branch. It is obvious that a country with stricter environmental policies will make domestic companies more difficult and expensive to be operated than

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[1] European Economic Area (EEA), European Free Trade Association (EFTA)

firms from other countries without such a strict environmental policy. The same situation as expected in EU will possibly occur at airports in near countries such as Turkey, Tunisia, Russia etc., which serve as transfers hubs between flights from EU and trans-continental flights. Such flight combinations might avoid EU air space not to pay for emissions but the trip will produce even more greenhouse gas than today because of the need to transfer in a different country.

A very similar situation will arise between different transport modes. Passengers will choose another kind of transport which is not included EU ETS. Such a situation may have a negative impact on European airlines as well as on the environment because the chosen transport might not necessarily be more environmentally friendly. A third example of carbon leakage can be found in the case of airlines that have to and don´t have to participate in EU ETS. The inclusion of air transport operators in EU ETS is determined by their annual transport performance. Therefore some smaller airlines that will not be included in EU ETS will exist. There is a risk that in an effort to avoid being included in EU ETS, some airlines will split the company into more independent companies not to reach the EU ETS limit and to avoid the need of reducing their greenhouse gas emissions. These small airlines will have a competitive edge over larger companies that will be included in EU ETS. Thus there is a possibility that these small operators will operate more flights and because their environmental policy is less prepared than the environmental strategy of greater airlines, the overall effect on the environment can be negative.

All these negative carbon leakage effects have one thing in common - they will disappear when EU environmental policy spreads worldwide or when it covers all transport modes or all air operators. As spreading EU ETS or similar policy worldwide and to all transport is a long time goal of EU, we may predict that the importance of carbon leakage will decrease. The market disadvantage of airlines included in EU ETS will be partially compensated by the advantage of experience which they acquire during their involvement in EU ETS against those airlines which will be included later. From this point of view, carbon leakage due to the inclusion doesn't seem as a great issue, especially in the first few years where there will be a larger percentage of allowances distributed freely among airlines. However, it will be interesting to observe how the inclusion in EU ETS influences especially low-cost airlines, which products are very price-sensitive.

As inclusion of aviation draws near protest against EU ETS are growing stronger, especially from non EU airlines and countries. They are trying to make pressure on EU by legal actions, but at 8 June European Commission President said the EU is not considering changing its law obliging. Any legal action wasn´t successful yet and inclusion aviation in EU ETS in year 2012, most probably, will not be postponed or canceled.

Problems connected with carbon leakage due to the inclusion of aviation in EU ETS are discussed widely in[5].

IV. Issue 2: Aviation Radiative Forcing Components

A. Radiative forcing

A more important issue seems to be the problem of radiative forcing from different sources , not only from CO_2 emissions. The basis of this problem is the fact that all EU ETS legislative documents and all directives deal only with the decrease production greenhouse gases production and stabilization of the emitted amount into the atmosphere. In fact, the decrease in greenhouse gases should not be the goal but only a device to achieve a real goal. The real aim should obviously be the reduction of atmospheric warming. Only one third of the aviation contribution to atmospheric warming is caused by CO_2 emissions. Contrails and induced cloudiness have a greater effect than CO_2 . However, contrails and induced cloudiness are not taken into account anywhere in EU ETS.

TABLE I
Aviation RF estimates

Source of RF	Estimated value (best estimate) (W/M^2)	Covered in EU ETS
CO_2	0,016 □ 0,041 (0,27)	Yes
NO_x - ozone	0,01 □ 0,083 (0,022)	NO easy cover by change of emission factor of fuel
NO_x - OH radical	-0,08 □ -0 (-0,011)	NO easy cover by change of emission factor of fuel
Water vapor (without contrails)	0 □ 0,02 (0,003)	NO
Sulfate aerosols	-0,03 □ 0 (-0,005)	NO
Soot aerosols	0 □ 0,03 (0,0037)	NO
Linear contrails	0,005 □ 0,03 (0,012)	NO
Induced cloudiness [a]	0,01 □ 0,085 (0,036)	NO
Total aviation	0,04 □ 0,14	

[a]Level of scientific understanding is very low, values should be interpreted with high level of potential error

Values are for whole aviation in 2010, share of flights included in EU ETS is less than 20%.Values taken from [6,7,8] and adjusted according aviation industry growth between 2005 - 2010. Other sources of RF included in [8] wasn´t taken in account because their expected low volume in aviation emissions.

Not including such an important effect as induced cloudiness can lead to a dangerous situation where we will be able to reduce emissions of CO_2 but this reduction will have an opposite effect on contrails and induced cloudiness, which will as a result lead to an overall increase in temperature, even when all standards of EU ETS will are fulfilled.

To clarify what is written above we have to try to explain the issues of aviation radiative forcing addition. Radiative forcing is a commonly used indicator of how much an activity influences the total energy balance of the Earth. RF is an indicator which shows to what extent each component of

aviation emission influences the global warming. The relation between radiative forcing and the equilibrium Earth surface temperature change (ΔTs) can be simply represented by the equation:

$$\Delta T_s = \lambda RF \quad (2)$$

where λ represents the climate sensitivity parameter ($K/(W/m^2)$).

There is a long-time ongoing debate about the value of λ. Climate sensitivity is a source of large uncertainty in the whole climate change science. Regrettably, the Earth atmosphere isn´t a simple model where λ can be easily derived from the basic laws of physics. The climate sensitivity parameter is influenced by many different factors for which LOSU (level of scientific understanding) is at a different level. These effects have a negative or positive impact on λ. For example, rising or decreasing temperature influences the amount of CO_2 taken up by water surfaces. So when less CO_2 is absorbed by water, more is emitted in the atmosphere and thus global temperature grows. A similar effect happens with the absorption of water vapor by air. A hotter atmosphere can absorb more water vapor, thus more vapor as a greenhouse gas is in the atmosphere where it adds an additional positive balance to the warming. More effects seem to have a positive impact on global temperature, which means that global temperature rises. There are some effects with negative impacts on global temperature, but as it was mentioned earlier, factors with a positive effect on temperature occur. So the temperature rise is partially self-produced. λ is only estimated and various atmosphere models have various estimates of λ value. If we hold onto IPCC values [8] λ is estimated to have at least doubled since the pre-industrial era. It means that the addition of the same amount of RF today will raise the temperature two times more than if the same amount of RF had been added in the pre-industrial era.

We must mention again that the radiative forcing indicator isn´t a precise tool and all results are only best estimates, but in general RF seems to be the best tool to predict the impact of certain activities on global temperature. We think that it would only benefit EU ETS system if it adopted RF as a gauge of success in the struggle against the global warming. The currently used system of simply decreasing emissions of CO_2 doesn´t have ideal results, because the decrease in emissions of only CO_2 in aviation wouldn't necessarily lead to a radiative forcing decrease and global temperature reduction as it will be shown later in this paper.

B. Aviation addition to radiative forcing

Radiative forcing from aviation is very specific and therefore slightly different from emission emitted by stationary industrial sources. The largest difference is based on the fact that emissions are emitted at high levels of troposphere or in lower stratosphere. The impacts of emission at a height of about 40000 feet are much more serious than the same emissions of ground sources with even the highest outlets about 1000 feet high.

We may divide aviation radiative forcing into three main chapters. The first chapter is the production of carbon dioxide and other pollutants which are contained in aviation emissions. These emissions and their radiative forcing are quite well known and understood. The second chapter are oxides of nitrogen which have both positive and negative effects on radiative forcing. The third and most important, but least understood chapter are contrails and induced cloudiness. Both aerodynamic- and emission-based contrails and induced cloudiness are problems with a low level of scientific understanding, so there is a possibility of significant inaccuracies. Clouds reflect solar radiation, which has a negative influence on RF, but reflects infrared radiation from the Earth too. It is expected that the effect of trapping radiation from the Earth prevails so clouds and contrails increase global temperature. This effect is especially significant at night when there is no positive effect of the reflected sun radiation.

Estimates about these three main chapters are different from study to study but for our research, we have chosen the estimates published in [6], which are in accordance with IPCC AR4. As mentioned above, more studies with different estimates exist, but even though those studies are different in values, the ratio between the chapters seems very similar and that is what is important to point our issues about EU ETS.

The estimate of total aviation RF according to [6] is 0,078 W/m^2 and estimates on RF carbon dioxide from aviation is about 0,028. It represents only about 35 %. This means that only one third of the estimated addition of aviation to RF and global warming is covered by EU ETS. 2/3 of all RF addition are not monitored or subject to any charge. EU annual allowances for year 2012 for aviation correspond to 212,892,052 tonnes of CO_2, and EU ETS aims to decrease this number by approximately 2% per year, which represents 208,502,525 tonnes in 2013. But in fact the aviation addition to RF is three times greater than the one of carbon dioxide only so the 4-million-tonnes reduction is not about 2 % but only 0,66%. In fact it is more than 0,66% because there is some correlation between the decrease in production of carbon dioxide and some other RF elements. However, many other elements are completely independent of carbon dioxide. Hence the annual decrease would be about 0,8 %. An easy way of removing part of this problem is to change the emissions factor which is used to calculate aviation emission. The addition of oxides of nitrogen should not be a great problem, the only change being that 1 tonne of fuel does not produce about 3 tones of CO_2 but about 5 tonnes of the equivalent of CO_2 emissions. There will still be RF from clouds and contrails, which represents about 40% of RF which will not be covered in EU ETS and a risk of negative effect of EU ETS on global atmosphere will still exist.

V. Possible reverse effect of EU ETS

Although the main goal of the European Union should be the decrease of global warming, EU ETS may in a specific situation actually lead to an increase of global warming. Because EU ETS is focused strictly on carbon dioxide emission and ignores other RF increasing effects, there may be situation when the decrease of carbon dioxide emissions is

connected with an addition of other effects that are in fact greater than the effect of reducing carbon dioxide.

One possible scenario of this reverse effect is connected with the choice of the optimum flight level. For most aircraft, it holds that the higher the flight level, the lower the fuel consumption and the lower the carbon dioxide emissions. So when an air operator decides to fly at a higher flight level, it decreases carbon dioxide emissions and it benefits from EU ETS. However, there is a higher risk that flying at a higher flight level will take aircraft to supersaturated air where contrails or induced cloudiness form. When contrails occurs, RF will increase, but because carbon dioxide emissions will be lowered, the airline may sell its surplus allowances and make profit. Another situation may occur when airlines change used fuel for alternative one, with a different Co_2, NO_x and water vapor ratio. For example, burning liquid hydrogen theoretically produces no Co_2 so airlines will spare all allowances, but in fact production of water vapor from burning liquid hydrogen, and emitting vapor at higher flight levels may have a more negative impact on RF because vapor supports the formation of contrails and cloudiness. A principle that every alternative fuel is assigned its own emission ratio should be established. The emissions of greenhouse gases would be then counted using this ratio. A single emission factor which considers only carbon dioxide should not be used. But [3] expects that "The emission factor for biomass shall be zero". There is potential of another reverse effect, because real RF addition from burning of biomass or biofuel depends on efficiency of biofuel production, biofuel produced by inappropriate procedure can have worst effect than common aviation fuel.

If the European Union insists on keeping aviation in EU ETS, it should change the model used for emission monitoring and calculation. A model that takes into account contrails and cloudiness should be developed. Very important shall be preparation of model air traffic control with taking of contrails in account. There will have to be some kind of prohibited or charged parts of air space where will be high risk of contrails and induced cloudiness. Without inclusion of all important RF influencing effects, EU ETS will never be an effective device for decreasing risk of global warming.

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