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Further development of the EU ETS for aviation against the background of the introduction of a global market-based measure by ICAO

Final report

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Further development of the EU ETS for aviation against the background of the introduction of a global market-based measure by ICAO

Final report

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Abstract: Further development of the EU ETS for aviation against the background of the introduction of a global market-based measure by ICAO

Air transport is a sector with particularly dynamic emissions growth. The European Union has led the way in climate protection and included aviation in the European Emissions Trading Scheme (EU ETS) in 2012. To support the international process for a global market-based measure to limit international aviation emissions under the umbrella of the International Civil Aviation Organisation (ICAO), the scope of emissions trading has been reduced. Instead of covering all flights taking off or landing in the territory of the European Economic Area (EEA) as originally planned, only intra-EEA flights will be covered by emissions trading until 2023.

The aim of the project is to explore the interactions between the two market-based measures tackling aviation emissions: the EU ETS and the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). Therefore, several options are explored how the two schemes can be combined. While in principle both schemes monitor emissions, MRV rules differ both on procedural level as well as in the details. The MRV cycles are presented and differences especially in regard to emission factors for alternative fuels are assessed. As the EU ETS currently covers only intra-EEA flights, the role of non-EEA operators on those routes is assessed.

A quantification of the extent to which the two market-based measures, the EU ETS and CORSIA, can be expected to contribute to the EU 2030 aviation emissions target is included in the study as well as ways to promote transition through an aviation innovation fund.

Kurzbeschreibung: Weiterentwicklung des EU-ETS im Luftverkehr vor dem Hintergrund der Einführung einer globalen marktbasierten Maßnahme durch die ICAO

Der Luftverkehr ist ein Sektor mit einem besonders dynamischen Emissionswachstum. Die Europäische Union hat beim Klimaschutz eine Vorreiterrolle übernommen und den Luftverkehr 2012 in das Europäische Emissionshandelssystem (EU ETS) einbezogen. Zur Unterstützung des internationalen Prozesses für eine globale marktgestützte Maßnahme zur Begrenzung der internationalen Luftverkehrsemissionen unter dem Dach der Internationalen Zivilluftfahrtorganisation (ICAO) wurde der Umfang des Emissionshandels reduziert. Anstatt alle Flüge, die wie ursprünglich geplant im Gebiet des Europäischen Wirtschaftsraums (EWR) starten oder landen, abzudecken, werden bis 2023 nur Flüge innerhalb des EWR durch den Emissionshandel abgedeckt.

Ziel des Projekts ist es, die Wechselwirkungen zwischen den beiden marktbasierten Maßnahmen zur Bekämpfung der Luftverkehrsemissionen zu untersuchen: dem EU-ETS und Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). Daher werden mehrere Optionen untersucht, wie die beiden Systeme kombiniert werden können. Während im Prinzip beide Systeme die Emissionen überwachen, unterscheiden sich die MRV-Regeln sowohl auf Verfahrensebene als auch im Detail. Die MRV-Zyklen werden dargestellt und Unterschiede insbesondere hinsichtlich der Emissionsfaktoren für alternative Kraftstoffe bewertet. Da das EU-EHS derzeit nur Flüge innerhalb des EWR abdeckt, wird die Rolle von Nicht-EWR-Operatoren auf diesen Strecken analysiert.

Eine Quantifizierung des Umfangs, in dem die beiden marktorientierten Maßnahmen, das EU-ETS und CORSIA, voraussichtlich zum Emissionsziel der EU im Jahr 2030 beitragen werden, wird in die Studie einbezogen, ebenso wie Möglichkeiten zur Förderung des Übergangs durch einen Innovationsfonds für die Luftfahrt.

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CNG	Carbon Neutral Growth
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
EEA	European Economic Area
ETS	Emissions Trading System
EU ETS	European Union Emissions Trading System
EUA	European Union Allowance
EUAA	European Union Aviation Allowance
GMBM	Global Market-based Measure
ICAO	International Civil Aviation Organisation
MBM	Market-based Measure

1 Introduction

Air transport is a sector with particularly dynamic emissions growth. The European Union has led the way in climate protection and included aviation in the European Emissions Trading Scheme (EU ETS) in 2012. To support the international process for a global market-based measure to limit international aviation emissions under the umbrella of the International Civil Aviation Organisation (ICAO), the scope of emissions trading has been reduced. Instead of covering all flights taking off or landing in the territory of the European Economic Area (EEA) as originally planned, only intra-EEA flights will be covered by emissions trading until 2023.

With its decision of 6 October 2016, ICAO decided to introduce the Offsetting and Reduction Scheme for International Aviation (CORSIA) from 2021 in order to achieve CO2-neutral growth. At present, key elements of CORSIA are still being developed. The Commission plans to implement CORSIA in Europe via the Emissions Trading Directive by 2023 at the latest, as soon as there is greater clarity about the nature and content of the legal instruments necessary to implement CORSIA and the application of CORSIA by other ICAO member states CORSIA exists.

The present research project different options were assessed how both market-based measures can be combined (chapter 1.1). The introduction of additional requirements is to operators flying on intra-EEA routes is easier if operators are registered in EEA states – therefore the share of non-EEA operators on intra-EEA routes is assessed in chapter 1.2. In both schemes aviation emissions are monitored and reported, but verification and compliance cycles differ. These are compared in chapter 1.3. Special attention is given to the emission factors for alternative fuels under the two regimes (chapter 1.4).

A quantification of the extent to which the two market-based measures, the EU ETS and CORSIA, can be expected to contribute to the EU 2030 aviation emissions target is presented in chapter 1.5. Finally, ways to promote transition through an aviation innovation fund are explored (chapter 1.6).

The full assessments can be found in the Annex. Furthermore, several calculation tools were provided to the client.

1.1 Possible ways in which CORSIA and the EU ETS can co-exist

The EU has committed itself to implement the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), a global market based mechanism under ICAO. Currently flights within and between countries of the European Economic Area (intra-EEA flights) are regulated under the EU ETS. If CORSIA were to replace the EU ETS this would reduce the climate ambition: the EU ETS cap is more ambitious than the CORSIA baseline of carbon neutral growth 2020 (CNG 2020) and furthermore contributes to reaching EU climate targets. Therefore four scenarios are assessed how CORSIA and EU ETS can co-exist.

The following scenarios are assessed:

1. Reference: Current scope EU ETS + CORSIA with use of EU ETS allowances (EUAs) as offsets for intra EEA/EFTA flights
2. Domestic aviation EU ETS + CORSIA with use of EUAs as offsets for intra EEA/EFTA flights
3. Current scope EU ETS + CORSIA with use of EUAs for EEA/EFTA airlines on all routes
4. Current scope EU ETS with strengthened cap + CORSIA

The four scenarios for co-existence elaborated have in common that they all ensure that the EU fulfills its international commitment to participate in CORSIA and that they can be implemented without requiring cooperation by third countries not participating in the EU ETS. In all scenarios aviation contributes to reaching the EU climate target but in none of them the indicative aviation target is reached. Scenarios differ according to the contribution the European aviation sector is making to reduce emissions in Europe and in third countries.

1.1.1 Scenario 1 (reference): Current scope EU ETS + CORSIA with use of EUAs as offsets for intra EEA/EFTA flights

In the reference scenario the EU ETS is continued in its current scope (intra EEA/EFTA) and CORSIA applies to international flights. For international flights to other countries, the CORSIA rules apply and aircraft operators have to surrender units eligible under CORSIA. In the reference scenario airlines would contribute to the EU climate target by buying certificates from the EU ETS and thus financing domestic emission reductions in the countries participating in the EU ETS. Aviation emissions are projected to be in 2030 nearly twice as high as the aviation emission target, in the reference scenario 49 Million t CO_2 emission reduction would stem from the EU ETS which can fill 42% of the gap between emissions and the target. Additionally, 67 Mt CO_2 are covered by offsets which are likely to originate from 3rd countries and thus trigger emission reductions abroad.

1.1.2 Scenario 2: Domestic aviation EU ETS + CORSIA with use of EUAs as offsets for intra EEA/EFTA flights

In this scenario the EU ETS coverage is reduced to domestic flights within EEA countries only. All international flights from/to states participating in CORSIA are covered by CORSIA. However, intra-EEA flights can only use EUAs to offset emissions above the 2020 level. The contribution to EU climate targets is lowest compared to the other scenarios. Also total emission reductions (in EEA/EFTA countries and in 3rd countries) are lowest in this scenario, because the CORSIA baseline is less ambitious than the EU ETS aviation cap.

1.1.3 Scenario 3: Current scope EU ETS + CORSIA with use of EUAs for EEA/EFTA airlines on all routes

This scenario combines the EU ETS with a requirement for EEA operators to use EEA offsets on <u>all</u> routes covered by CORSIA. International intra EEA flights remain covered by the EU ETS and at the same time all international flights are subject to CORSIA. The difference to the reference scenario is that the additional requirements concerning units to be surrendered under CORSIA by EEA aircraft operators do not only apply to intra-EEA flights but also to other international flights (mainly outbound and inbound EEA flights). In this respect it is noted that the EU target under the NDC for 2030 includes not only intra-EEA flights but also outbound EEA flights.

In this scenario the largest contribution to the EU climate target can be reached. The contribution to reduction in third countries is partially reduced as more EUAs are used than international credits. As opposed to the other scenarios in this case EEA/EFTA operators face different compliance requirements on the routes to and from third countries than operators registered in third countries which may cause a distortion of competition. If international credits are less expensive than EUAs, operators from third countries will face lower costs (in our assessment the price difference amounts to about 0,7% of total operating costs).

1.1.4 Scenario 4: Current scope EU ETS with strengthened cap + CORSIA

This option is a variant of the reference scenario. The difference is the way in which the EU ETS baseline is calculated: the baseline is adjusted downwards to ensure that the demand from the aviation sector for EUAs (i.e. the contribution of the aviation sector to the EU GHG emissions target) is not changed by the introduction of CORSIA. No additional requirements apply to the units to be used under CORSIA. Overall emission reductions are highest in this scenario: the contribution of the aviation sector to the EU climate target corresponds to the reference scenario, but the contribution to international mitigation effort is higher.

The assessment of the scenarios shows that there are options how to implement CORSIA while ensuring that the aviation sector contributes to domestic emission reductions that do not require cooperation from third countries. The contribution to both domestic and international mitigation depends on how the EU ETS and CORSIA are combined. Further options to strengthen the contribution of the aviation sector include a higher auctioning share; the proceeds can then in turn be used to incentivize the development of emission reduction technologies for the aviation sector. The assumed cost to operators is highly sensitive to the price assumptions taken and does not depend on the aviation sector alone but also how the stationary ETS is developed further and how international carbon markets evolve.

The full assessment is included in the Annex.

1.2 Role of non-EEA aircraft operators in EU ETS and implications of exempting operators applying a threshold of 10,000 t CO2 based on Intra EEA scope

Presently about half of the number of aircraft operators with verified emissions is from outside the EEA, but these non-EEA aircraft operators take account of only 2% of the total verified emissions on Intra EEA flights. The share of non-EEA operators in the number of Intra EEA flight operations is also limited.

Since 2013 aircraft operators only have to surrender allowances for emissions on Intra EEA flights. The exemption for the obligations under the EU ETS however is based on a threshold of 10,000 tonnes CO_2 which is related to the original scope EU ETS for aviation (all arriving and departing flights). We have looked at the implications of a revised threshold of 10,000 tonnes CO_2 which is based on the Intra EEA scope The conclusion is that the revised threshold would significantly reduce the number of operators (minus 70%) which are subject to the EU ETS obligations, but that the emissions coverage is only very limitedly reduced (only by about 0.5%). For non-EEA aircraft operators the reduction of the number of operators would be larger (minus 90%), compared to the reduction for EEA aircraft operators (minus 50%).

The report is included in the Annex.

1.3 MRV Requirements under CORSIA and the EU ETS

CORSIA and the EU ETS have different monitoring, reporting and verification requirements and different obligations for aircraft operators, verifiers and states. UBA has asked Öko Institut, CE Delft and TAKS to provide an overview of the similarities and differences in the form of a flow chart.

- In a separate file, two flow charts are presented:
- One that compares the tasks various actors have in the two systems
- One that highlights the compliance cycle in CORSIA.

In compiling these charts, the following sources have been used:

- ATTACHMENT A to ICAO State letter AN 1/17.14 – 17/129, especially Appendix 1;

- The consolidated version of Directive 2003/87/EC[1]; and
- Commission Regulation (EU) No 601/2012 of 21 June 2012 on the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC.

The flow charts focus on the compliance cycle or cycles for emissions in 2021, 2022 and 2023.

The flow charts focus on the monitoring, reporting, verifying of emissions as well as on surrendering allowances or acquiring offsets. Other requirements for competent authorities or states under either system have not been included in the charts. These are, for example:

- Auctioning allowances;
- Informing ICAO about the participation of the State in CORSIA;
- Updating lists of administered aircraft operators.

1.3.1 The main MRV similarities between CORSIA and the EU ETS

Even though the EU ETS and CORSIA are different systems, they have some common MRV requirements.

- Both systems require aircraft operators to monitor fuel use on each flight and use the data to calculate annual emissions in the scope of the system.
- Both systems require aircraft operators to compile annual emissions reports, and have them externally verified before submitting them to the competent authority.

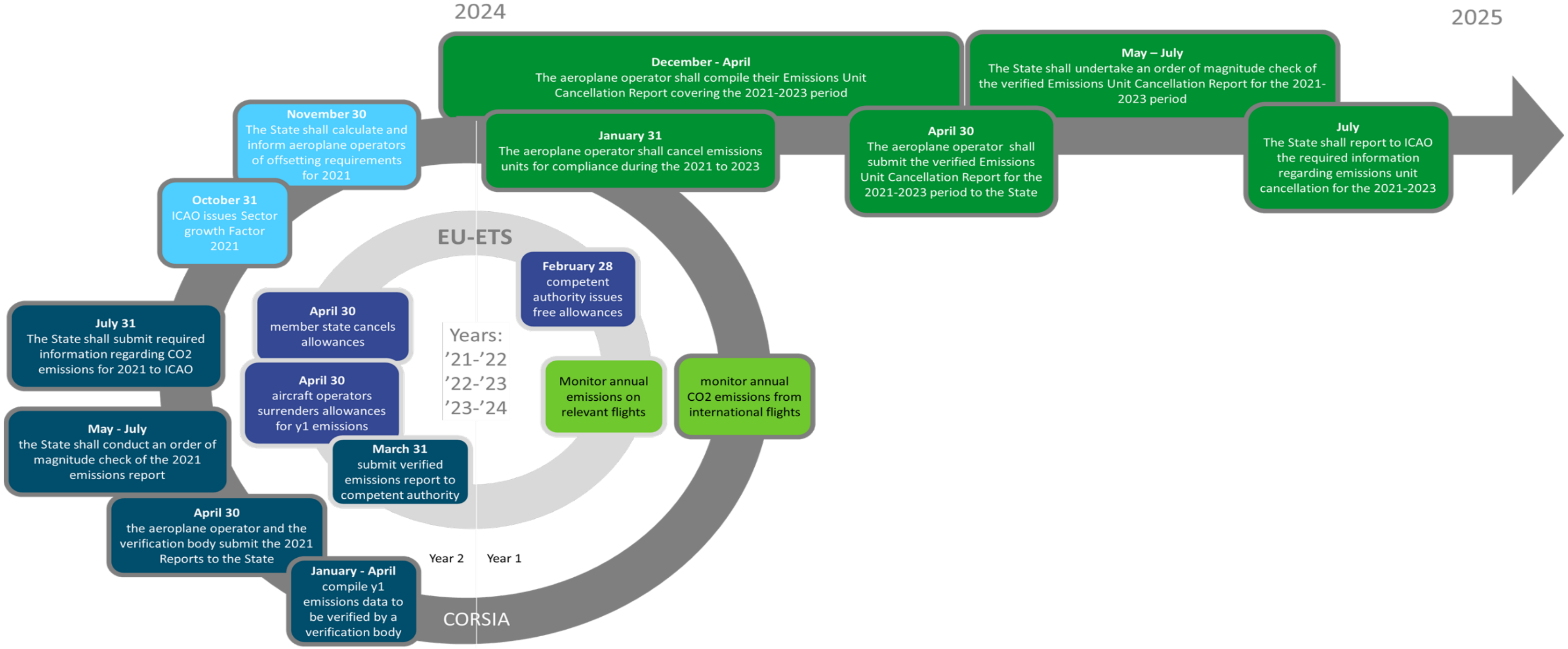
1.3.2 The main MRV differences between CORSIA and the EU ETS

The main differences between the EU ETS and CORSIA are that:

- Under CORSIA, aircraft operators have one month more to compile their emissions reports and have them verified, as they have to be submitted by 30 April instead of 31 March.
- Under the EU ETS, aircraft operators have to surrender allowances on 30 April for the emissions in the preceding year, whereas CORSIA requires them to cancel emissions units once every three years for the years y-4, y-3 and y-2.
- In CORSIA, aircraft operators are only informed about their offsetting obligation for a certain year on 30 November of the following year, whereas under EU ETS, they know how many allowances they have to purchase on the date that they have compiled their annual emissions report.

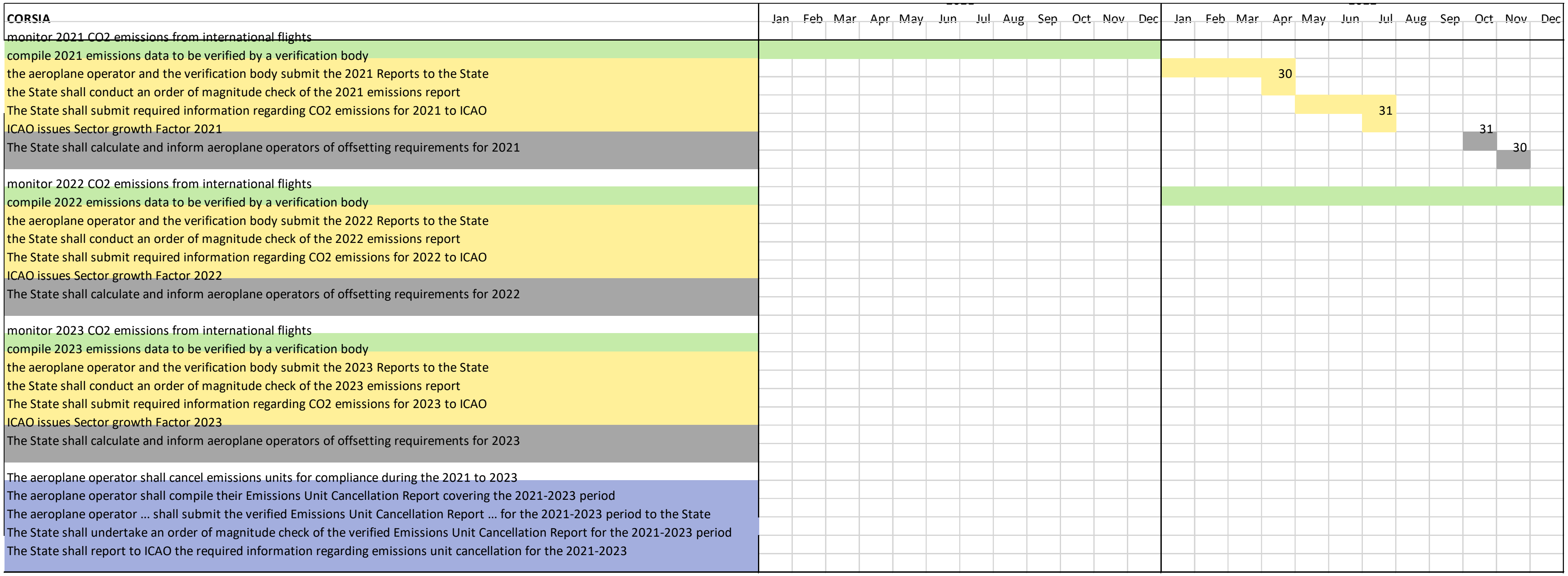
[1] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02003L0087-20140430&from=EN

Figure 1: Flow chart of EU ETS and CORSIA MRV requirements



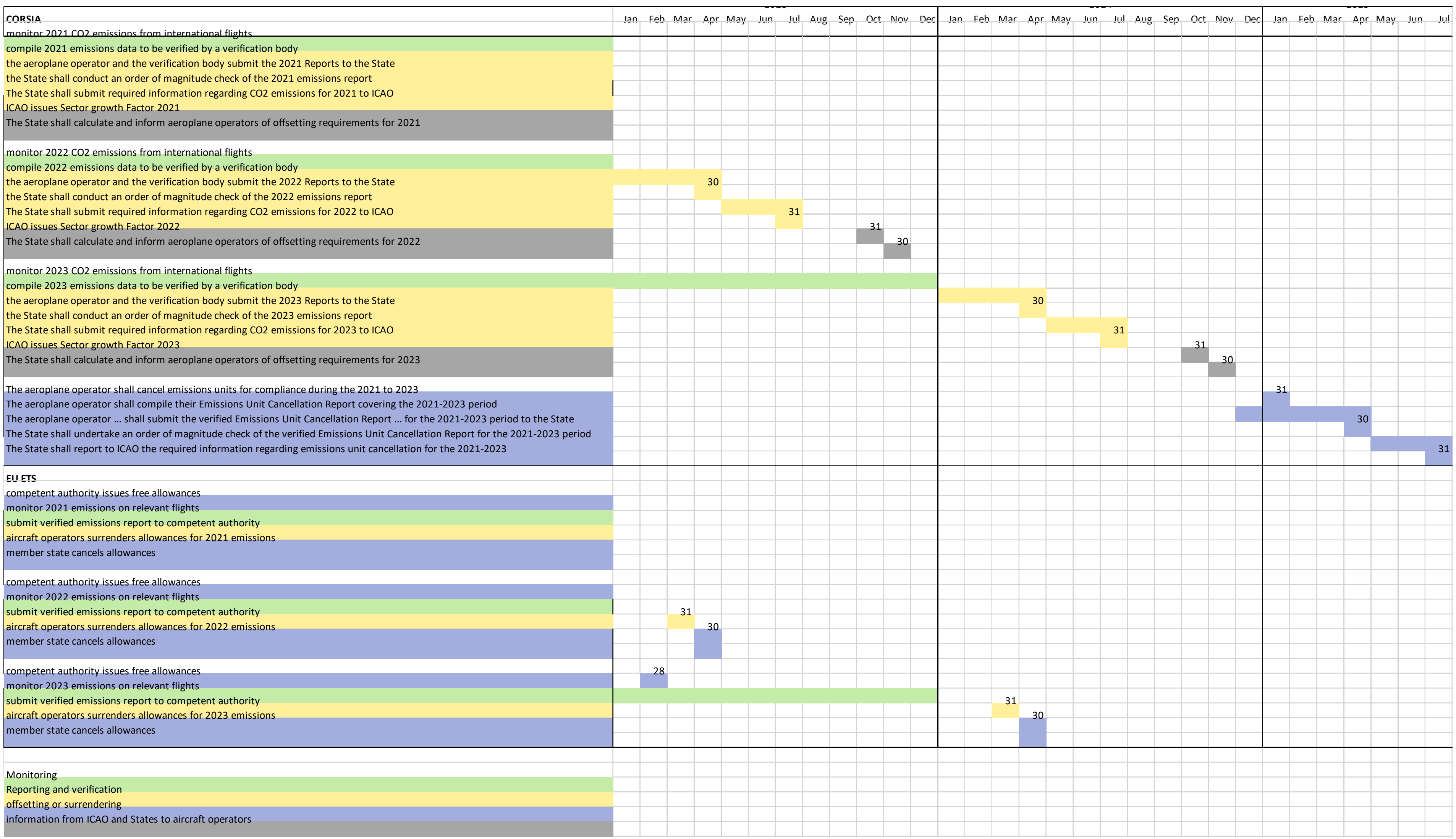
Source: own presentation

Figure 2: EU ETS and CORSIA MRV requirements (years 2021-2022)



Source: own presentation

Figure 3: EU ETS and CORSIA MRV requirements (years 2023-2025)



Source: own presentation

1.4 Emission factors for alternative fuels under CORSIA and under the EU ETS

The aim of this document is to compare emission factors for alternative aviation fuels used under the European Emissions Trading System (EU ETS) and the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). The main result is that absolute amounts of emissions from alternative fuels which will be reported under both systems can't be compared. One obvious reason is that both schemes address different geographical scopes and participants. Although under both schemes the use of alternative aviation fuels reduces the need to buy certificates (EU ETS) or offsets (CORSIA), the quantification of these amounts follows very different rules. To calculate emission reductions from eligible alternative aviation fuels for compliance under CORSIA, life cycle emissions of alternative fuels are compared against benchmark life cycle emissions. This means that fossil fuels can reduce the need to buy offsets, too, as long as they meet the criteria of achieving a reduction of at least 10 % compared to baseline life cycle emissions. On contrary, under the EU ETS, biofuels are accounted with zero emissions if they comply with greenhouse gas reductions and sustainability criteria from the European Renewable Energy Directive. Many details on eligible alternative fuels under CORSIA are not available in the moment of writing (September 2019). The calculation of life cycle emissions and the definition of eligibility criteria related to the carbon stock are especially relevant for the future use of biofuels under CORSIA.

1.5 Market Based Measures and the EU 2030 aviation emissions target

The EU has committed itself under the Paris agreement to reduce its emissions by 40% GHG emissions reduction relative to 1990 until the year 2030. Aviation emissions are covered by this target. The EC has set an indicative target for aviation, including all flights departing from EU airports, to about 111 Mt of CO_2. Because EU Emissions Trading Scheme (EU ETS) regulations have EEA relevance we have estimated the equivalent aviation target for the EEA (112.7 Mt). A reduction of 40% relative to 1990 for aviation would imply a level of about 51 Mt of CO_2 emissions. The indicative aviation target for EEA countries of 112.7 Mt is clearly higher. Under the indicative target aviation is allowed to increase emissions by 33% compared to 1990.

Aviation emissions on all departing EEA flights are forecast to grow to 216.5 Mt in 2030. Hence Market Based Measures have to bring about an emission reduction of 103.8 Mt in 2030 in order to meet the target.

The aim of the assessment is to assess how the EU ETS and the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), as they are presently designed, contribute to reaching the EU 2030 emissions target, and if additional policy measures are required.

Presently it is not clear how CORSIA and the EU ETS will work together in 2030. We have assumed the EU ETS will remain in place for Intra EEA flights and in 2030 CORSIA will apply to all international flights between EEA States and all States which are expected to join the mandatory phase 2 of CORSIA. The EU ETS will imply a demand for EUAs from the aviation industry of 46.3 Mt in 2030. EUAs represent reductions in other EU ETS sectors and contribute to reaching the target. As part of CORSIA the demand for international credits on Outbound EEA flights will be 33.6Mt. However, these credits are expected to stem from countries outside of the EEA and thus not contribute to reaching the target. The shortage in reaching the indicative aviation emissions target of 112.7 Mt in 2030 is estimated to 57.5 Mt. The shortage is mainly due to the fact that at present no Market Based Measures are foreseen for Outbound EEA flights which contribute to reaching the EU aviation emissions target.

We have explored supplemental policy measures which could be taken in order to reach the aviation emissions target. First, we have looked for stricter rules for Intra EEA flights under the EU ETS, viz. lower the cap and additional EUAs to surrender to account for non-CO_2 climate impacts. By this it would be possible to reach the aviation target in 2030, but it would mean that Intra EEA flights would fully take account of reaching the EU aviation emissions target whereas MBMs for Outbound EEA flights would not make any contribution.

An alternative is to introduce a tax for Outbound flights and use proceeds to buy EUAs. It is estimated the required tax level on Outbound EEA flights is about 8€ per departing passenger in 2030 in order to generate the proceeds needed to buy EUAs so that the target is met. There are however a number of drawbacks with this policy measure which need to be further addressed and investigated. A final option is to require the use of sustainable aviation fuels. In order to meet the target the fuels uplifted for Outbound flights would need to contain 50% of sustainable aviation fuels. It is not clear whether sufficient amounts of sustainable aviation fuels can be produced by 2030.

The assessment is included in the Annex.

1.6 Promoting transition through an aviation innovation fund (AIF)

Aviation accounts for more than 2% of global CO_2 emissions and the share is increasing due to strong emissions growth despite efficiency improvements. For de-carbonizing international aviation radical technological change is required. In order to be in line with the Paris Agreement temperature goals, full decarbonization by 2050 should be pursued (IPCC, 2018). Since many conventional powered fuel aircraft currently on order may still fly around that time, and because climate-neutral technologies are not available on the market (e.g. battery-electric aircraft), low- or zero-carbon drop-in fuels need to enter the fuel mix in increasing shares between now and 2050.

Low- or zero-carbon fuels can be biofuels or e-fuels (power-to-liquid). Both fuel types are currently available in very small quantities, so the transition fund should aim for increasing production capacity, thus lowering the unit costs of production through economies of scale and learning. Neither the EU ETS nor CORSIA will provide sufficient incentives to make climate-neutral fuels competitive (CE Delft, 2015).

However, despite post-fossil fuels many other new and improved technologies will be required to reduce and finally eliminate aviation's impact on the global atmosphere. This includes improved airframes and engines and potentially operational improvements such as climate friendly routing to avoid non-CO_2 impacts of aviation.

In the paper we assess, how such technological developments, which facilitate the transition of the aviation sector towards a Paris Agreement compatible pathway, can be spurred through the establishment of and Aviation Innovation Fund (AIF). Such an AIF should basically be open to address technical improvements of other (environmental) issues as well. We first look into experiences from similar funds or instruments and then into the more fundamental aspect of such a fund and address question such as its purpose, its core focus, how the transitional momentum can be ensured and which actors should be addressed by the fund. In a second step we focus on more administrative issues such as sources of funding, how the budget should be spent and who and where such a fund should be established.

A Possible ways in which CORSIA and the EU ETS can co-exist

Environmental Research of the
Federal Ministry for the
Environment, Nature Conservation,
Building and Nuclear Safety

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Possible ways in which CORSIA and the EU ETS can co-exist

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Abstract

The EU has committed itself to implement the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), a global market-based mechanism under ICAO. Currently flights within and between countries of the European Economic Area (intra-EEA flights) are regulated under the EU ETS. If CORSIA were to replace the EU ETS this would reduce the climate ambition: the EU ETS cap is more ambitious than the CORSIA baseline of carbon neutral growth 2020 (CNG 2020) and furthermore contributes to reaching EU climate targets. Therefore, four scenarios are assessed how CORSIA and EU ETS can co-exist.

The following scenarios are assessed:

1. Reference: Current scope EU ETS + CORSIA with use of EU ETS allowances (EUAs) as offsets for intra EEA/EFTA flights
2. Domestic aviation EU ETS + CORSIA with use of EUAs as offsets for intra EEA/EFTA flights
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4. Current scope EU ETS with strengthened cap + CORSIA

The four scenarios for co-existence elaborated have in common that they all ensure that the EU fulfills its international commitment to participate in CORSIA and that they can be implemented without requiring cooperation by third countries not participating in the EU ETS. In all scenarios aviation contributes to reaching the EU climate target but in none of them the indicative aviation target is reached. Scenarios differ according to the contribution the European aviation sector is making to reduce emissions in Europe and in third countries.

Kurzbeschreibung

Die EU hat sich verpflichtet, das Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) umzusetzen. CORSIA ist ein globaler marktbasierter Mechanismus unter dem Dach der Internationale Zivilluftfahrtorganisation ICAO. Derzeit werden Flüge innerhalb und zwischen Ländern des Europäischen Wirtschaftsraums (Intra-EWR-Flüge) vom EU Emissionshandel (EU ETS) erfasst. Sollte im Flugverkehr CORSIA den EU Emissionshandel ersetzen, würde dies Ambition in Bezug auf das Klimaziel verringern: Die Obergrenze für Emissionen im EU ETS (die Cap) ist ehrgeiziger als die CORSIA-baseline für klimaneutrales Wachstum 2020 und darüber hinaus trägt der Flugverkehr im Rahmen des EU ETS zur Erreichung der EU-Klimaziele bei. Daher werden vier Szenarien untersucht, wie CORSIA und EU ETS koexistieren können:

1. Referenz: EU ETS im aktuellen Anwendungsbereich + CORSIA mit Verwendung von EU ETS Emissionsberechtigungen (EUAs) als Ausgleich für Intra-EWR/EFTA-Flüge
2. EU ETS für Inlandsflüge + CORSIA mit Verwendung von EUAs als Ausgleich für Intra-EWR/EFTA-Flüge
3. EU ETS im aktuellen Anwendungsbereich + CORSIA mit Nutzung von EUAs für EWR/EFTA-Fluggesellschaften auf allen Strecken
4. EU ETS im aktuellen Anwendungsbereich mit stärkerer Cap + CORSIA

Die vier erarbeiteten Szenarien haben gemeinsam, dass die EU ihrer internationalen Verpflichtung zur Teilnahme an CORSIA nachkommt und dass sie umgesetzt werden können, ohne dass Drittländer, die nicht am EU ETS teilnehmen, zur Zusammenarbeit verpflichtet sind. In allen Szenarien trägt der Luftverkehr zur Erreichung des EU-Klimaziels bei, aber in keinem von ihnen wird das indikative Luftverkehrsziel erreicht. Die Szenarien unterscheiden sich je nachdem, welchen Beitrag der europäische Luftverkehrssektor zur Reduzierung der Emissionen in Europa und in Drittländern leistet.

List of Abbreviations

CNG	Carbon Neutral Growth
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
EEA	European Economic Area (EU Member States, Norway, Iceland and Liechtenstein)
EFTA	European Free Trade Association (EU Member States, Norway, Iceland, Liechtenstein, Switzerland)
EU ETS	European Union Emissions Trading System
EUA	European Union Allowance
EUAA	European Union Aviation Allowance
GMBM	Global Market-based Measure
ICAO	International Civil Aviation Organisation
LRF	Linear reduction factor
MBM	Market-based Measure

Summary

The EU has committed itself to implement the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), a global market-based mechanism under ICAO. Currently flights within and between countries of the European Economic Area (intra-EEA flights) are regulated under the EU ETS. If CORSIA were to replace the EU ETS this would reduce the climate ambition: the EU ETS cap is more ambitious than the CORSIA baseline of carbon neutral growth 2020 (CNG 2020) and furthermore contributes to reaching EU climate targets. Therefore, options are explored how CORSIA and EU ETS can co-exist. The options assessed are required to meet the following three criteria:

1. The EU Member States comply with international law, i.e. international flights between EEA countries will be subject to CORSIA;
2. The aviation sector contributes to meeting the EU climate target; and
3. The policy option does not require support of third states or ICAO, i.e. it can be realized independent from ICAO-process.

The four scenarios for co-existence elaborated have in common that they all ensure that the EU fulfills its international commitment to participate in CORSIA and that they can be implemented without requiring cooperation by third countries not participating in the EU ETS. In all scenarios aviation contributes to reaching the EU climate target but in none of them the indicative aviation target is reached. Scenarios differ according to the contribution the European aviation sector is making to reduce emissions in Europe and in third countries.

Scenario 1 (reference): Current scope EU ETS + CORSIA with use of EUAs as offsets for intra EEA/EFTA flights

In the reference scenario the EU ETS is continued in its current scope (intra EEA/EFTA) and CORSIA applies to international flights. For international flights to other countries, the CORSIA rules apply and aircraft operators have to surrender units eligible under CORSIA. In the reference scenario airlines would contribute to the EU climate target by buying certificates from the EU ETS and thus financing domestic emission reductions in the countries participating in the EU ETS. Aviation emissions are projected to be in 2030 nearly twice as high as the aviation emission target, in the reference scenario 49 Million t CO_2 emission reduction would stem from the EU ETS which can fill 42% of the gap between emissions and the target. Additionally, 67 Mt CO_2 are covered by offsets which are likely to originate from 3rd countries and thus trigger emission reductions abroad.

Scenario 2: Domestic aviation EU ETS + CORSIA with use of EUAs as offsets for intra EEA/EFTA flights

In this scenario the EU ETS coverage is reduced to domestic flights within EEA countries only. All international flights from/to states participating in CORSIA are covered by CORSIA. However, intra-EEA flights can only use EUAs to offset emissions above the 2020 level. The contribution to EU climate targets is lowest compared to the other scenarios. Total emission reductions (in EEA/EFTA countries and in 3rd countries) are also lowest in this scenario, because the CORSIA baseline is less ambitious than the EU ETS aviation cap.

Scenario 3: Current scope EU ETS + CORSIA with use of EUAs for EEA/EFTA airlines on all routes

This scenario combines the EU ETS with a requirement for EEA operators to use EEA offsets on all routes covered by CORSIA. International intra EEA flights remain covered by the EU ETS and at the same time all international flights are subject to CORSIA. The difference to the reference scenario is that the additional requirements concerning units to be surrendered under CORSIA by EEA aircraft operators do not only apply to intra-EEA flights but also to other international flights (mainly

outbound and inbound EEA flights). In this respect it is noted that the EU target under the NDC for 2030 includes not only intra-EEA flights but also outbound EEA flights.

In this scenario the largest contribution to the EU climate target can be reached. The contribution to reduction in third countries is partially reduced as more EUAs are used than international credits. As opposed to the other scenarios in this case EEA/EFTA operators face different compliance requirements on the routes to and from third countries than operators registered in third countries which may cause a distortion of competition. If international credits are less expensive than EUAs, operators from third countries will face lower costs (in our assessment the price difference amounts to about 0,7% of total operating costs).

Scenario 4: Current scope EU ETS with strengthened cap + CORSIA

This option is a variant of the reference scenario. The difference is the way in which the EU ETS baseline is calculated: the baseline is adjusted downwards to ensure that the demand from the aviation sector for EUAs (i.e. the contribution of the aviation sector to the EU GHG emissions target) is not changed by the introduction of CORSIA. No additional requirements apply to the units to be used under CORSIA. Overall emission reductions are highest in this scenario: the contribution of the aviation sector to the EU climate target corresponds to the reference scenario, but the contribution to international mitigation effort is higher.

The assessment of the scenarios shows that there are options how to implement CORSIA while ensuring that the aviation sector contributes to domestic emission reductions that do not require cooperation from third countries. The contribution to both domestic and international mitigation depends on how the EU ETS and CORSIA are combined. Further options to strengthen the contribution of the aviation sector include a higher auctioning share; the proceeds can then in turn be used to incentivize the development of emission reduction technologies for the aviation sector. The assumed cost to operators is highly sensitive to the price assumptions taken and does not depend on the aviation sector alone but also how the stationary ETS is developed further and how international carbon markets evolve.

Zusammenfassung

Die EU hat sich verpflichtet, das Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) umzusetzen. CORSIA ist ein globaler marktbasierter Mechanismus unter dem Dach der Internationale Zivilluftfahrtorganisation ICAO. Derzeit werden Flüge innerhalb und zwischen Ländern des Europäischen Wirtschaftsraums (Intra-EWR-Flüge) vom EU Emissionshandel (EU ETS) erfasst. Sollte im Flugverkehr CORSIA den EU Emissionshandel ersetzen, würde dies Ambition in Bezug auf das Klimaziel verringern: Die Obergrenze für Emissionen im EU ETS (die Cap) ist ehrgeiziger als die CORSIA-baseline für klimaneutrales Wachstum 2020 und darüber hinaus trägt der Flugverkehr im Rahmen des EU ETS zur Erreichung der EU-Klimaziele bei. Daher werden Optionen untersucht, wie CORSIA und EU ETS koexistieren können. Die bewerteten Optionen müssen die folgenden drei Kriterien erfüllen:

1. Die EU-Mitgliedstaaten halten sich an das Völkerrecht, d.h. internationale Flüge zwischen den EWR-Ländern unterliegen CORSIA;
2. Der Luftfahrtsektor trägt dazu bei, das EU-Klimaziel zu erreichen; und
3. Die Politikoption erfordert keine Unterstützung von Drittstaaten oder der ICAO, d.h. sie kann unabhängig vom ICAO-Prozess realisiert werden.

Die vier erarbeiteten Szenarien haben gemeinsam, dass die EU ihrer internationalen Verpflichtung zur Teilnahme an CORSIA nachkommt und dass sie umgesetzt werden können, ohne dass Drittländer, die nicht am EU ETS teilnehmen, zur Zusammenarbeit verpflichtet sind. In allen Szenarien trägt der Luftverkehr zur Erreichung des EU-Klimaziels bei, aber in keinem von ihnen wird das indikative Luftverkehrsziel erreicht. Die Szenarien unterscheiden sich je nachdem, welchen Beitrag der europäische Luftverkehrssektor zur Reduzierung der Emissionen in Europa und in Drittländern leistet.

Szenario 1 (Referenz): EU ETS im aktuellen Anwendungsbereich + CORSIA mit Verwendung von EUAs als Ausgleich für Intra-EWR/EFTA-Flüge

Im Referenzszenario wird das EU-ETS in seinem derzeitigen Anwendungsbereich (intra EEA/EFTA) fortgesetzt und CORSIA gilt für internationale Flüge. Für internationale Flüge in andere Länder gelten die CORSIA-Regeln und Flugzeugbetreiber müssen die nach CORSIA zugelassenen Einheiten abgeben. Im Referenzszenario würden die Fluggesellschaften zum EU-Klimaziel beitragen, indem sie Zertifikate aus dem EU ETS kaufen und damit inländische Emissionsreduktionen in den am EU ETS teilnehmenden Ländern finanzieren. Die Projektionen erwarten, dass die Emissionen des Luftverkehrs 2030 im Vergleich zum Emissionsziel fast doppelt so hoch liegen werden. Im Referenzszenario würden Emissionszertifikate in der Höhe von 49 Millionen t CO_2 aus dem EU ETS stammen, um die Lücke zwischen Emissionen und dem Ziel von 42 % zu schließen. Zusätzlich werden 67 Mio. t CO_2 durch Emissionsgutschriften gedeckt, die voraussichtlich aus Drittländern stammen und somit Emissionsminderungen im Ausland auslösen.

Szenario 2: EU ETS für Inlandsflüge + CORSIA mit Verwendung von EUAs als Ausgleich für Intra-EWR/EFTA-Flüge

In diesem Szenario wird die Abdeckung des EU ETS nur auf Inlandsflüge innerhalb der EWR-Länder reduziert. Alle internationalen Flüge von/nach den an CORSIA teilnehmenden Staaten werden allein von CORSIA abgedeckt. Intra-EWR-Flüge können jedoch nur Emissionsberechtigungen aus dem stationären Emissionshandel (EUAs) verwenden, um Emissionen über dem Niveau von 2020 auszugleichen. Der Beitrag zu den EU-Klimazielen ist im Vergleich zu den anderen Szenarien am geringsten. Auch die Gesamtemissionsreduktionen (in den EWR/EFTA-Ländern und in Drittländern)

sind in diesem Szenario am geringsten, da die CORSIA-baseline weniger ambitioniert ist als die EU ETS-Luftverkehrscap.

Szenario 3: EU ETS im aktuellen Anwendungsbereich + CORSIA mit Nutzung von EUAs für EWR/EFTA-Fluggesellschaften auf allen Strecken

Dieses Szenario kombiniert das EU ETS mit der Verpflichtung für EWR-Betreiber, Emissionsberechtigung aus dem EU Emissionshandel auf allen von CORSIA bedienten Strecken zu verwenden. Internationale Intra-EWR-Flüge bleiben vom EU Emissionshandel erfasst und gleichzeitig unterliegen alle internationalen Flüge CORSIA. Der Unterschied zum Referenzszenario besteht darin, dass die zusätzlichen Anforderungen an die von den EWR-Luftfahrzeugbetreibern im Rahmen von CORSIA abzugebenden Einheiten nicht nur für Flüge innerhalb des EWR, sondern auch für andere internationale Flüge (hauptsächlich abgehende und ankommende Flüge des EWR) gelten. In diesem Zusammenhang wird darauf hingewiesen, dass das EU-Ziel im Rahmen des Übereinkommens von Paris für 2030 nicht nur Flüge innerhalb des EWR, sondern auch Flüge außerhalb des EWR umfasst.

In diesem Szenario kann der größte Beitrag zum EU-Klimaziel erreicht werden. Der Beitrag zur Emissionsminderung in Drittländern wird teilweise reduziert, da mehr EU Emissionsberechtigungen als internationale Kredite verwendet werden. Im Gegensatz zu den anderen Szenarien in diesem Fall unterliegen Betreiber des EWR/EFTA auf den Strecken von und nach Drittländern anderen Anforderungen als die in Drittländern registrierten Betreiber, was zu einer Wettbewerbsverzerrung führen kann. Wenn internationale Emissionsgutschriften preiswerter sind als EUAs, müssen Betreiber aus Drittländern mit niedrigeren Kosten rechnen (nach unserer Einschätzung beträgt die Preisdifferenz etwa 0,7% der Gesamtbetriebskosten).

Szenario 4: EU ETS im aktuellen Anwendungsbereich mit stärkerer Cap + CORSIA

Diese Option ist eine Variante des Referenzszenarios. Der Unterschied besteht in der Art und Weise, wie die Flugverkehrscap des EU ETS berechnet wird: Die Cap wird nach unten angepasst, um sicherzustellen, dass die Nachfrage des Luftfahrtsektors nach EUAs (d.h. der Beitrag des Luftfahrtsektors zum EU Klimaziel) durch die Einführung von CORSIA nicht verändert wird. Für die unter CORSIA zu verwendenden Einheiten gelten keine zusätzlichen Anforderungen. Die Gesamtemissionsreduktionen sind in diesem Szenario am höchsten: Der Beitrag des Luftverkehrs zum EU-Klimaziel entspricht dem Referenzszenario, aber der Beitrag zu den internationalen Minderungsmaßnahmen ist höher.

Die Bewertung der Szenarien zeigt, dass es Optionen gibt, wie CORSIA umgesetzt werden kann, während gleichzeitig sichergestellt wird, dass der Luftfahrtsektor zur Erreichung der EU Klimazielen beiträgt und die keine Zusammenarbeit von Drittländern erfordern. Der Beitrag zur nationalen und internationalen Minderung hängt davon ab, wie das EU ETS und CORSIA kombiniert werden. Weitere Optionen zur Stärkung des Beitrags des Luftfahrtsektors sind ein höherer Auktionsanteil; der Erlös kann wiederum dazu verwendet werden, die Entwicklung von Technologien zur Emissionsminderung für den Luftfahrtsektor anzuregen. Die angenommenen Kosten für die Betreiber sind stark abhängig von den getroffenen Preisannahmen und hängen nicht nur vom Luftfahrtsektor allein ab, sondern auch davon, wie sich der stationäre Emissionshandel in der EU und die internationalen Kohlenstoffmärkte weiterentwickeln.

A.1 Background

The EU has committed itself to implement the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), the global market-based mechanism under ICAO. Currently flights within and between countries of the European Economic Area[2] (intra-EEA flights) are regulated under the EU ETS. If CORSIA was to replace the EU ETS this would reduce the climate ambition: the EU ETS cap is more ambitious than the CORSIA baseline of carbon neutral growth 2020 (CNG 2020) and furthermore contributes to reaching EU climate targets. Therefore, options are explored how CORSIA and EU ETS can co-exist. The options assessed are required to meet the following three criteria:

1. The EU Member States comply with international law, i.e. international flights between EEA countries will be subject to CORSIA;
2. The aviation sector contributes to meeting the EU climate target; and
3. The policy option does not require support of third states or ICAO, i.e. it can be realized independent from ICAO-process.

Four scenarios how the EU ETS and CORSIA can co-exist are elaborated in this paper:

- Scenario 1 (reference): Current scope EU ETS + CORSIA with use of EUAs as offsets for intra EEA/EFTA flights
- Scenario 2: Domestic aviation EU ETS + CORSIA with use of EUAs as offsets for intra EEA/EFTA flights
- Scenario 3: Current scope EU ETS + CORSIA with use of EUAs for EEA/EFTA airlines on all routes
- Scenario 4: Current scope EU ETS with strengthened cap + CORSIA

All options have in common that CORSIA applies to all international flights (also intra EEA) and thus Member States comply with their commitment under ICAO (criterion 1). At the same time the EU ETS continues to apply. Domestic flights within EEA countries (and from 2030 onwards within Switzerland) are covered by the EU ETS only in all scenarios. International flights to countries not covered by the EU ETS are subject to CORSIA only. The scenarios differ in relation to their treatment of international flights between countries covered by the EU ETS and whether operators based in EEA/EFTA countries are required to surrender EUAs as offsets under CORSIA.

The continuation of the EU ETS and the requirement to surrender EUAs as offsets under CORSIA are means to comply with the criterion 2, that the aviation sector shall contribute to reaching the EU climate target. It is assumed that units from the EU ETS (EUAs) are eligible as offsets under CORSIA and that States are allowed to limit the eligible offsets at least for their national operators to those complying with certain quality criteria, e.g. the reduction occurring in EEA countries. The current ICAO Resolution A39-3 does not specify the quality requirements of offsets, and neither indicates whether States would be allowed to set higher requirements unilaterally for aircraft operators registered in the state. Article 15 notes the work of the Council, amongst others on 'recommended criteria for emissions units to be purchased by aircraft operators'. Article 20 states that the Emissions Unit Criteria will be developed by the Council and laid down in 'Standards And Recommended Practices' (SARPs) and 'related guidance material'. SARPs are Annexes to the Chicago Convention. The language suggests that ICAO will recommend, rather than set, eligibility criteria. In the further development of this option, we will assume that states can indeed set requirements that are stricter than the ICAO recommendations.

[2]Currently all flights in and between the 28 EU Member States and the EEA countries Norway, Iceland and Liechtenstein are covered by the EU ETS. From 2020 onwards Switzerland is envisaged to link their ETS to cover aviation jointly. In the paper we refer to EEA/EFTA to reflect this change in coverage (Switzerland is a Member of EFTA).

In order not to require support of third States for the implementation of the policy scenario (criterion 3), we restrict the requirements to operators registered in EEA/EFTA states. Intra-EEA flights (both domestic and international) are almost entirely operated by aircraft operators registered in EEA states. Non-EEA-operators operate very few flights on intra EEA routes, they cause about 1% of emissions currently regulated under the EU ETS. Therefore, the treatment of non-EEA/non-EFTA operators on routes covered by the EU ETS is not elaborated in further detail in the following assessment. In principle there are two options for the treatment of non-EEA/non-EFTA operators under the EU ETS: either they are exempted from the EU ETS and have to comply with CORSIA only or their surrendering requirements under the EU ETS is reduced by the surrendered amounts under CORSIA by that operator.

The scenarios are defined in detail as follows (see also Table 1):

Scenario 1 (reference): Current scope EU ETS + CORSIA with use of EUAs as offsets for intra EEA/EFTA flights

In the reference scenario the EU ETS is continued in its current scope (intra EEA/EFTA) and CORSIA applies to international flights. For EEA/EFTA aircraft operators there is no change for domestic and international intra EEA/EFTA routes: participating in the EU ETS also covers their CORSIA obligation.

For international flights to other countries, the CORSIA rules apply. For emissions on routes to non-EEA/non-EFTA countries aircraft operators have to surrender units eligible under CORSIA. The individual surrendering requirements for emissions above the carbon neutral growth 2020 level are defined by CORSIA rules.

Scenario 2: Domestic aviation EU ETS + CORSIA with use of EUAs as offsets for intra EEA/EFTA flights

In this scenario the EU ETS coverage is reduced to domestic flights within EEA countries only. All international flights from/to states participating in CORSIA are covered by CORSIA. However, intra-EEA flights can only use EUAs to offset emissions above the 2020 level. The difference compared to the reference scenario is the treatment of international intra-EEA flights. Whereas in the reference scenario these flights are included in both regimes, in the CORSIA scenario they are covered by CORSIA only. For those flights the surrendering requirements as well as their contribution to reaching the EU climate targets (criteria 2) are lower than in the reference scenario.

Scenario 3: Current scope EU ETS + CORSIA with use of EUAs for EEA/EFTA airlines on all routes

This scenario combines the EU ETS with a requirement for EEA operators to use EEA offsets on all routes covered by CORSIA. International intra EEA flights remain covered by the EU ETS and at the same time all international flights are subject to CORSIA. EEA Member States set additional requirements to the CORSIA eligible units for operators registered in EEA States in such a way that the units contribute to reaching the EU climate target (criteria 2) for all flights covered by CORSIA. The additional requirements for EEA operators can be that EUAs are used to offset emissions or that only offsets can be used which reflect emission reduction in one of the EEA Member States. For the ease of comparison, we assume that EUAs are used.

The difference to the reference scenario is that the additional requirements concerning units to be surrendered under CORSIA by EEA aircraft operators do not only apply to intra-EEA flights but also to other international flights (mainly outbound and inbound EEA flights). In this respect it is noted that the EU target under the NDC for 2030 includes not only intra-EEA flights but also outbound EEA flights.

Scenario 4: Current scope EU ETS with strengthened cap + CORSIA

This option is a variant of the reference scenario. The difference is the way in which the EU ETS baseline is calculated. In this option, the baseline is adjusted downwards to ensure that the demand from the aviation sector for EUAs (i.e. the contribution of the aviation sector to the EU GHG emissions target) is not changed by the introduction of CORSIA. This can be done by subtracting the amount of emissions to be offset by CORSIA from the original EU ETS baseline.[3] No additional requirements apply to the units to be used under CORSIA.

Table 1: Overview of the CORSIA and EU ETS co-existence scenarios

	Scenario 1. Current scope EU ETS + CORSIA with use of EUAs as offsets for intra EEA/EFTA flights	Scenario 2 Domestic aviation EU ETS + CORSIA with use of EUAs as offsets for intra EEA/EFTA flights	Scenario 3 Current scope EU ETS + CORSIA with use of EUAs for EEA/EFTA airlines on all routes	Scenario 4 Current scope EU ETS with strengthened cap + CORSIA
EU ETS (including Swiss ETS linked to the EU ETS by 2030)				
Coverage of intra EEA/EFTA flights	Domestic and international intra EEA/EFTA flights	Domestic flights only	Domestic and international intra EEA/EFTA flights	Domestic and international intra EEA/EFTA flights
Aviation cap	95% of 2004-2006 with LRF of 2.2% in 2021-2030	95% of 2004-2006 with LRF of 2.2% in 2021-2030 Cap to be adjusted in response to coverage of domestic flights only	95% of 2004-2006 with LRF of 2.2% in 2021-2030	95% of 2004-2006 with LRF of 2.2% in 2021-2030 minus emissions on intra EU/EFTA flights above CORSIA baseline
Use of emission units	EUAAs for emissions under cap EUAs for emissions above EU ETS cap which are not covered by CORSIA	EUAAs for emissions under cap EUAs for emissions above EU ETS cap	EUAAs for emissions under cap EUAs for emissions above EU ETS cap which are not covered by CORSIA	EUAAs for emissions under cap EUAs for emissions above EU ETS cap which are not covered by CORSIA
CORSIA				
Coverage of flights from and to EEA/EFTA	International flights between EEA/EFTA airports and airports in ICAO Member States participating in CORSIA	International flights between EEA/EFTA airports and airports in ICAO Member States participating in CORSIA	International flights between EEA/EFTA airports and airports in ICAO Member States participating in CORSIA	International flights between EEA/EFTA airports and airports in ICAO Member States participating in CORSIA
Baseline	Average of 2019-2020 baseline emission level	Average of 2019-2020 baseline emission level	Average of 2019-2020 baseline emission level	Average of 2019-2020 baseline emission level
Use of emission units for intra EEA/EFTA flights	EUAs	EUAs	EUAs for EEA/EFTA airlines, all eligible units under CORSIA for other airlines	All eligible units under CORSIA
Use of emission units for other international flights	All eligible units under CORSIA	All eligible units under CORSIA	EUAs for EEA/EFTA airlines, all eligible units under CORSIA for other airlines	All eligible units under CORSIA

[3]Under extreme growth assumptions or at some point in the future the difference between CNG and emissions might be higher than the cap. But this is not relevant in the period up to 2030 and therefore not further assessed in this paper.

	Scenario 1. Current scope EU ETS + CORSIA with use of EUAs as offsets for intra EEA/EFTA flights	Scenario 2 Domestic aviation EU ETS + CORSIA with use of EUAs as offsets for intra EEA/EFTA flights	Scenario 3 Current scope EU ETS + CORSIA with use of EUAs for EEA/EFTA airlines on all routes	Scenario 4 Current scope EU ETS with strengthened cap + CORSIA
Clarification remarks				
Flights subject to EU ETS and CORSIA	International intra EEA/EFTA flights		International intra EEA/EFTA flights by EEA/EFTA airlines	International intra EEA/EFTA flights
Additional requirements on offsets under CORSIA	Intra EEA/EFTA flights can only use EUAs as offsets.	Intra EEA/EFTA flights can only use EUAs as offsets.	EEA/EFTA airlines can only use EUAs as offsets.	

Source: own presentation

A.2 Basic assumptions

A.2.1 Aviation emissions by flight group

The scenarios distinguish different flight groups that are covered by either the EU ETS or CORSIA or both. The CO_2 emissions in 2016 and 2030 for flight groups which are relevant in relation to the CORSIA and EU ETS co-existence scenarios are presented in Table 2**Fehler! Verweisquelle konnte nicht gefunden werden.**. The results for 2030 are based on the aviation demand growth forecast for the coming decades which was published by ICAO [ICAO, 2016]. This forecast is underlying the AERO-MS computation of aviation emissions for 2030.

Table 2: CO_2 emissions in 2016 and 2030 on flights to and from EU/EFTA countries.

	CO_2 emissions in 2016 (Mt)	CO_2 emissions in 2030 (Mt)	Annual growth rate (CAGR)
1. Domestic flights in EEA/EFTA countries			
1a. Domestic flights included in the EU ETS+	12.8	15.3	1.3%
1b. Domestic flights excluded from EU ETS+*	4.3	5.1	1.3%
Total domestic flights	17.0	20.4	1.3%
2. International flights from and to EEA/EFTA countries			
2a. Intra EU/EFTA flights (included in the EU ETS+)	52.0	64.5	1.5%
2b. Outbound flights departing from EEA/EFTA countries	103.9	139.1	2.1%
2c. Inbound flights arriving at EEA/EFTA countries	103.9	139.1	2.1%
Total international flights	**259.9**	**342.7**	**2.0%**
Grand total	**276.9**	**363.1**	**2.0%**

Notes: "EU ETS+" refers to the EU ETS plus the Swiss ETS which will be linked to the EU ETS. The EU and Switzerland have signed an agreement to link their emission trading schemes in November 2017. The agreement will enter into force on the 1st January of the year after ratification. Figures referring to 2030 include Switzerland.
* These are flights between an EU/EFTA Member State and Outermost Regions or Overseas Territories of a Member State.
Source: AERO-MS

Currently the EU ETS covers all EEA countries (EU Member States as well as Norway, Iceland and Liechtenstein). The Swiss ETS will be linked to the EU ETS in 2030. Therefore, the scope of the EU ETS will be enlarged to cover all intra EFTA flights (flights between and within 32 countries – 28 EU MS as well as Norway, Iceland, Liechtenstein and Switzerland).[4] We refer to the EU ETS including flights to/from Switzerland as EU ETS+.

In relation to domestic flights a distinction is made between domestic flights included in and excluded from the EU ETS+. The excluded domestic flights relate to flights between an EEA/EFTA Member State and Outermost Regions or Overseas Territories of a Member State [EC, 2014]. These are for example flights between Spain and the Canary Islands, between Portugal and the Azores or Madeira and between France and French Guiana, Guadeloupe, Martinique or Réunion.

For international flights a distinction is made between the Intra EEA/EFTA flights which is 2030 will be included in the EU ETS+, and outbound/inbound flights. The outbound and inbound flights relate to flights between an EEA/EFTA country and countries outside the EEA/EFTA. International flights between an EEA/EFTA Member State and the Outermost Regions or Overseas Territories of another EEA/EFTA Member State (for example a flight between Germany and the Canary Islands which is not subject to the EU ETS) are also considered as outbound/inbound flights.

All Intra EEA/EFTA flights are expected to be subject to CORSIA in 2030. This because all EEA/EFTA Member States, which are also a member of ICAO[5], have signed up to CORSIA. CORSIA will not cover all outbound and inbound flights. At present 74 ICAO Member States have agreed to voluntary join CORSIA from the start in 2021 (ICAO, 2018), and it has been assessed that another 7 States have to mandatory join the second phase of CORSIA from 2027 onwards[6]. About 85% of the emissions on the outbound and inbound EU/EFTA flights are related to flights to and from ICAO Member States which are currently expected to have joined CORSIA in 2030. Hence 15% of the emissions on the outbound and inbound EEA/EFTA flights will be on flights to ICAO Member States not participating in CORSIA.

A.2.2 Price assumptions

In the comparison of CORSIA and EU ETS co-existence scenarios, as presented in chapter A.3, the impacts in 2030 are assessed. For this impact assessment price assumptions for both EU ETS allowances and the price of eligible carbon units under CORSIA are required.

The EC has a set of recommended ETS carbon prices for projections covering the period up to 2040 (EC, 2018). These prices are based on a comprehensive analysis performed for the EU Reference Scenario and present the best available knowledge with respect to a plausible trajectory taking account all EU policies adopted by the end of 2017. The order of magnitude for the carbon prices in 2025 to 2040 is similar to the assumptions of the latest IEA World Energy Outlook 2017. The EU ETS allowance price for the year 2030, based on the EU Reference scenario, is € 35 per tonne of CO_2. This price is adopted in the impact assessment presented in this paper.

Over the last years, due to the large supply of international credits, the price of credits has been below 10% of the price of European allowances. However, it is expected that the price of international credits will increase in the post-2020 period. As part of a study for the EC, a price scenario for international credits has been developed, whereby it was assessed that the price of international credits in 2030 could be 50% of the price of European Allowances (Ricardo, 2016). This assumption is also adopted for this paper, which implies the price of international credits will be € 17,5 per tonne of CO_2 in 2030.

[4] It is assumed that United Kingdom will continue to participate in the EU ETS also in the event of leaving the European Union.

[5] With the exception of Liechtenstein all EEA/EFTA Member States are also a member of ICAO.

[6] Brazil, Chile, China, India, Philippines, Russia and South Africa.

A.3 Comparison of the options

A.3.1 Contribution to EU climate target

The EU has not explicitly defined an emission reduction target for aviation in order to contribute to achieving the overall reduction target of -40% relative to 1990 in 2030. But the Nationally Determined Contribution (NDC) and the EU ETS cap give an indication: the aviation emissions on departing flights from the EU are proposed to be capped at 111 Mt of CO_2. This can be regarded as the EU's indicative aviation emissions target for 2030.

The EU ETS regulations have EEA relevance, and therefore all Intra EEA flights are subject to the EU ETS. By 2030 flights between Switzerland and the EEA countries will also be subject to emission trading because the Swiss ETS will be linked to the EU ETS. Based on reported aviation emissions data to the UNFCCC for the years 2004, 2005 and 2006 of Norway, Iceland, Liechtenstein and Switzerland we have adjusted the deduced EU aviation emissions target of 111 Mt to an EEA/EFTA aviation emission target of 115.4 Mt. This implies that the reported aviation emissions on departing flights from the 4 EFTA countries are about 4% of what is reported for EU28. For the analysis in this paper we thus assume that the 4 EFTA countries will apply a similar aviation emissions target as for EU28.

The target relates to the emissions on all departing flights. Table 2 shows that emissions on all departing flights from EEA/EFTA Member States are computed to 224 Mt in 2030 (i.e. summation of emissions in 2030 on domestic flights, Intra EEA/EFTA flights and outbound flights).

Table 3**Fehler! Verweisquelle konnte nicht gefunden werden.** shows the demand for EU allowances (both EUAAs and EUAs) and international credits for the various co-existence scenarios in 2030 on the flights to and from EEA/EFTA countries. For scenario 1 the number of EUAAs reflects the cap in 2030 taking into account the LRF of 2.2% over the years 2021-2030. The EUAs in scenario 1 are to be surrendered partly under CORSIA (Intra EEA/EFTA emissions above the 2019-2020 baseline) and partly under the EU ETS (emissions above the EU ETS cap not covered by CORSIA). The international credits to be surrendered relate to both outbound and inbound flights considering that not all of these flights will be subject to CORSIA in 2030.[7]

Table 3: Demand for EU Allowances and international credits for co-existence scenarios in 2030 on flights to and from EEA/EFTA countries (in Mt).

	EUAAs	EUAs (EU ETS+)	EUAs (CORSIA)	International credits
Scenario 1 (reference): Current scope EU ETS + CORSIA with use of EUAs as offsets for intra EEA/EFTA flights	30.8	31.7	17.3	67.0
Scenario 2: Domestic aviation EU ETS + CORSIA with use of EUAs as offsets for intra EEA/EFTA flights	11.6	3.7	17.3	67.0
Scenario 3: Current scope EU ETS + CORSIA with use of EUAs for EEA/EFTA airlines on all routes	30.8	31.7	50.5	33.8

[7] CORSIA establishes the amount of emissions to be offset (ICAO Assembly Resolution A39-3, paragraph 11, which specifies detailed rules on 'the amount of CO2 emissions required to be offset by an aircraft operator in a given year').

	EUAAs	EUAs (EU ETS+)	EUAs (CORSIA)	International credits
Scenario 4: Current scope EU ETS with strengthened cap + CORSIA	13.5	49.0	0.0	84.2

Note: Differences are due to rounding.

Source: AERO-MS

For scenario 2 the number of both EUAAs and EUAs to be surrendered under the EU ETS will be reduced in line with the reduction of the EU ETS scope to domestic flights only. Based on reported domestic emissions for 2004-2006 and taking into account the LRF of 2.2% it is estimated the adjusted cap will be 11.6 Mt for scenario 2. The demand for EUAs under the EU ETS will be reduced to 3.7 Mt in scenario 2. The demand for EUAs and international credits under CORSIA for scenario 2 is the same as for scenario 1.

For scenario 3 the demand for EUAs under CORSIA will be higher relative to the other scenarios. For the computation of the demand of EUAs under CORSIA we have assumed for 2030 that 98% of emissions on Intra EEA/EFTA flights and 50% of the emissions on inbound/outbound flights are related to airlines from EEA/EFTA countries. This implies that in scenario 3 EEA/EFTA airlines have to surrender EUAs for 50.5 Mt of CO_2 under CORSIA.

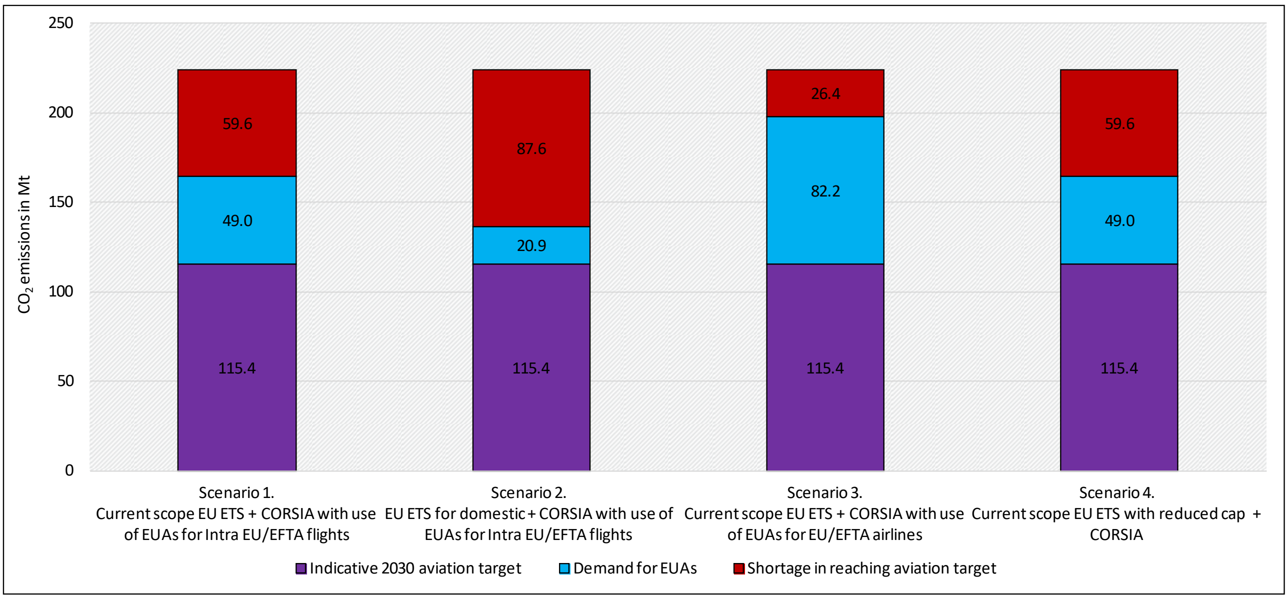
In scenario 4 there are no additional requirements under CORSIA and all emissions above the 2019-2020 CORSIA baseline are covered by international credits. The EU ETS cap in scenario 4 is reduced by the emissions on intra EEA/EFTA flights above the CORSIA baseline, implying a cap of 13.5 Mt compared to the cap of 30.8 Mt in scenario 1. This results in an increase in the number of EUAs to be surrendered under the EU ETS (49.0 Mt – see Table 3).

Figure 4 shows the extent by which the 2030 aviation emissions target is met for the 4 scenarios. For all 4 scenarios the figure divides the total of 224 Mt of CO_2 emissions in 2030 on EU/EFTA departing flights into the emissions under the target (115.4 Mt), the emissions reduction brought about by the demand for EUAs and the emissions above the target which are not covered by EUAs. The latter reflects the shortage in reaching the aviation emission target. International credits will not contribute to reaching the EU target and are therefore not considered in Figure 4.

Figure 4 shows that all 4 scenarios will not reach the aviation emission target in 2030. In scenario 2, where only domestic flights remain to be included in the EU ETS, the shortage in reaching the emission target is largest (87.6 Mt). Scenario 3, where EUAs have to be surrendered under CORSIA by EU/EFTA airlines on all routes, shows the smallest shortage in reaching the target. In this scenario it is assumed that all EUAs surrendered under CORSIA, also the EUAs on EU/EFTA inbound flights, will be counted as a contribution to the aviation emissions target which is related to departing flights.

The extent by which the target is reached is the same for scenarios 1 and 4. The difference however is that in scenario 4 all EUAs are surrendered under the EU ETS, whereas in scenario 1 part of EUAs is surrendered under CORSIA (see Figure 1).

Figure 4: Contribution of co-existence scenarios to reaching the aviation emissions target in 2030.



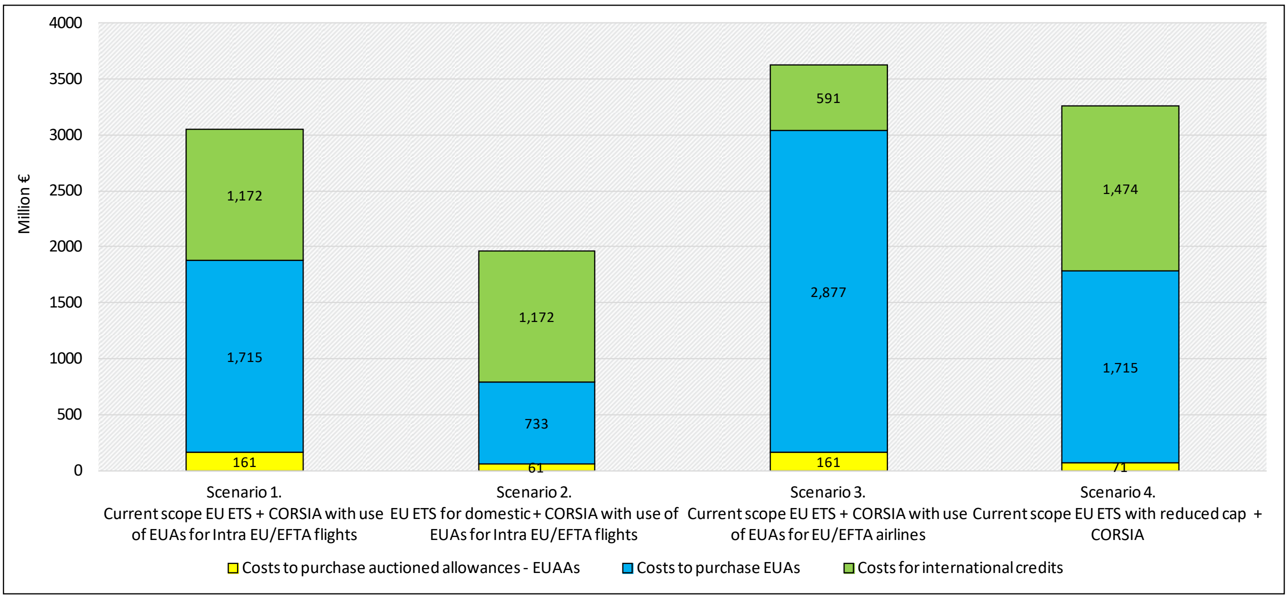
Source: AERO-MS

A.3.2 Costs and distortion of competition

For all 4 scenarios costs in 2030 for airlines to purchase EUAAs, EUAs and international credits for flights to and from EEA/EFTA countries are assessed. The costs are simply computed by multiplying the demand for EU allowances and international credits with the assumed prices in 2030 (see section A.2.2). For the computation of the costs to purchase EUAAs it is assumed that, as in the current situation, 15% of EUAAs are auctioned and the remainder are allocated free of charge.

The total purchase costs for scenario 1 are around € 3 billion in 2030. For scenario 2 the costs are significantly less because the obligation to surrender allowances under the EU ETS is reduced to intra-EU flights. Under scenario 3, relative to scenario 1, under CORSIA a larger number of EUAs need to be surrendered. Because of the assumed lower price for international credits relative to the price of EUAs, a larger number of EUAs to be surrendered implies higher costs. The total costs to purchase EUA in case of scenario 3 are computed to around € 3.6 billion in 2030. This is estimated to be around 1% of total operating costs for all flights to and from EEA/EFTA countries in 2030.

Figure 5: Costs for airlines to purchase EUAAs, EUAs and international credits for co-existence scenarios in 2030 on flights to and from EU/EFTA countries (in M€).



Source: Own calculation

We have also looked at the potential for distortion of competition in case of the various co-existence scenarios. Only in scenario 3 there are differences in the cost impact for airlines competing on routes to and from EEA/EFTA countries. In all other scenarios the obligations, related to either the EU ETS or CORSIA, on any route is the same for all airlines.

In scenario 3 there is a difference in the cost impact between airlines from EEA/EFTA countries and airlines from other countries because the EEA/EFTA airlines have to surrender EUAs under CORSIA which are expected to be more expensive compared to international credits. For the market of intra EEA/EFTA flights this is not expected to cause serious competitive distortions. This because the intra EEA/EFTA market is largely regulated by EU air services regulations and is thereby very much dominated by EEA/EFTA airlines (market share about 98%). This is different for the market of outbound and inbound flights. On these markets the EEA/EFTA airlines compete with airlines from other countries. For the outbound and inbound flights which will be subject to CORSIA, the cost increase for EEA/EFTA airlines in scenario 3 is estimated 1.4% of total operating costs on these flights. For airlines from other countries the cost increase is estimated to 0.7% on the same flights. The ratio between the cost increases follow from the assumption that the price for international credits (to be surrendered by airlines from outside the EEA/EFTA) will be 50% of the price for EUAs (to be surrendered by EEA/EFTA airlines). Clearly the assumption on the ratio between the price of international credits versus EUAs is very critical for the potential for competitive distortion in case of scenario 3.

A.3.3 Auctioning revenues

The auctioning revenues for the EU/EFTA Member States are the same as the costs for to purchase the auctioned allowances for airlines. Figure 5 shows that the auctioning revenues related to EUAAs in 2030 will vary between € 161 million for scenarios 1 and 3 and € 61 million in scenario 2. In scenario 4 the EU ETS cap is reduced and thus the total amount of allowances to be auctioned; revenues are estimated to be € 71 million.

A.3.4 Administrative implications

All scenarios analyzed have in common that firstly emissions have to be monitored on all domestic and international flights to countries participating in CORSIA and secondly, the current EU ETS system remains in place and is complemented by CORSIA. The scenarios differ in relation to the flights covered by the EU ETS and CORSIA.

Administrative costs for the implementation of any policy can be divided into one-off costs mainly occurring when new regulations are introduced and on-going costs that occur yearly. One-off costs for operators and governments include the initial preparation (interpreting legislation, training employees), the set-up of a compliance system, the elaboration of a monitoring plan for operators and checking/approving them for the regulator and the provision and of data by the operators e.g. for free allocation or defining the firm specific CNG level and the corresponding routines and decision from the regulator (Ricardo, 2016).

One-off costs for the continuation of the EU ETS are limited. The system is established and routines in place. In all options additionally CORSIA is introduced. This will require a one-off cost both for operators and regulators. The technical details of CORSIA are not fully defined yet. It is assumed that systems will be integrated: emissions will be monitored and verified for all flights and reported according to flight groups which fall under one or the other regulation. Compliance requirements will then differ according to the flight groups. It is assumed that there is a relevant one-off cost for the introduction of CORSIA which is identical for all scenarios.

On-going costs depend both on the number of flights to be monitored and the requirements related to monitoring, reporting, verification as well as compliance (the effort of purchasing allowances) for the operator and the effort to check emission reports, verification statements and compliance information, enforce compliance, ensure that the registry is correct and providing guidance to operators and verifiers e.g. through trainings or a help desk.

In all scenarios assessed all flights are covered which is beyond the current scope of the ETS and will require additional resources. If the requirements for monitoring, reporting and verification are aligned between CORSIA and EU ETS the administrative effort will be the same in all scenarios.

A.3.5 Summary and conclusion

The four scenarios for co-existence assessed have in common that they all ensure that the EU fulfills its international commitment to participate in CORSIA and that they can be implemented without requiring cooperation by third countries not participating in the EU ETS. In all scenarios aviation contributes to reaching the EU climate target but in none of them the indicative aviation target is reached. Scenarios differ according to the contribution the European aviation sector is making to reduce emissions in Europe and in third countries. Only in one scenario there are concerns in regard to distortion of competition. Furthermore, the administrative costs are comparable for all scenarios (see Table 4).

In the reference scenario airlines would contribute to the EU climate target by buying certificates from the EU ETS and thus financing domestic emission reductions in the countries participating in the EU ETS. Aviation emissions are projected to be in 2030 nearly twice as high as the aviation emission target, in the reference scenario 49 Million t CO_2 emission reduction would stem from the EU ETS which can fill 42% of the gap between emissions and the target. Additionally, 67 Mt CO_2 are covered by offsets which will are likely to stem from 3rd countries and thus trigger emission reductions abroad. Member States would generate revenues of about 161 Million Euros from auctioning EU aviation allowances (EUAAs). Total cost to airline operators for all flights within Europe and to third countries participating in CORSIA are estimated to amount to 3 billion Euro, which corresponds to less than 1% of total operating costs.

The contribution to EU climate targets is lowest if only domestic flights remain covered by the EU ETS (scenario 2). Total emission reductions (in EEA/EFTA countries and in 3rd countries) are also lowest in this scenario, because the CORSIA baseline is less ambitious than the EU ETS aviation cap. Costs for airlines are reduced and also auctioning revenues for Member States. In conclusion this scenario is the weakest from the environmental point of view.

The largest contribution to the EU climate target can be reached when all EEA/EFTA operators are required to surrender EUAs as offsets also for flights to third countries. The contribution to reduction in third countries is reduced as more EUAs are used than international credits. Total emission reductions are the same as in the reference scenario and also auctioning revenues are unchanged. The total cost to airlines is higher, as EUAs are expected to have a higher price than international credits. As opposed to the other scenarios in this case EEA/EFTA operators face different compliance requirements on the routes to and from third countries than operators registered in third countries which may cause a distortion of competition. If international credits are less expensive than EUAs, operators from third countries will face lower costs (in our assessment the price difference amounts to about 0,7% of total operating costs).

Overall emission reductions are highest in the scenario with a strengthened cap: the contribution of the aviation sector to the EU climate target corresponds to the reference scenario, but the contribution to international mitigation effort is higher. A lower cap for the aviation sector leads to a lower auctioning volume and thus lower revenues for Member States unless the auctioning share is increased. The compliance cost for operators is higher than in the reference scenario but lower than for the scenario 3 where EEA/EFTA operators have to surrender EUAs on all routes.

Table 4: Comparison of the options

	Contribution to EU climate target	Contribution to GHG reduction in 3rd countries	Auctioning revenues (EUAAs)	Costs for airlines	Distortion of compe-tition	Adminis-trative effort
Scenario 1 (reference): Current scope EU ETS + CORSIA with use of EUAs as offsets for intra EEA/EFTA flights	49 Mt CO_2	67 Mt CO_2	161 Million Euro	3 Billion Euro	No	Same for all scenarios
Scenario 2: Domestic aviation EU ETS + CORSIA with use of EUAs as offsets for intra EEA/EFTA flights	21 Mt CO_2	67 Mt CO_2	61 Million Euro	2 Billion Euro	No	Same for all scenarios
Scenario 3: Current scope EU ETS + CORSIA with use of EUAs for EEA/EFTA airlines on all routes	82 Mt CO_2	34 Mt CO_2	161 Million Euro	3,6 Billion Euro	Yes (extra EEA/EFTA internat. flights)	Same for all scenarios
Scenario 4: Current scope EU ETS with strengthened cap + CORSIA	49 Mt CO_2	84 Mt CO_2	71 Million Euro	3,3 Billion Euro	No	Same for all scenarios

Notes: Contribution to EU climate target corresponds to the amount of certificates from the stationary ETS bought by airline operators. Contribution to GHG reduction in 3rd countries refers to the amount of offsets not stemming from the EU ETS.

Source: own compilation/calculation

The assessment of the scenarios shows that there are options how to implement CORSIA while ensuring that the aviation sector contributes to domestic emission reductions that do not require cooperation from third countries. The contribution to both domestic and international mitigation depends on how the EU ETS and CORSIA are combined. Further options to strengthen the contribution of the aviation sector include a higher auctioning share; the proceeds can then in turn be used to incentivize the development of emission reduction technologies for the aviation sector. The assumed cost to operators is highly sensitive to the price assumptions taken and does not depend on the aviation sector alone but also how the stationary ETS is developed further and how international carbon markets evolve.

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B Role of non-EEA aircraft operators in EU ETS and implications of exempting operators applying a threshold of 10,000 t CO2 based on Intra EEA scope

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Role of non-EEA aircraft operators in EU ETS and implications of exempting operators applying a threshold of 10,000 t CO_2 based on Intra EEA scope

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Report Cover Sheet

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Abstract

This paper is involved with the role of non-EEA aircraft operators in the EU ETS and the implications of exempting aircraft operators from the EU ETS applying a threshold of 10,000 t CO_2 based on the Intra EEA scope.

Presently about half of the number of aircraft operators with verified emissions is from outside the EEA, but these non-EEA aircraft operators take account of only 2% of the total verified emissions on Intra EEA flights. The share of non-EEA operators in the number of Intra EEA flight operations is also limited.

Since 2013 aircraft operators only have to surrender allowances for emissions on Intra EEA flights. The exemption for the obligations under the EU ETS however is based on a threshold of 10,000 tonnes CO_2 which is related to the original scope EU ETS for aviation (all arriving and departing flights). We have looked at the implications of a revised threshold of 10,000 tonnes CO_2 which is based on the Intra EEA scope. The conclusion is that the revised threshold would significantly reduce the number of operators (minus 70%) which are subject to the EU ETS obligations, but that the emissions coverage is only very limitedly reduced (only by about 0.5%). For non-EEA aircraft operators, the reduction of the number of operators would be larger (minus 90%), compared to the reduction for EEA aircraft operators (minus 50%).

Kurzbeschreibung

Dieses Papier befasst sich mit der Rolle von Nicht-EWR-Luftfahrzeugbetreibern im EU-ETS und den Auswirkungen der Freistellung von Luftfahrzeugbetreibern aus dem EU-ETS unterhalb eines Grenzwertes von 10.000 t CO_2 auf der Grundlage des EWR-Erfassungsbereichs.

Zurzeit stammen etwa die Hälfte der Luftfahrzeugbetreiber mit verifizierten Emissionen aus Ländern außerhalb des EWR, doch auf diese Nicht-EWR-Luftfahrzeugbetreiber entfallen nur 2% der gesamten überprüften Emissionen auf EWR-internen Flügen. Der Anteil der Nicht-EWR-Betreiber an der Gesamtzahl der Flüge innerhalb des EWR ist ebenfalls begrenzt.

Seit 2013 müssen Luftfahrzeugbetreiber nur Emissionszertifikate für EWR-interne Flüge abgeben. Die Ausnahme für die Verpflichtungen im Rahmen des EU-ETS basiert jedoch auf einem Schwellenwert von 10.000 Tonnen CO_2, bezogen auf den ursprünglichen Geltungsbereich des EU-ETS für den Luftverkehr (alle ankommenden und abfliegenden Flüge). Wir haben die Auswirkungen eines revidierten Schwellenwerts von 10.000 Tonnen CO_2 untersucht, der auf dem EWR-internen Geltungsbereich basiert. Die Schlussfolgerung ist, dass der revidierte Schwellenwert die Anzahl der Betreiber, die den EU-ETS-Verpflichtungen unterliegen, erheblich reduzieren würde (minus 70%), aber erfassten Emissionsabdeckung nur sehr eingeschränkt reduziert würden (nur um ca. 0,5%). Bei den Nicht-EWR-Luftfahrtunternehmen wäre die Verringerung der erfassten Betreiber größer (minus 90%) als bei den EWR-Luftfahrzeugbetreiber (minus 50%).

List of Abbreviations

AOHA	Aviation Operator Holding Account
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
EEA	European Economic Area
EU ETS	European Union Emissions Trading System
EUTL	European Union Transaction Log
MRV	Monitoring, Reporting, Verification

B.1 Introduction

A challenge for the co-**existence** of the EU ETS and CORSIA on intra-EEA routes is the treatment of aircraft operators for which the State of origin is outside the EEA (further referred to as "non-EEA aircraft operators"). It is therefore of high interest to gain a better understanding on the importance of non-EU carriers in relation to their share in emissions.

Furthermore, we have looked at the threshold defining when aircraft operators are exempted from the obligations under the EU ETS. Presently commercial aircraft operators which emit less than 10,000 tonnes CO_2 per year are exempted from the MRV and surrendering obligations under the EU ETS. Hereby the threshold of 10,000 tonnes CO_2 is based on the (original) full scope of the EU ETS for aviation (all arriving and departing flights). For non-commercial aircraft operators the threshold is lower (1,000 tonnes CO_2), and also based on the full EU ETS scope.

Hence, presently if in any year a commercial aircraft operator emits less than 10,000 tonnes of CO_2 on Intra EEA flights (current scope) but emits more than 10,000 tonnes of CO_2 per year on the full scope of EU ETS flights, it has to surrender allowances for its Intra EEA flights. This situation is especially likely to occur for non-EEA aircraft operators, which operate between their home Sate and an EEA State, but generally limitedly operate on Intra EEA flights.

We have defined a revised threshold whereby both commercial and non-commercial aircraft operators are exempted when they emit less than 10,000 tonnes of CO_2 on Intra EEA flights. Hence the threshold would no longer be based on the emissions on the original scope, but on the Intra EEA scope.

We have looked at the following impacts of the alternative threshold:

1. The number of aircraft operators which will additionally be exempted;
2. The extent by which the aviation CO_2 emissions covered by the EU ETS will be reduced;
3. The States of origin of the aircraft operators which will be additionally exempted, mainly focusing on the distinction between EEA and non-EEA aircraft operators.

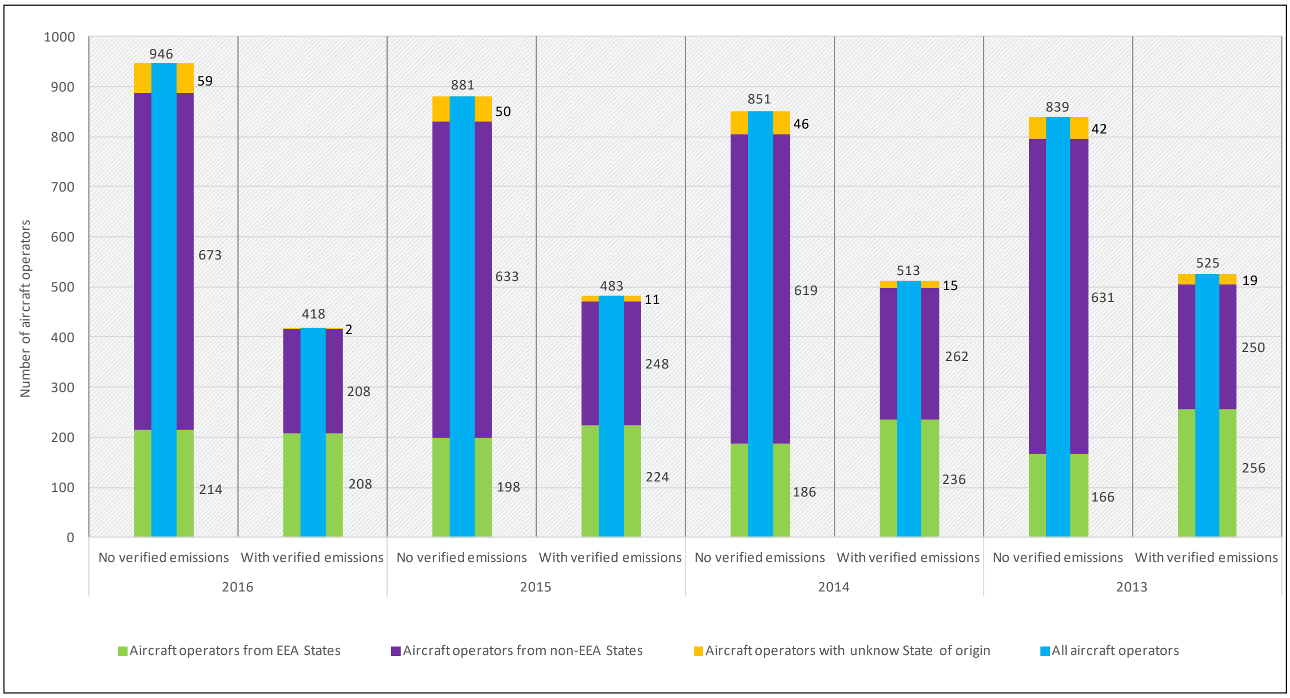
For the analysis we have used emission data from the EU Transaction Log (EUTL). The EUTL contains data from aircraft operators which have an Aviation Operator Holding Account (AOHA). An AOHA is required in order to participate in the EU ETS. The AOHA data do not contain data on the States of origin of aircraft operator. Therefore, for the analysis we have joint the official EC list of aircraft operators[8] with the EUTL data.

B.2 Role of non-EEA aircraft operators on Intra EEA flights

The EUTL contains data for 1,364 aircraft operators. Figure 6 presents the number of aircraft operators with and without verified emissions for the Intra EEA scope. The majority of aircraft operators included in the EUTL have not reported emissions for the Intra EEA scope. For 2016, 946 aircraft operators have not reported emissions for the Intra EEA scope, which is about 70% of the total number of aircraft operators included in the EUTL. A large part of the aircraft operators with no verified emissions for the Intra EEA scope are from outside the EEA (in 2016: 673 out of the total of 946).

[8] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017R0294&from=EN.

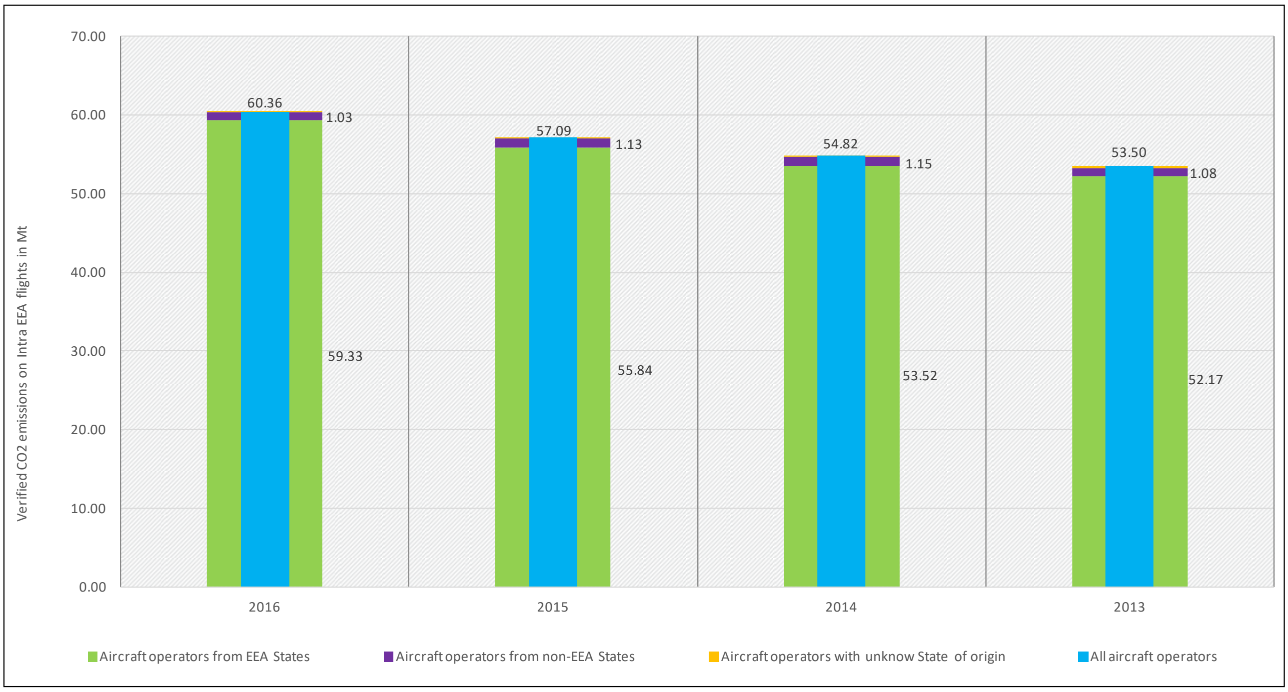
Figure 6: Number of aircraft operators in EUTL with and without verified emissions in 2013-2016



Source: AERO-MS

The number of aircraft operators with verified emissions for the Intra EEA scope range from 525 in 2013 to 418 in 2016 (see also Figure 6). The figure also shows that in all years about half of the aircraft operators with Intra EEA scope related emissions are from outside the EEA. A limited number of aircraft operators which are included in the EUTL are not included in the official EC list of aircraft operators. For these aircraft operators the State of origin is unknown.

Figure 7: EU ETS verified CO_2 emissions reported by aircraft operators in 2013-2016 in Mt (Intra EEA scope)



Source: AERO-MS

The verified CO_2 emissions of aircraft operators for the years 2013-2016 are presented in Figure 7. For all these years the verified emissions are based on the Intra EEA scope. The figure show that total verified emissions go up from 53.50 Mt in 2013 to 60.36 Mt in 2016. For all 4 years about 1 Mt of the verified emissions are related to flight operations of airlines from outside the EEA, which equals about 2% of the total verified emissions. Hence the vast amount of emissions on Intra EEA flights is from EEA aircraft operators.

The share in emissions of non-EEA aircraft operators provides a reasonable indication for the share in the number of flights operations of non-EEA aircraft operators. Hence the share in the number of flight operations of non-EEA operators will also be about 2%, or at least it can be safely assumed it will be between 1% and 3%.

The main conclusion is that about half of the number of aircraft operators with verified emissions is from outside the EEA, but that these non-EEA aircraft operators take account of only 2% of the total verified emissions on Intra EEA flights. The share of non-EEA operators in the number of Intra EEA flight operations is also limited.

B.3 Implications of applying a threshold of 10,000 t CO2 to Intra EEA scope

We have looked at the implications of a revised threshold whereby an aircraft operator is exempted from the EU ETS obligations when it emits less than 10,000 t CO_2 on Intra EEA flights. Hereby it is noted that based on an average Intra EEA flight distance of 1,000 km, the average emissions of a flight is about 10 t CO_2. This would mean that the revision of the revised threshold would roughly mean that an aircraft operator with less than 1,000 Intra EEA flights per year would be exempted.

For the years 2013-2016, the EUTL data contains the verified emissions related to the Intra EEA scope broken down by aircraft operator. An analysis can thus be made of how many aircraft operators would have been exempted if the revised threshold would have been applied in these years. The results of the analysis for the years 2013-2016 gives a very good indication of what the implications of a revised threshold are if it would be implemented in the future years.

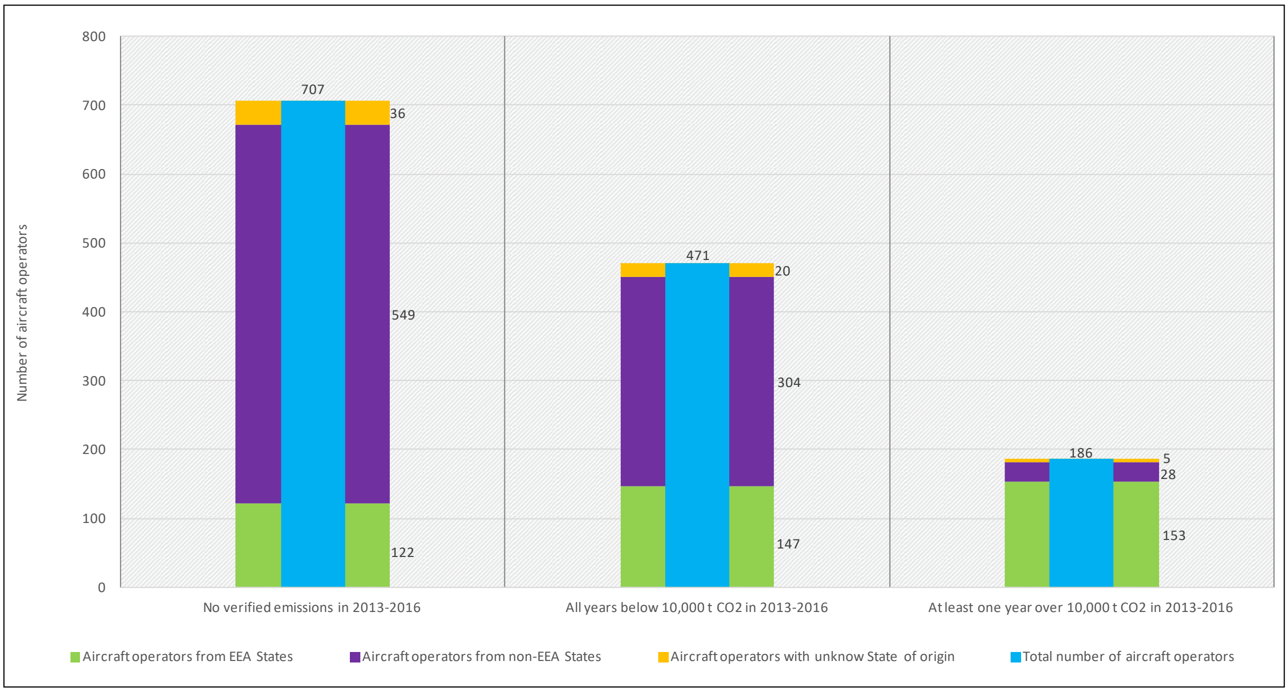
In a first step we have split the 1,364 aircraft operators in the EUTL data in 3 groups:

1. Aircraft operators which have not reported any emissions for the Intra EU scope in any of the years for which historic data are available (2013-2016);
2. Aircraft operators which have reported emissions for the Intra EU scope and where emissions are below the threshold of 10,000 t CO_2 in all years in the period 2013-2016;
3. Aircraft operators which have reported emissions above 10,000 t CO_2 at least once for the years 2013-2016.

Figure 8 shows that 707 aircraft operators have not reported any emissions for the Intra EEA scope in the years 2013-2016. These are mainly operators which are already exempted given the current threshold of 10,000 t CO_2 related to the full scope EU ETS. This has been verified based on the EUTL data for 2012 when the full scope EU ETS was applied. There are also a limited number of operators which have reported above 10,000 t CO_2 for 2012 (full scope) but have not reported any emissions for intra EEA scope. These operators are not exempted based on the present threshold but de facto have no surrendering obligations under the present EU ETS as they do not operate on Intra EEA flights.

The second group is the group which presently reports emissions for Intra EEA scope but will additionally be exempted if the threshold of 10,000 t CO_2 is based on Intra EEA scope. Figure 8 shows that there are 471 in this group. The number of aircraft operators which have reported emissions above 10,000 t CO_2 for the Intra EEA scope (third group) is 186. Hence over 70% of the aircraft operators that have reported emissions in the 2013-2016 would be additionally exempted with the revised threshold. The situation is quite different for EEA and non-EEA operators. For EEA aircraft operators about 50% of the aircraft operators that have reported emissions in the 2013-2016 would be additionally exempted with the revised threshold (147 out of a total of 300 – see Figure 8). For aircraft operators from outside the EEA only 28 aircraft operators have reported emissions above 10,000 t CO_2 for the Intra EEA scope, whereas 304 operators have reported emissions below 10,000 t CO_2 in all years in 2013-2016. This implies that over 90% of the non-EEA aircraft operators that have reported emissions in the 2013-2016 would be additionally exempted and that the involvement of non-EEA aircraft operators in the EU ETS will be very significantly reduced with the revised threshold.

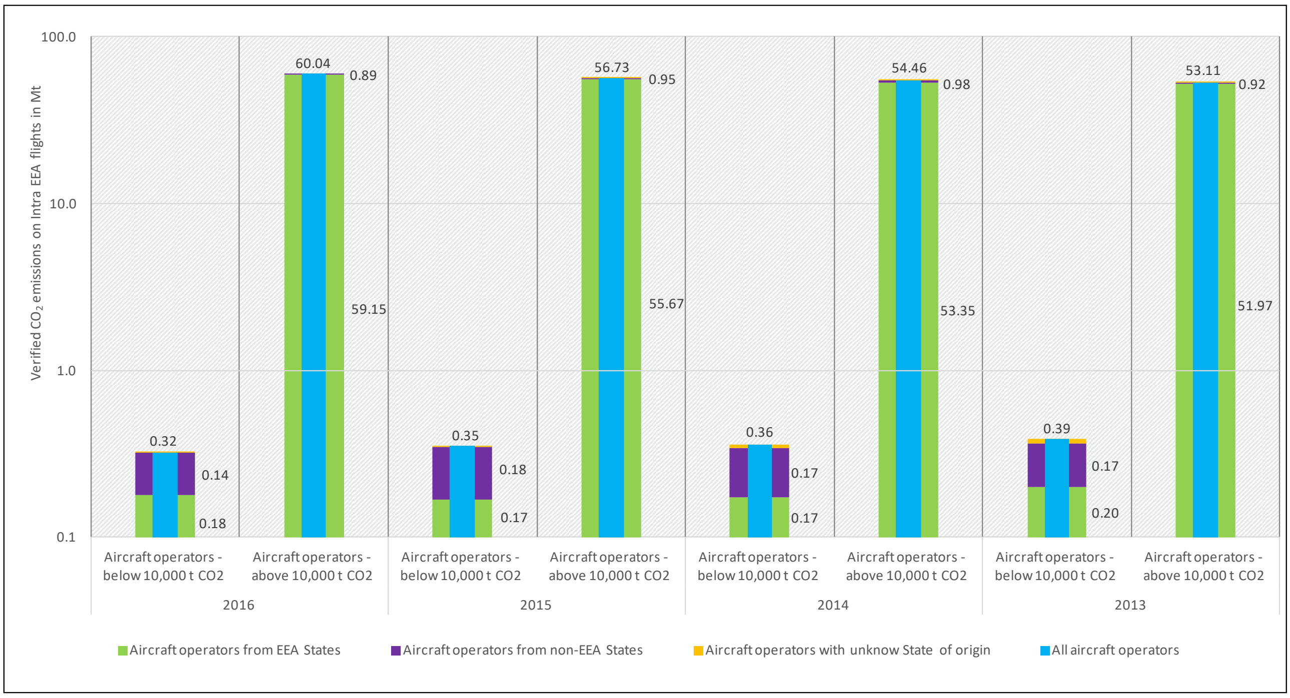
Figure 8: Number of aircraft operators split by the magnitude of EU ETS verified emissions (Intra EEA scope)



Source: AERO-MS

We have made an overview of the 28 non-EEA aircraft operators with above 10,000 tonnes of CO_2 on Intra EEA scope in at least one of the years 2013-2016, including the State of the operators and the verified Intra EEA emissions in 2013-2016. This overview is provided in Figure 10. Note that 7 out of these 28 operators have not reported any emissions for the year 2016. Another 3 operators have reported less than 10,000 tonnes of CO_2 for 2016. So likely the number of non-EEA aircraft operators which would still be subject to the EU ETS with the revised threshold will be less than 28. Figure 8 also includes information on the 5 operators with above 10,000 tonnes of CO_2 on Intra EEA, which are not included in the official EU list of operators (in figure 8 included in the category "unknown"). On the internet we have checked the details on these operators and found out that these 5 are all from EEA Member States. During the period 2013-2016, the 5 operators have ceased operations because of financial problems or because they are merged into a new company. In any case they are not to be added to the list of non-EEA operators which would still be subject to the EU ETS in case of a revised threshold.

Figure 9: EU ETS verified CO_2 emissions in 2013-2016 for aircraft operators below and above threshold of 10,000 t CO_2 based on Intra EEA scope (logarithmic scale)



Source: AERO-MS

In a next step we have looked at the extent by which the aviation CO_2 emissions covered by the EU ETS will be reduced because of the revised threshold. For the years 2013-2016 the verified emissions are split into the emissions for the aircraft operators which will be additionally exempted (group 2) and the aircraft operators which in 2013-2016 have at least once reported emissions above 10,000 t CO2 (group 3). The results are presented in Figure 9. The figure shows that with the revised threshold the emission coverage would be very limitedly reduced. The emissions related to the additionally exempted aircraft operators vary between 0.39 Mt in 2013 and 0.32 Mt in 2016, which equals respectively 0.5% and 0.7% of total verified emissions.

The overall conclusion is that the revised threshold would significantly reduce the number of operators (minus 70%) which are subject to the EU ETS obligations, but that the emissions coverage is only very limitedly reduced (only by about 0.5%).

Figure 10: Annex A

Nr	Admini-strative EU MS	Name	Home State of the operator	Installation Identified	Verified emissions in 2016 (tonnes)	Verified emissions in 2015 (tonnes)	Verified emissions in 2014 (tonnes)	Verified emissions in 2013 (tonnes)	Maximum emissions in 2013-2016 (tonnes)
Aircraft operators included in official EU list									
1	ES	Latam Airlines Group, S.A.	CHILE	201750	25344	22713	22614	19429	25344
2	DE	Air China Limited	CHINA	203540	20690	20712	16701	7851	20712
3	GB	Cathay Pacific Airways Limited	CHINA	201533	11183	12945	14827	17905	17905
4	NL	China Southern Airlines	CHINA	207018	8409	10724	8462	5246	10724
5	IT	ETHIOPIAN AIRLINES	ETHIOPIA	203475	37715	34705	25712	17323	37715
6	DE	Iran Air	IRAN, ISLAMIC REPUBLIC OF	203338	5351	15856	13343	12550	15856
7	BE	04369.CAL CARGO AIRLINES	ISRAEL	202757	12383	11993	9897	11259	12383
8	NL	Nippon Cargo Airlines	JAPAN	200169	12458	10809	10386	9580	12458
9	DE	EU-ETS trading account for KOREANAIR	KOREA, REPUBLIC OF	200400	24095	25598	31069	30803	31069
10	DE	Asiana Airlines	KOREA, REPUBLIC OF	200474	15667	14065	18897	21038	21038
11	GB	Kuwait Airways Corporation	KUWAIT	201537	10215	12560	13965	12293	13965
12	GB	Qatar Airways	QATAR	200060	22345	18725	17743	13416	22345
13	DE	VDA_Operator	RUSSIAN FEDERATION	201758	14161	10925	12407	11965	14161
14	DE	Air Bridge Cargo	RUSSIAN FEDERATION	201840	25815	26693	9127	3533	26693
15	BE	02344.SAUDI ARABIAN AIRLINES	SAUDI ARABIA	207689	0	400	7103	14309	14309
16	GB	Singapore Airlines Limited	SINGAPORE	201347	31520	34372	34688	35166	35166
17	DE	Farnair Switzerland	SWITZERLAND	202702	0	14729	15251	16718	16718
18	FR	EASYJET SWITZERLAND	SWITZERLAND	200835	210786	214144	204621	171783	214144
19	GB	SWISS INTERNATIONAL AIR LINES LTD	SWITZERLAND	200642	349	13623	37475	39156	39156
20	GB	Darwin Airline Account	SWITZERLAND	201217	0	5352	25041	26515	26515
21	DE	Turkish Airlines Inc.	TURKEY	200312	0	7866	11417	4476	11417
22	DE	STATE ENTERPRISE "ANTONOV"	UKRAINE	201689	0	0	10715	8678	10715
23	GB	Emirates	UNITED ARAB EMIRATES	201598	40414	41141	34291	37082	41141
24	BE	07649.ABX Air Inc	UNITED STATES	203385	0	11550	16577	16039	16577
25	DE	Atlas Air, Inc.	UNITED STATES	202691	18723	20582	17443	13193	20582
26	DE	Omni Air International, Inc.	UNITED STATES	201607	0	4122	12669	3243	12669
27	DE	United Parcel Service Co	UNITED STATES	200334	163132	151345	147133	150058	163132
28	FR	FEDERAL EXPRESS CORPORATION	UNITED STATES	200322	179547	177450	180430	186409	186409
Aircraft operators not included in official EU list									
1	EE	Estonian Air as	ESTONIA	200417	0	61092	63413	62181	63413
2	FR	AIR MEDITERRANEE	FRANCE	200698	0	53423	49626	58996	58996
3	FR	HOP - REGIONAL	FRANCE	200472	0	0	0	63252	63252
4	FR	HOP - BRITAIR	FRANCE	200121	0	0	0	38788	38788
5	LT	UAB Air Lituanica	LITHUANIA	207033	0	0	25849	0	25849

Source: European Union (2019)

C Emission factors for alternative fuels under CORSIA and under the EU ETS

Environmental Research of the
Federal Ministry for the
Environment, Nature Conservation
and Nuclear Safety

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Emission factors for alternative fuels under CORSIA and the EU ETS

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Abstract

The aim of this document is to compare emission factors for alternative aviation fuels used under the European Emissions Trading System (EU ETS) and the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). The main result is that absolute amounts of emissions from alternative fuels which will be reported under both systems cannot be compared. One obvious reason is that both schemes address different geographical scopes and participants. Although under both schemes the use of alternative aviation fuels reduces the need to buy certificates (EU ETS) or offsets (CORSIA), the quantification of these amounts follows very different rules. To calculate emission reductions from eligible alternative aviation fuels for compliance under CORSIA, life cycle emissions of alternative fuels are compared against benchmark life cycle emissions. This means that fossil fuels can reduce the need to buy offsets, too, as long as they meet the criteria of achieving a reduction of at least 10% compared to baseline life cycle emissions. In contrast, under the EU ETS, biofuels are accounted with zero emissions if they comply with greenhouse gas reductions and sustainability criteria from the European Renewable Energy Directive. Many details on eligible alternative fuels under CORSIA are not available at the time of writing (September 2019). The calculation of life cycle emissions and the definition of eligibility criteria related to the carbon stock are especially relevant for the future use of biofuels under CORSIA.

Kurzbeschreibung

Ziel dieses Dokuments ist es, Emissionsfaktoren für alternative Flugkraftstoffe zu vergleichen, die im Rahmen des Europäischen Emissionshandelssystems (EU ETS) und des Klimaschutzsystems für die internationale Luftfahrt (CORSIA) verwendet werden. Das Hauptergebnis ist, dass die absoluten Emissionsmengen von alternativen Kraftstoffen, die unter beiden Systemen ausgewiesen werden, nicht vergleichbar sind. Ein offensichtlicher Grund dafür ist, dass beide Systeme unterschiedliche geografische Bereiche und Teilnehmer abdecken. Obwohl bei beiden Systemen die Verwendung alternativer Flugtreibstoffe den Kauf von Zertifikaten (EU ETS) oder Ausgleichszertifikaten (CORSIA) reduziert, folgt die Quantifizierung dieser Mengen sehr unterschiedlichen Regeln. Um Emissionsreduktionen aus geeigneten alternativen Flugkraftstoffen zur Einhaltung von CORSIA zu berechnen, werden die Lebenszyklusemissionen alternativer Kraftstoffe mit den Benchmark-Lebenszyklusemissionen verglichen. Das bedeutet, dass fossile Brennstoffe auch den Kauf von Ausgleichszahlungen reduzieren können, solange sie die Kriterien erfüllen, eine Reduzierung um mindestens 10 % gegenüber den Emissionen des Basislebenszyklus zu erreichen. Im Gegensatz dazu werden Biokraftstoffe im Rahmen des EU-EHS emissionsfrei bilanziert, wenn sie den Treibhausgasreduktionen und Nachhaltigkeitskriterien der europäischen Richtlinie über erneuerbare Energien entsprechen. Es liegen viele Details zu den im Rahmen von CORSIA förderfähigen alternativen Kraftstoffen zum Zeitpunkt der Berichterstellung (September 2019) noch nicht vor. Die Berechnung der Lebenszyklusemissionen und die Definition von Förderkriterien für den Kohlenstoffvorrat sind besonders relevant für die zukünftige Verwendung von Biokraftstoffen im Rahmen von CORSIA.

List of Abbreviations

ASTM	American Society for Testing and Materials International
CAEP	(ICAO) Committee on Aviation Environmental Protection
CEF	CORSIA eligible fuels
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
DLUC	Direct Land Use Change
EASA	European Union Aviation Safety Agency
GHG	Shorthand for greenhouse gas
ICAO	International Civil Aviation Organization
ILUC	Induced Land Use Change
IPCC	Intergovernmental Panel on Climate Change
LCA	Life Cycle Assessment
LCAF	Lower Carbon Aviation Fuels
LULUCF	Land Use and Land Use Change
MRV	Monitoring, Reporting and Verification
RED II	Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (European Commission 2018a)
SAF	Sustainable Aviation Fuels
SARPs	Standards and Recommended Practices

C.1 Introduction

What do the different emission factors for alternative fuels mean for the co-existence of the EU ETS with CORSIA? What complications can this cause? How can this be handled?

Before looking in detail at the emission factors for alternative fuels it is helpful to set the context by comparing CORSIA and the EU ETS. By definition CORSIA is a carbon offsetting scheme whereas the EU ETS is an emissions trading scheme. Both have the objective of mitigating CO_2 emissions. The EU ETS first began operating in 2005, and the aviation sector has been included since 2012. This system now has well-established rules and procedures while CORSIA is being developed and will enter its pilot phase by 2021.

The two schemes have quite different scopes. With respect to aviation the EU ETS applies to all airlines operating in the European Economic Area. Airline operators are required to monitor, report and verify their emissions, and to surrender allowances against those emissions.

Under CORSIA, airlines will have to acquire sufficient offsets and/or allowances from emission trading schemes to match their share of the growth in emissions from the international aviation industry. The share is to be calculated in line with each airline's proportion of *total* emissions, not the contribution to the growth in total emissions[9]. Emissions reduction offsets will be bought from CORSIA-approved offsets in other sectors. Separately and in addition to purchasing offsets, airlines can reduce the amount of offsets required by using 'CORSIA eligible fuels'.

CORSIA-eligible fuels (CEF) include Sustainable Aviation Fuels (SAF) and Lower Carbon Aviation Fuels (LCAF). The ICAO Committee on Aviation Environmental Protection (CAEP) has tasked the former Alternative Fuel Task Group (AFTF), now Fuel Task Group (FTG), so far only to calculate the default life cycle emissions of SAF pathways (ICAO 2019e).

We include as section C.6 a brief discussion on some of the issues and problems arising from LCAF. At this stage it is the emission factors for SAF and for aviation fuels under EU ETS that are the main focus in this report.

C.2 Overview of alternative aviation fuels

In order to be used in commercial flights, an alternative aviation fuel – whether it is eligible under EU ETS, CORSIA or not – has to comply with international standards for fuel use in aviation. The American Society for Testing and Materials International (ASTM) has developed standards to approve production pathways for synthetic aviation fuels and those derived from biomass. The properties and characteristics of certified non-fossil aviation fuel are essentially identical to conventional jet fuel: it is the certified production pathway which permits interchangeable use with conventional jet fuel. The standards currently require blending with conventional jet fuel with maximum blended amounts of alternative aviation fuels of between 10% and 50%.

C.2.1 Certification of alternative aviation fuels

The actual use of biofuels under CORSIA and EU ETS rests on the certifications under ASTM D1655 Standard Specification for Aviation Turbine Fuels and D7566 Standard Specification for Aviation

[9] Each State will calculate the offsetting requirements attributed to an airline operator, where the:

airline's annual emissions x growth factor = CO_2 offsetting requirements

In a given year from 2021, the growth factor is the percent increase in the amount of emissions from the baseline, and is calculated by ICAO. The growth factor changes every year and takes into account the emissions growth of both the sector and the individual operators (ICAO 2019a).

Turbine Fuel Containing Synthesized Hydrocarbons. The document 'CORSIA Eligible Fuels - LCA Methodology' (ICAO 2019e) begins with a section on adding new alternative fuels, anticipating that new bio or non-bio fuels may become available. The methodology document then provides details on the life cycle assessment (LCA) values of the conversion processes currently approved for sustainable aviation fuels.

The MRR Regulation (EU) No 601/2012 (European Commission 2012) does not directly reference ASTM D1655 or D7566. However, the EU ETS Guidance document: General guidance for Aircraft Operators (European Commission 2018b) includes a footnote on biofuel complying with ASTM standards. The European Union Aviation Safety Agency (EASA) is the EU agency with responsibility for civil aviation safety, certification, regulation, and standardisation – including for aviation fuels used in the EU. The EASA notes that while there is interest in non-bio-based 'electrofuels'[10], only bio-based aviation fuels currently have ASTM certifications (EASA 2019).

The table below lists the current production pathways (conversion processes) which have international approval for use as aviation fuel under ASTM.

Table 5: Certified alternative aviation fuel production pathways under ASTM

#	Conversion technology	Standard	Maximum blending ratio
1	FT-SPK (Fischer-Tropsch Synthetic Paraffinic Kerosene). Biomass is converted to synthetic gas and then into bio-based aviation fuel	ASTM D7566 Annex 1	50 %
2	HEFA (Hydroprocessed Fatty Acid Esters and Free Fatty Acid). Lipid feedstocks, such as vegetable oils, used cooking oils, tallow, etc. are converted using hydrogen into green diesel, and this can be further separated to obtain bio-based aviation fuel	ASTM D7566 Annex 2	50 %
3	HFS-SIP (Hydroprocessing of Fermented Sugars - Synthetic Iso-Paraffinic kerosene). Using modified yeasts, sugars are converted to hydrocarbons	ASTM D7566 Annex 3	10 %
4	FT-SPK/A is a variation of FT-SPK, where alkylation of light aromatics creates a hydrocarbon blend that includes aromatic compounds	ASTM D7566 Annex 4	50 %
5	ATJ-SPK (Alcohol-to-Jet Synthetic Paraffinic Kerosene). Dehydration, oligomerization and hydroprocessing are used to convert alcohols, such as iso-butanol, into hydrocarbon	ASTM D7566 Annex 5	50 %
6	Co-processing of biocrude fats, oils, and greases (FOG) up to 5% according to volume of lipidic feedstock in petroleum refinery processes (details added to the Standard Specification for Aviation Turbine Fuels)	ASTM D1655 Annex 1	5 %

Source: (EASA 2019), (ICAO 2019e)

C.2.2 Emission factors and emission calculation

The conventional fuels used within the aviation sector are highly standardised and the associated CO_2 emission factors are therefore also well established. The general equation for CO_2 emissions from aviation fuels is based on the mass of the fuel used multiplied by its emission factor. Since fuel delivery is typically measured by volume, it is necessary to use a density value to convert fuel volume into mass. Under CORSIA and the EU ETS the fuel density can be the fuel density already used for

[10] EASA uses the term 'electrofuels' and cites the ICAO working paper on Power-to-Liquids (PtL): Sustainable alternative fuels produced from renewable electricity (presented by Germany, Mexico 2017),

operational and safety reasons (typically obtained from the fuel supplier). Where the fuel density is not known, a standard fuel density of 0.80 kg/l is used.

The following descriptions of the emissions factors under EU ETS and CORSIA draw on the respective annual reporting requirements The different ways that the non-fossil fuel emissions are handled under the two systems are explained.

CORSIA

Under the EU ETS which takes biofuels into account, the annual emission factor is determined from the conventional emission factor and the biomass fraction of the fuel. The default emission factors from conventional fuels are listed in Section 3 of Annex III of the MRR (European Commission 2012) and are consistent with those used under the UNFCCC/IPCC. The emission factor for biofuels is zero, as defined by the MRR. For biofuels to be zero-rated the biofuel must satisfy the sustainability criteria defined by the original Renewable Energy Sources Directive (European Union (EU) 2009) and as recast in the RED II Directive (European Commission 2018a), which introduced criteria for indirect land-use change[11]. In the annual emissions report, the 'preliminary emission factor' is the assumed total emission factor of a mixed fuel or material, based on the total carbon content composed of biomass fraction and fossil fraction. The 'final emission factor' is calculated from the preliminary emission factor and the zero-rated sustainable biomass content.

Aviation emissions from conventional fuels are calculated from the weight of fuel used. Biomass fuel which does not comply with the sustainability criteria is treated like fossil material and contributes to reported fossil emissions.

The following table is adapted from an excerpt of 'Template No 5: Annual emissions report of aircraft operators'. The table shows the standard emission factors for the standard fuel types as "preliminary EF". The table provides the example of a situation 100 000 tonnes of jet kerosene, of which 10% is sustainable biofuel from used cooking oil and 10% is non-sustainable bio fuel.

Table 6: EU ETS aircraft fuel consumption and emissions

Fuel No.	**Name of fuel**		**preliminary EF [t CO_2 / t fuel]**	**NCV [GJ/t]**	**biomass content (sustainable) [%]**	**biomass content (non-sustainable) [%]**
1	Jet kerosene (jet A1 or jet A)		**3.15**	*44.10*	10.00	10.00
2	Jet gasoline (Jet B)		**3.10**	*44.30*	0.00	0.00
3	Aviation gasoline (AvGas)		**3.10**	*44.30*	0.00	0.00
Fuel No.	**Name of fuel**	**(final) EF [t CO_2 / t fuel]**	**fuel consumption [tonnes]**	**CO_2 emissions [t CO_2]**	CO_2 from sustainable biomass	CO_2 from non-sustainable biomass
1	Jet kerosene (jet A1 or jet A)	**2.835**	100 000.00	**283 500**	31 500	31 500
2	Jet gasoline (Jet B)	**3.10**				
3	Aviation gasoline (AvGas)	**3.10**				

[11] See section C.4: In the following "compliance with sustainability criteria" is understood as compliance with Article 29 of Red II.

Fuel No.	Name of fuel	preliminary EF [t CO_2 / t fuel]	NCV [GJ/t]	biomass content (sustainable) [%]	biomass content (non-sustainable) [%]
Total CO_2 emissions in the reporting year:			**283 500**		
Memo Item: Sustainable biomass:				31 500	
Memo Item: Non-sustainable biomass:					31 500

Source: (European Commission 2015)

The CO_2 from sustainable biomass is calculated from the percentage of sustainable biomass and deducted from total emissions. The above table uses the final EF derived from the preliminary EF minus the percentage of sustainable bio fuel, in this case 10%.

Final EF = 3.15 - 0.315 = 2.835

Total CO_2 emissions in the reporting year equals the amount of "fossil" emissions plus emissions from biomass for which no evidence for compliance with the sustainability criteria has been provided. Total emissions are identical to the emissions for which allowances are to be surrendered. The amounts of CO_2 from sustainable and non-sustainable biomass are also recorded as separate memo-items.

The total emissions reduction in this example of burning 10 000 litres of sustainable bio fuel is

3.15 × 10 000 = 31 500 tonnes of CO_2

The following section includes a similar example of using 10 000 litres of sustainable bio fuel under CORSIA.

CORSIA

Under CORSIA each airline operator is required to meet their offsetting requirements by cancelling CORSIA Eligible Emissions Units in a quantity equal to its total final offsetting requirements from 2021 onwards. Operators can reduce their offsetting requirements by claiming emission reductions from CORSIA-eligible fuels. The emission reductions calculations are based on:

- amounts of CORSIA-eligible fuels purchased
- the life cycle emissions reduction factors for each CORSIA-eligible fuel
- valid sustainability certification documents.

Similar to under the EU ETS, each airline operator will report its CO_2 emissions to a single State under CORSIA. The airline operator reports to and claims verified reductions of its emissions from the use of CORSIA-eligible fuels to the State (ICAO 2019b). An annual emissions report includes all CO_2 emissions minus any emission reductions claimed from CORSIA-eligible fuels. The reductions from the use of CORSIA-eligible fuels are based on the mass of the neat CORSIA-eligible fuel and life cycle emissions values.

CORSIA uses a slightly higher emission factor of 3.16 kg CO_2/kg fuel for Jet-A and Jet-A1 fuel than the IPCC defaults for these fuels (ICAO SARP Annex 16 Volume IV, Part II, Chapter 2, 2.2.3 (ICAO 2018)). This is 0.3% higher than the 3.15 kg CO_2/kg fuel for Jet-A and Jet-A1 fuel specified in Section 3 of Annex III of the MRR (European Commission 2012), and used in EU ETS calculations. The CORSIA emission factors for Jet gasoline (Jet B) and Aviation gasoline (AvGas) are the same as for EU ETS and IPCC.

The following table is an excerpt from the 'CORSIA Template of Emissions Report (from aeroplane operator to State)' (ICAO 2019g). Only those parts relevant to emissions reductions are shown here.

Table 7: CORSIA emissions report (excerpt)

b1) CORSIA eligible fuels claimed

If claiming emission reductions from the use of CORSIA eligible fuels, please complete the table below. Supplementary information about the claim is also required, and can be reported using the CORSIA eligible fuels supplementary information template.

Fuel type					
Fuel type (e.g., Jet-A	Feed-stock	Conversion process	Total mass of the neat CORSIA eligible fuel (in tonnes)	Approved Life Cycle Emissions values	Emission reductions claimed
Jet-A	UCO	HEFA pathway	10 000	13.9 g CO_2e/MJ	26 665
Total emission reductions from the use of CORSIA eligible fuel(s) claimed					**26 665**

Source: (ICAO 2019g)

For example, under CORSIA if an operator uses 10 000 tonnes of Jet-A fuel produced from used cooking oil (UCO), the amount of emissions reductions will be:

$$\mathbf{3.16 \times 10\,000 \times (1 - 13.9/89) = 26\,665 \text{ tonnes of } CO_2}$$

with the:

- emission factor for Jet-A fuel: 3.16 kg CO_2/kg fuel
- life cycle emissions value: used cooking oil HEFA pathway is 13.9 gCO_2e/MJ (ICAO 2019e)
- baseline life cycle emissions: 89 gCO_2e/MJ for jet fuel (ICAO 2018, p. II-3-3)

The above formula is based on ICAO SARP Annex 16 Volume IV Part II, Chapter 3, 3.3 (ICAO 2018), which is reproduced as Appendix C.10.2 in this report.

The document on the 'CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels' will become officially available following approval by the ICAO Council. Although the underlying CORSIA supporting document: CORSIA Eligible Fuels - LCA Methodology (ICAO 2019f) is available, and it includes (as yet unofficial) default emissions values. It is anticipated that the upcoming document will include a combination of the default core LCA values and the region-specific default induced land use change (ILUC) emission intensities.

C.3 CORSIA-eligible fuels

Standards and Recommended Practices (SARPs) are the mechanism by which ICAO sets out administrative and technical requirements, monitoring, reporting and verification rules. The following section reflects the availability of documentation about 'CORSIA Eligible Fuels'. At time of writing (September 2019), most documents are not publicly available:

'CORSIA-eligible fuels' are an ICAO CORSIA 'Implementation Element' that is reflected in the five ICAO documents referenced in the ICAO SARP, known as "Annex 16 - Environmental Protection, Volume IV - Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)" (ICAO 2018), which became effective on 22 October 2018 and applicable on 1 January 2019. Only one of the five ICAO documents is available to date. The remainder will be presented to the ICAO Contracting States in the last quarter of 2019 as part of a state letter process for written comments. The following list provides names and the availability of the five ICAO documents:

CORSIA Eligibility Framework and Requirements for Sustainability Certification Schemes: will become available following approval by the ICAO Council.

CORSIA Approved Sustainability Certification Schemes: will become available following approval by the ICAO Council

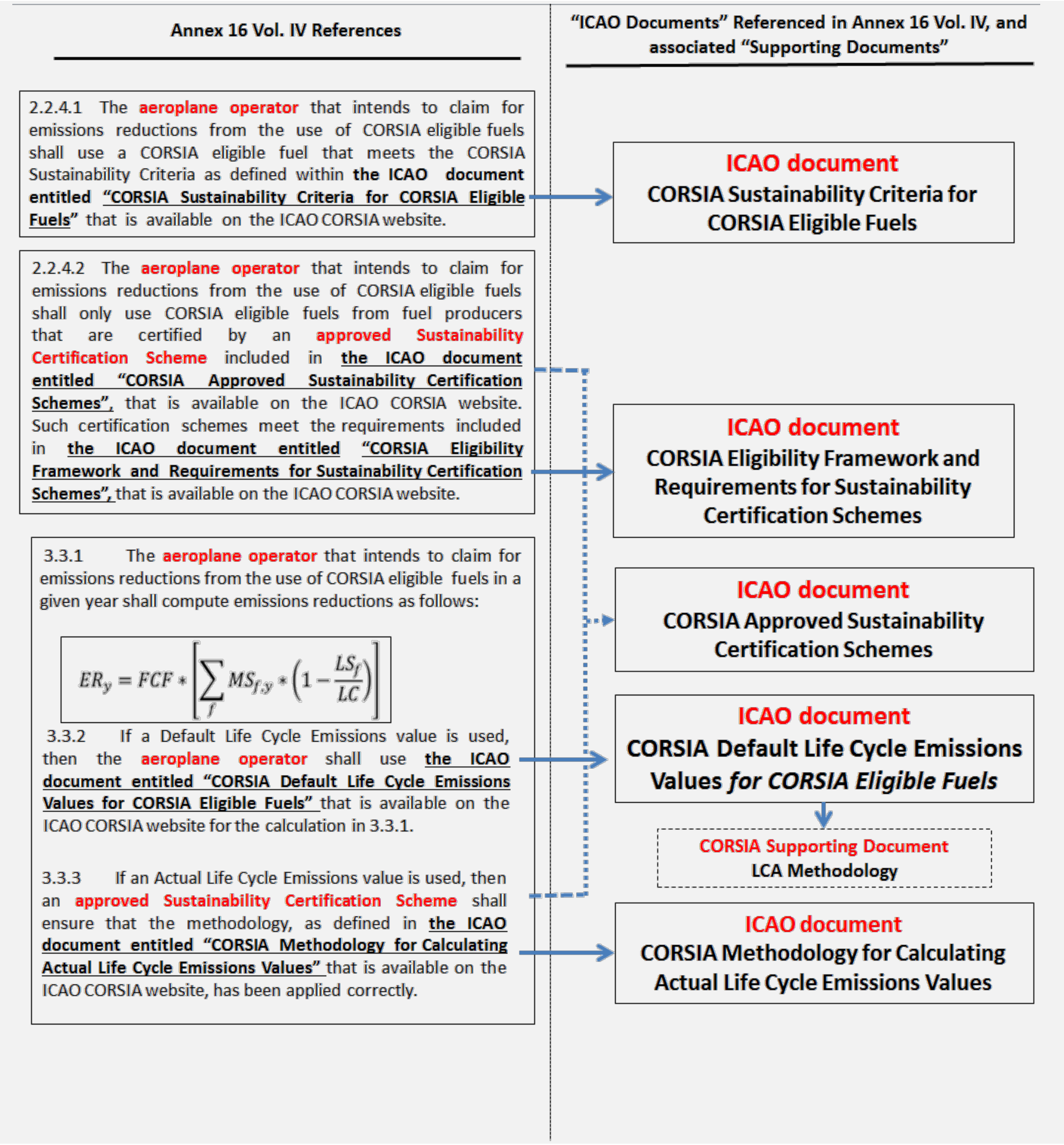
CORSIA Sustainability Criteria for CORSIA Eligible Fuels: is available for download.

CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels: will become available following approval by the ICAO Council. The underlying CORSIA supporting document:
CORSIA Eligible Fuels - LCA Methodology is available for download.

CORSIA Methodology for Calculating Actual Life Cycle Emissions Values: will become available following approval by the ICAO Council.

The current status of these documents is available on the CORSIA page at: www.icao.int/environmental-protection/CORSIA/Pages/CORSIA-Eligible-Fuels.aspx. The following flow chart illustrates the relationships between the documents and the SARP Annex 16, Vol IV.

Figure 11: Relationships between the documents and the SARP Annex 16, Vol IV



Source: (ICAO 2019c)

C.4 Comparison of sustainability and greenhouse gas saving criteria

While there is general alignment between the sustainability criteria, the different criteria metrics and thresholds mean that fuels qualifying under one scheme could be excluded in the other. The text in Table 8: is taken directly from the relevant Articles and sections of the Renewable Energy Directive and the ICAO document 05 - Sustainability Criteria for CORSIA Eligible Fuels.

The latter lists criteria for greenhouse gas savings and criteria to safeguard the carbon stock under the title "sustainability criteria" while the RED II Directive handles both aspects together under Article 29 but addresses them separately in the title of the Article "Sustainability and greenhouse gas emissions saving criteria for biofuels, bioliquids and biomass fuels". As mentioned in section **Fehler! V**

erweisquelle konnte nicht gefunden werden. for biofuels to be zero-rated under the EU ETS, the biofuel must satisfy the sustainability criteria. In the templates in (European Commission 2015) it is stated that "compliance with sustainability criteria pursuant RES Directive" needs to be demonstrated. The latest guidance document on biomass issues has not been updated (European Commission 2017). It refers to Article 17 of the RED Directive of 2009, which does not mention any greenhouse gas saving criteria. In the following it is assumed that compliance to the whole Article 29 has to be demonstrated, including greenhouse gas emissions saving criteria. This is concluded from the explanation in the mentioned guidance document that "*due to the zero-rating of emissions from biomass, the EU ETS constitutes a support scheme within the meaning of the RES-D. Pursuant to Article 17(1) of the RES-D, bioliquids and biofuels may only receive support and count towards the national targets where they comply with sustainability criteria set out in Article 17 of that Directive. Consequently, the sustainability criteria must be applied for biofuels and bioliquids that are consumed and zero-rated for greenhouse gas emissions within an installation or an aircraft operator's activities covered by the EU ETS.*" With the recast of the Directive, both the greenhouse gas saving and sustainability criteria in Article 29 need to be met to account for EU and national targets and to be eligible for financial support (Article 1).

Table 8: Sustainability and greenhouse gas saving criteria under RED II and CORSIA

Scheme / criteria	Renewable Energy Directive (EU) 2018/2001, eligible biofuels in renewable energy shares towards the EU target	CORSIA sustainability criteria for CORSIA-eligible fuels
GHG reductions	The greenhouse gas emissions savings from the use of renewable liquid and gaseous transport fuels of non- biological origin (efuels) shall be at least 70 % from 1 January 2021 (Article 25, paragraph 2). Greenhouse gas emissions from biofuels must be lower than from the fossil fuels they replace: at least 50% for installations older than 5 October 2015, 60% for installations after that date, 65% for biofuels produced in installations starting operation after 2021 and 70% for biofuels produced in installations starting operation after 2026. (Article 29, paragraph 10). For the calculation of the GHG impact of biofuels, Article 31 needs to be considered which refers to Annex V of RED II.	Principle: CORSIA-eligible fuel should generate lower carbon emissions on a life cycle basis. Criterion 1: CORSIA-eligible fuel shall achieve net greenhouse gas emissions reductions of at least 10% compared to the baseline life cycle emissions values for aviation fuel on a life cycle basis.
Land use change – Carbon stock and biodiversity:	Sustainability criteria are listed in Article 29, paragraph 2-7: Biofuels produced from waste and residues derived not from forestry but from agricultural land shall be taken into account only where operators or national authorities have monitoring or management plans in place to address the impacts on soil quality and soil carbon. Biofuels from agricultural biomass shall not be made from raw material obtained from land with a high biodiversity value, a high-carbon stock or from land that was peatland. Biofuels from forest biomass shall meet specific criteria to minimise the risk of using forest biomass derived from unsustainable production	Principle: CORSIA-eligible fuel should not be made from biomass obtained from land with high carbon stock. Criterion 1: CORSIA-eligible fuel shall not be made from biomass obtained from land converted after 1 January 2008 that was primary forest, wetlands, or peat lands and/or contributes to degradation of the carbon stock in primary forests, wetlands, or peat lands as these lands all have high carbon stocks

Scheme / criteria	Renewable Energy Directive (EU) 2018/2001, eligible biofuels in renewable energy shares towards the EU target	CORSIA sustainability criteria for CORSIA-eligible fuels
	and shall meet specific land-use, land-use change and forestry (LULUCF) criteria. The amount of biofuels produced from cereal and other starch-rich crops, sugars and oil crops and from energy crops grown on agricultural land that can be counted as a source of renewable energy is limited to 7% of the energy in transport in the Member States in 2020 (Article 26, paragraph 1).	Criterion 2: In the event of land use conversion after 1 January 2008, as defined based on IPCC land categories, direct land use change (DLUC) emissions shall be calculated. If DLUC greenhouse gas emissions exceed the default induced land use change (ILUC) value, the DLUC value shall replace the default ILUC value.

Sources: (European Commission 2018a), (ICAO 2019f)

Under both schemes it is necessary to prove both the greenhouse gas reduction and the sustainability criteria in parallel. Following the comparison in Table 8:, environmental integrity of both schemes appears to be only generally comparable. Under the EU ETS demonstrating compliance with sustainability criteria for biofuels will use voluntary (non-government) schemes that will certify the standards for the production of sustainable fuels. Even though the schemes are 'voluntary', demonstrating compliance with the sustainability criteria is achieved via certification from such a scheme. The Commission plans to instigate recognition of voluntary schemes for the period after 2020 (European Commission 2018a). Further information and a link to the relevant web page is included in Appendix C.10.3. Under CORSIA the verification of data compiled by aeroplane operators also includes verification of the consistency of information on the use of CORSIA-eligible fuels. Sustainability Certification Schemes will need to have been approved by CORSIA.

CORSIA would allow fuels which only achieve net minimum greenhouse gas emissions reductions of 10%, whereas the minimums for biofuels under RED II are at least 50% for older installations rising to 65% for biofuels produced in installations which begin operation after 2021 and to 70% in installations after 2026 (see Table 8:).

In terms of GHG reduction under the EU ETS the reduction of GHG is calculated against the baseline of GHG from fossil fuels they replace. If compliance to Article 29 has been demonstrated, CO_2 emissions of biofuels and upstream-emissions of fossil fuels are not considered. This is very different to the criteria of CORSIA whereby the whole life cycle-emissions of both fuel types, the conventional and alternatives, are considered by definition.

For land use change – carbon stock and biodiversity, both systems seek to avoid the use of biomass from high carbon stocks, where the definition in RED II is much more defined. The exclusion of biofuels production from land with high biodiversity is not mentioned in the CORSIA criteria.

Under the EU ETS the overall production of biomass which interferes with nutrition needs is limited to 7% of the energy in transport in 2020 (RED II, Article 26, paragraph 1). Such a limit is not implemented with CORSIA criteria. Under the latter it is ensured that for the event of land use conversion after 1 January 2008 the higher of the ILUC or DLUC value is used for the further calculation.

From these points it is clear that sustainable criteria for the aspect of land use change are more stringent under the RED II and hence for the EU ETS than under CORSIA.

For a comparison of emissions reduction due to the use of jet fuel produced from sustainable biofuel (used cooking oil) see section C.7.

C.5 Comparison of general MRV requirements under CORSIA and EU ETS

Both CORSIA and the EU ETS require annual reporting and annual verification processes based on an approved monitoring plan. Both systems use a flight-by-flight monitoring approach.

Under the EU ETS compliance with the reporting obligations involves preparation or the update of a monitoring plan, calculation of emissions and submission and verification of an annual report. Once verified, operators must surrender the equivalent number of allowances. The EU ETS guidance documents are available from the webpage of the European Commission (European Commission 2019).

Just as conventional jet fuel has to comply with ASTM standards, alternative aviation fuels may only be used when they are produced according to the certified alternative aviation fuel production pathways that comply with ASTM standards.

With respect to verification, the monitoring approach under the EU ETS has a specific methodology for verifying the quantity of biofuels from purchase records. Only biofuel meeting the relevant sustainability criteria can be taken into account. The requirements include that records are kept in a transparent and traceable system, and are made available to the EU ETS verifier, and upon request to the competent authority of the administering Member State (European Commission 2018b). The general verification process under the EU ETS includes annual deliveries of emission reports by aircraft operators to accredited verifiers. These are under the surveillance of national accreditation bodies. Verified emission reports are submitted to competent authorities which conduct spot checks. Regular incentives to improve monitoring plans are initiated by verifiers.

Under CORSIA all aircraft operators must monitor their emissions from all international flights (Country A – Country B) beginning on 1 January 2019. The mandatory regulation requires all international operators to submit a Monitoring Plan to their Member State by the end of 2018. The ICAO website has a range of guidance material on the implementation and monitoring options at: www.icao.int/environmental-protection/CORSIA/Pages/CORSIA-communication.aspx. This page includes a series of 10 'CORSIA at a glance leaflets' on topics such as implementation and offsetting requirements, the central registry, verification and eligible fuels.

With respect to verification, an outline of the verification pathway is provided in the CORSIA at a glance leaflet 8 (ICAO 2019a). CORSIA foresees a three-step verification pathway. Firstly CORSIA recommends an internal pre-verification by the airline operator. Secondly a verification of the report is performed by an independent third-party verification body. The verification body must be accredited by a National Accreditation Body to an ISO Standard, and to the relevant requirements described in Annex 16, Volume IV, Appendix 6 (ICAO 2018). Finally the State Authority conducts an order of magnitude check to verify the data against different sources of information.

With regard to the general setting, the monitoring, reporting and verification processes of the EU ETS and CORSIA are comparable. As the system under CORSIA is in its infancy and there are still details that need to be clarified, more differences in the details of the implementation may come about. For example, regular incentives for improving monitoring plans have not yet been implemented under CORSIA.

C.6 Issues arising from Lower Carbon Aviation Fuels (LCAF)

CORSIA-eligible fuels (CEF) include Sustainable Aviation Fuels (SAF) and Lower Carbon Aviation Fuels (LCAF). The use of LCAF allows airlines to reduce their offset obligation through fossil fuels that have lower life cycle emissions. Fossil fuels with 10% or more reduction in life cycle emissions compared to the standard may be counted as LCAF.

One of the main problems with this approach is 'additionality'. It would be difficult to argue that the reductions attributed to LCAF use are additional because by definition LCAF rely on reductions elsewhere – and those lower levels emissions will be reported elsewhere.

While it remains to be seen whether the ICAO Committee on Aviation Environmental Protection makes any progress on LCAF, even in their most benign form the use of LCAF takes CORSIA further away from alignment with the EU ETS.

C.7 Example of calculating emissions reduction

The use of alternative fuels as 'CORSIA-eligible fuels' reduces an airline's CORSIA offsetting requirements whereas the use of alternative fuels under the EU ETS lowers reported emissions. For a given amount of alternative fuel that meets the sustainability criteria, the amount by which emissions are lowered is different for each system.

Under the EU ETS the reductions are directly proportional to the volume of conventional fuels displaced by biofuels. In contrast, under CORSIA the reported emissions reduction are a ratio of the life cycle emissions savings, whereby the use of biofuels in effect constitutes a life cycle credit for CO_2 reductions.

From the earlier example under the EU ETS in which biofuels meet the sustainability criteria, the calculated emissions are zero. Thus, the amount of emissions reductions from 10 000 tonnes of Jet-A fuel produced from used cooking oil are calculated from the emission factor for Jet-A fuel: 3.15 kg CO_2/kg fuel:

$$\mathbf{3.15 \times 10\,000 \quad = 31\,500 \text{ tonnes of } CO_2}$$

From the earlier example under CORSIA, if an operator uses 10 000 tonnes of Jet-A fuel produced from used cooking oil the amount of emissions reductions will be:

$$\mathbf{3.16 \times 10\,000 \times (1 - 13.9/89) = 26\,665 \text{ tonnes of } CO_2}$$

Clearly these emissions reductions are not comparable. The comparison of jet fuel derived from 'used cooking oil' under the EU ETS and CORSIA is one of the simplest. Comparison of a fuel produced directly from crops would have a greater difference because of the higher life cycle emission values attributed under CORSIA calculations. This means that the use of the same amount of alternative fuels leads to a lower reduction of emissions under CORSIA than under the EU ETS. To achieve the same quantity of reduction under CORSIA more emissions would need to be offset while under the EU ETS fewer allowances would need to be surrendered.

C.8 Conclusions and recommendations

The EU ETS and CORSIA are two quite separate mitigation programs. Airline operators will report separately for both programs. There are a number of issues that arise from the different approaches, meaning that it is not possible to compare the emission reductions across the two schemes.

From a general perspective, it should be stressed that the target setting in both systems is not comparable: While under the EU ETS emissions of all covered flights need to be compensated with EUAs or EUAAs, CORSIA targets the increase of emissions after 2020 with the requirement to buy offsets only for these additional emissions. The general reporting of aviation emissions in the two schemes is not comparable due to different geographical coverage, participation of aircraft operators and different target setting. With regard to conventional fuels, the CORSIA emission factor for Jet gasoline (Jet A) is different to the one used under the EU ETS and IPCC.

In both schemes the use of alternative aviation fuels reduces the need to buy certificates (EU ETS) or offsets (CORSIA). But the quantification of these emission reductions follows very different rules: To reduce the need to buy offsets under CORSIA, the life cycle emissions of aviation fuels need to be lower than benchmark emissions. Differences can be accounted as emission reductions. Under the EU ETS only biofuels can be used to reduce the need to buy certificates; their emissions are counted as zero. This means that biofuels reduce emissions equal to those which would have been emitted from replaced conventional fuels.

Alternative aviation fuels that might be acceptable in one system to reduce emissions for compliance will not necessarily be acceptable in the other. For both systems, alternative aviation fuels need to prove compliance with "sustainability" criteria which cover both GHG reduction and carbon stock criteria. Under the EU ETS, biofuels are treated as zero emissions if they comply with criteria defined in RED II. Eligible alternative aviation fuels under CORSIA need to comply with lower GHG reduction criteria. This also allows the accounting of emission reductions of fossil fuels that result from production chains with lower emissions.

If a biofuel gets accepted as a CORSIA-eligible fuel but does not pass the EU ETS criteria to be accounted as biofuel, it is likely to be reported as a memo item under EU ETS. A final comparison of both systems as regards the accounting of alternative fuels is not possible at the time of writing since only one of five ICAO documents for the implementation element of "CORSIA-eligible fuels" is available. It needs to be stressed that alternative fuels are hydrocarbons. In addition to CO_2, their non-CO_2 climate impacts contribute to global warming. These impacts may to some extent be reduced by 'well-designed' alternative fuels but they cannot be eliminated entirely. This fact should not be ignored because it could lead to an overestimation of the contribution of alternative fuels contribution to addressing aviation's impact on climate change.

For operators the reporting to two systems will be time- and labour-consuming. Beyond the general difference of the different scope of the systems, The use of different emission factors and amounts of eligible alternative fuels lead to the fact that resulting numbers cannot be directly compared. This means that it is not possible to implement easy checks on the side of operators to ensure the correctness of reporting to both schemes. It means also that it may not be possible to calculate and report total amounts of alternative fuel which can be accounted in parallel in both systems.

Operators under the EU ETS might calculate the effect of the use of alternative fuels which meet even higher sustainability and greenhouse gas emissions saving criteria than required to be eligible under CORSIA. Higher standards of alternative fuels are usually more cost-intensive, because the use of new technologies and the avoidance of the non-sustainable exploitation of the carbon stock lead to higher investment needs. But if the same or at least comparable high standards for alternative fuels were used in parallel under both schemes to reduce emissions which need to be offset or balanced with EUA or EUAA, this could be an advantage. To direct the technology in sustainable directions, it would be helpful to align the sustainability and greenhouse gas emissions saving criteria of the two schemes to avoid differing technological innovation incentives which are fed by the cost differences of EUA and offsets under CORSIA. To avoid unsustainable use of biofuel in the aviation sector, there are two main points which need to be followed during the next months: The obvious one is the definition of the carbon stock criteria for the eligibility of alternative aviation fuels under CORSIA. The other is the definition of the methodology and default parameters to calculate life cycle emissions from biofuels. The lower the estimated life cycle emissions of biofuels, the higher the incentive for their use. If the demand for biofuels becomes too great, it could bring about negative effects on the environment overall in terms of carbon sinks as well as biodiversity.

C.9 References

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C.10 Appendices

C.10.1 CORSIA Implementation Elements

This table on CORSIA Implementation Elements is reproduced here from the CORSIA web page of the same name: www.icao.int/environmental-protection/CORSIA/Pages/implementation-elements.aspx (ICAO 2019d).

Table 9: CORSIA Implementation Elements

ICAO CORSIA Implementation Elements	ICAO documents
CORSIA States for Chapter 3 State Pairs	1. CORSIA States for Chapter 3 State Pairs
ICAO CORSIA CO_2 Estimation and Reporting Tool (CERT)	2. ICAO CORSIA CO_2 Estimation and Reporting Tool
CORSIA Eligible Fuels	3. CORSIA Eligibility Framework and Requirements for Sustainability Certification Schemes 4. CORSIA Approved Sustainability Certification Schemes 5. CORSIA Sustainability Criteria for CORSIA Eligible Fuels 6. CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels 7. CORSIA Methodology for Calculating Actual Life Cycle Emissions Values
CORSIA Eligible Emissions Units	8. CORSIA Eligible Emissions Units 9. CORSIA Emissions Unit Eligibility Criteria
CORSIA Central Registry (CCR)	10. CORSIA Central Registry: Information and Data for the Implementation of CORSIA 11. CORSIA Aeroplane Operator to State Attributions 12. CORSIA 2020 Emissions 13. CORSIA Annual Sector's Growth Factor (SGF) 14. CORSIA Central Registry (CCR): Information and Data for Transparency

Notes: The five ICAO CORSIA Implementation Elements listed are reflected in 14 ICAO documents approved by the ICAO Council for publication. These ICAO documents are directly referenced in Annex 16, Volume IV and are essential for the implementation of the CORSIA.
Click on the links to get more information on each of the ICAO CORSIA Implementation Elements and the corresponding ICAO documents.
Source: (ICAO 2019d)

C.10.2 Emission reductions from the use of CORSIA eligible fuels

Calculation of emission reductions in accordance with equations is described in ICAO SARP Annex 16 Volume IV Part II, Chapter 3, 3.3 (ICAO 2018). The relevant section is reproduced here:

3.3 Emissions reductions from the use of CORSIA eligible fuels

3.3.1 The aeroplane operator that intends to claim for emissions reductions from the use of CORSIA eligible fuels in a given year shall compute emissions reductions as follows:

$$ER_y = FCF * \left[\sum_f MS_{f,y} * \left(1 - \frac{LS_f}{LC}\right)\right]$$

where:

ER_y = Emissions reductions from the use of CORSIA eligible fuels in the given year y (in tonnes);

FCF = Fuel conversion factor, equal to 3.16 kg CO_2/kg fuel for Jet-A fuel / Jet-A1 fuel and 3.10 kg CO_2/kg fuel for AvGas or Jet-B fuel;

$MS_{f,y}$ = Total mass of a neat CORSIA eligible fuel claimed in the given year y (in tonnes), as described and reported in Field 12.b in Table A5-1 from Appendix 5;

LS_f = Life cycle emissions value for a CORSIA eligible fuel (in gCO_2e/MJ); and

LC = Baseline life cycle emissions values for aviation fuel, equal to 89 gCO_2e/MJ for jet fuel and equal to 95 gCO_2e/MJ for AvGas.30

Note 1. – The ratio $\left(1 - \frac{LS_f}{LC}\right)$ *is also referred to as the emissions reduction factor (ERFf) of a CORSIA eligible fuel*

Note 2. – For each of the CORSIA eligible fuels claimed, the total mass of the neat CORSIA eligible fuel claimed in the given year y needs to be multiplied by its emissions reduction factor (ERFf). Then the quantities are summed for all CORSIA eligible fuels.

Source: ICAO SARP Annex 16 Volume IV Part II, Chapter 3, 3.3 (ICAO 2018)

C.10.3 Voluntary schemes

Voluntary schemes help to ensure that biofuels are sustainably produced by verifying that they comply with the EU sustainability criteria. The Commission plans to adopt a number of regulations to provide guidance on the implementation of the new sustainability criteria and to update the EU rules for voluntary schemes. Existing voluntary schemes recognised by the Commission will be required to adjust their certification approaches to the new rules.

The Commission plans to start the recognition of voluntary schemes for the period after 2020 and outlined the minimum recognition criteria. The Commissions page on voluntary schemes includes a list of approved voluntary schemes and approved national schemes.

https://ec.europa.eu/energy/en/topics/renewable-energy/biofuels/voluntary-schemes

D Market Based Measures and the EU 2030 aviation emissions target

Environmental Research of the
Federal Ministry for the
Environment, Nature Conservation,
Building and Nuclear Safety

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Market Based Measures and the EU 2030 aviation emissions target

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Abstract

In this paper it is assessed to what extent the EU Emissions Trading Scheme (EU ETS) and the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), as they are presently designed, contribute to reaching the EU 2030 emissions target, and if additional policy measures are required.

For 2030 the overall reduction target of the EU is to achieve of 40% GHG emissions reduction relative to 1990. As part of this the EC has set an indicative target for aviation, including all flights departing from EU airports, to about 111 Mt of CO_2. Because EU ETS regulations have EEA relevance, we have estimated the equivalent aviation target for the EEA (112.7 Mt). A reduction of 40% relative to 1990 for aviation would imply a level of about 51 Mt of CO_2 emissions. The indicative aviation target for EEA countries of 112.7 Mt is clearly higher. Under the indicative target aviation is allowed to increase emissions by 33% compared to 1990.

Aviation emissions on all departing EEA flights are forecast to grow to 216.5 Mt in 2030. Hence Market Based Measures have to bring about an emission reduction of 103.8 Mt in 2030 in order to meet the target.

Presently it is not clear how CORSIA and the EU ETS will work together in 2030. We have assumed the EU ETS will remain in place for Intra EEA flights and in 2030 CORSIA will apply to all international flights between EEA States and all States which are expected to join the mandatory phase 2 of CORSIA. The EU ETS will imply a demand for EUAs from the aviation industry of 46.3 Mt in 2030. EUAs represent reductions in other EU ETS sectors and contribute to reaching the target. As part of CORSIA the demand for international credits on Outbound EEA flights will be 33.6Mt. However, these credits are expected to stem from countries outside of the EEA and thus not contribute to reaching the target. The shortage in reaching the indicative aviation emissions target of 112.7 Mt in 2030 is estimated to 57.5 Mt. The shortage is mainly because at present no Market Based Measures are foreseen for Outbound EEA flights which contribute to reaching the EU aviation emissions target.

We have explored supplemental policy measures which could be taken in order to reach the aviation emissions target. First, we have looked for stricter rules for Intra EEA flights under the EU ETS, viz. lower the cap and additional EUAs to surrender to account for non-CO_2 climate impacts. By this it would be possible to reach the aviation target in 2030, but it would mean that Intra EEA flights would fully take account of reaching the EU aviation emissions target whereas MBMs for Outbound EEA flights would not make any contribution.

An alternative is to introduce a tax for Outbound flights and use proceeds to buy EUAs. It is estimated the required tax level on Outbound EEA flights is about 8€ per departing passenger in 2030 in order to generate the proceeds needed to buy EUAs so that the target is met. There are however several drawbacks with this policy measure which need to be further addressed and investigated. A final option is to require the use of sustainable aviation fuels. In order to meet the target, the fuels uplifted for Outbound flights would need to contain 50% of sustainable aviation fuels. It is not clear whether sufficient amounts of sustainable aviation fuels can be produced by 2030.

Kurzbeschreibung

In diesem Papier wird untersucht, inwieweit der EU Emissionshandel (EU ETS) und das Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) zur Erreichung des Emissionsziels der EU im Jahr 2030 beitragen können und ob zusätzliche politische Maßnahmen erforderlich sind.

Für 2030 ist das Klimaziel der EU die Reduktion der EU Treibhausgasemissionen um 40 % gegenüber 1990. In diesem Zusammenhang hat die EU ein indikatives Ziel für den Luftverkehr (einschließlich aller Flüge von EU-Flughäfen) von etwa 111 Mio. t CO_2 festgelegt. Der der EU Emissionshandel neben den EU Mitgliedsländern auch Norwegen und Island erfasst, wurde für die Analyse ein gleichwertiges Luftverkehrsziel für den Europäischen Wirtschaftsraum (EWR) abgeleitet (112,7 Mio. t). Eine Reduktion der Luftverkehrsemissionen um 40 % gegenüber 1990 würde einen CO_2-Ausstoß von etwa 51 Mio. t bedeuten. Das indikative Luftfahrtziel für die EWR-Länder von 112,7 Mio. t ist deutlich höher: im Vergleich zu 1990 darf der Luftverkehr die Emissionen um 33% erhöhen.

Für die Luftverkehrsemissionen auf allen abgehenden Flügen von Flughäfen im EWR wird bis 2030 ein Anstieg auf 216,5 Mio. t projiziert. Marktbasierte Maßnahmen müssen daher zu einer Emissionsminderung von 103,8 Mio. t im Jahr 2030 führen, um das Ziel zu erreichen.

Derzeit ist nicht klar, wie CORSIA und der EU ETS im Jahr 2030 zusammenarbeiten werden. Wir gehen davon aus, dass der EU ETS für Intra-EWR-Flüge in Kraft bleiben wird und CORSIA im Jahr 2030 für alle internationalen Flüge zwischen den EWR-Staaten und allen weiteren Staaten gelten wird, die voraussichtlich in der verpflichtenden zweiten Phase von CORSIA erfasst werden. Der EU ETS wird eine Nachfrage der Luftfahrtindustrie nach Emissionsberechtigungen aus dem stationären ETS von 46,3 Mio. EUAs im Jahr 2030 verursachen. EUAs stellen eine Treibhausgasminderung in anderen Sektoren des EU ETS dar und tragen dadurch zur Erreichung des EU Klimaziels bei. Im Rahmen von CORSIA wird die Nachfrage nach internationalen Krediten für abgehende Flüge von Flughäfen des EWR 33,6 Mio. t CO_2 betragen. Es wird jedoch erwartet, dass diese Kredite aus Ländern außerhalb des EWR stammen und somit nicht zur Erreichung des EU Ziels beitragen. Der Fehlbetrag zur Erreichung des indikativen Ziel für den Luftverkehr von 112,7 Mio. t im Jahr 2030 wird auf 57,5 Mio. t geschätzt und ist hauptsächlich darauf zurückzuführen, dass abgehende Flüge keinen Beitrag zu Erreichung des EU Emissionszieles leisten.

Wir haben zusätzliche politische Maßnahmen geprüft, die ergriffen werden könnten, um das Ziel für Luftverkehrsemissionen zu erreichen. Erstens haben wir nach strengeren Regeln für inner-EWR Flüge im Rahmen des EU EHS gesucht, d.h. Senkung der Cap für Luftverkehr und zusätzliche Abgabeverpflichtungen für Luftverkehrsbetreiber, um Nicht-CO_2-Klimaauswirkungen Rechnung zu tragen. Auf diese Weise wäre es möglich, das Luftverkehrsziel im Jahr 2030 zu erreichen. Es würde jedoch bedeuten, dass Intra-EWR-Flüge einen höheren Beitrag zur Erreichung der Klimaziele leisten würden, während MBMs für abgehende Flüge aus dem EWR keinen Beitrag leisten würden.

Eine Alternative ist die Einführung einer Steuer für abgehende Flüge und die Verwendung der Erlöse zum Kauf von EUAs. Es wird geschätzt, dass das erforderliche Steuerniveau auf abgehende Flüge aus dem EWR im Jahr 2030 etwa 8 € pro Passagier beträgt, um die Einnahmen zu erzielen, die für den Kauf von EUAs zur Zielerreichung erforderlich sind. Es gibt jedoch eine Reihe von Nachteilen dieser politischen Maßnahme, die adressiert und weiter untersucht werden müssen. Eine letzte Option besteht darin, die Verwendung von nachhaltigen Flugkraftstoffen zu verlangen. Um das Ziel zu erreichen, müssten die für ausgehende Flüge aufgenommenen Treibstoffe 50% nachhaltige Flugkraftstoffe enthalten. Es ist allerdings nicht klar, ob bis 2030 genügend nachhaltige Flugkraftstoffe produziert werden können.

List of Abbreviations

AERO-MS	Aviation Emissions and Evaluation of Reduction Options - Modeling System
CAGR	Compound Annual Growth Rate
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
CNG	Carbon Neutral Growth
EC	European Commission
EEA	European Economic Area (covering EU28 plus Norway, Iceland and Liechtenstein)
EUA	European Union Allowance
EU ETS	European Union Emissions Trading System
EU INDC	Intended Nationally Determined Contribution of the European Union and its Member States
GHG	Greenhouse Gas
ICAO	International Civil Aviation Organization
LRF	Linear Reduction Factor
MBM	Market Based Measure
Mt	Megatonne
RTK	Revenue Tonne Km
UBA	Umweltbundesamt (German Environment Agency)
UNFCCC	United Nations Framework Convention on Climate Change
UK	United Kingdom

D.1 Introduction

Market Based Measures (MBMs) are considered as an important means to bring about emission reduction by the aviation sector. In 2012 aviation was brought into the EU's emission trading system (EU ETS) covering all flights to and from EEA airports. In order to provide time to ICAO to agree on a global Market Based Measure, in 2013 the scope of flights subject to the EU ETS was reduced to only Intra EEA flights. As part of the EU ETS airlines have to surrender EUAs for their emissions above the EU ETS aviation cap.

In October 2016 ICAO agreed to implement a global Market Based Measure, called the Carbon Offset and Reduction Scheme for International Aviation (CORSIA), which aims to stabilise net emissions at 2020 levels referred to as carbon neutral growth 2020 (CNG 2020). CORSIA requires airlines to offset their emissions of international aviation above the 2020 level and will start in 2021, from which year ICAO Member States can voluntarily participate. From 2027 onwards CORSIA will be mandatory for States that have a share in international aviation above 0.5% of total Revenue Tonne Kilometres (RTKs). At present 72 ICAO Member States have agreed to voluntary join CORSIA from the start in 2021 including all EEA Member States which are also a Member State of ICAO [1][12].

In the Intended Nationally Determined Contribution (INDC) of the EU, the EU and its Member States are committed to a binding target of an at least 40% reduction in greenhouse gas emissions by 2030 compared to 1990 [2]. The EU 2030 target includes CO_2 emissions of aviation.

In this paper we assess to what extent the EU ETS for aviation and CORSIA, as they are presently designed, contribute to reaching the EU 2030 target, and whether additional policy measures are required in order to meet the target. First, we further elaborate on the EU 2030 target, whereby we focus on the target for aviation (part 2). In part 3 we present the forecast of aviation emissions for 2030. In a next step we present the emission coverage of the EU ETS and CORSIA in 2030 in relation to the aviation emissions target (part 4) followed by an overview of a possible ways to reach the target (part 5).

D.2 The EU aviation emissions target for 2030

The overall EU target under the INDC for 2030 is to achieve a 40% reduction for greenhouse gas emissions relative to the year 1990. The scope of the EU target under the INDC includes CO_2 emissions from all departing flights from the EU [3].

In order to infer a contribution of aviation to the overall target, the number of ETS allowances for aviation in 2030 is calculated by the EC by applying a Linear Reduction Factor (LRF) of 2.2% per year from 2021 onwards on the existing ETS cap for aviation (95% of the average emissions in 2004-2006). The resulting estimate for the EU ETS aviation cap in 2030, covering all departing flights from the EU, is 111 Mt of CO_2 emissions [3]. Hence in order to achieve the overall reduction target of -40% relative to 1990 in 2030, the aviation emissions on departing flights from the EU are proposed to be capped at 111 Mt of CO_2. This can be regarded as the EU's indicative aviation emissions target for 2030.

The EU ETS regulations have EEA relevance, and therefore all Intra EEA flights are subject to the EU ETS. Because of this, in the remainder of this analysis we have taken the EEA as the scope, and we have assessed the target for the EEA. Hereby an important distinction is made between Intra EEA flights (flights with both the airport of departure and the airport of arrival in one of the EEA Member States) and Outbound EEA flights (flights with the airport of departure in one of the EEA Member States and the airport of arrival outside the EEA).

[12] With the exception of Liechtenstein, all EEA Member States are also a Member State of ICAO.

Based on reported aviation emissions data to the UNFCCC for the years 2004, 2005 and 2006 of Norway, Iceland and Liechtenstein [4] we have adjusted the deduced EU aviation emissions target of 111 Mt to an EEA aviation emission target of 112.7 Mt. This implies that the reported aviation emissions on departing flights from these 3 countries are about 1.5% of what is reported for EU28. For this analysis we thus assume that the 3 countries will apply a similar aviation emissions target as for EU28.

We have also looked at the UNFCCC data with respect to International Aviation Bunkers (1D.1.a) and Domestic Aviation (1.A.3.a) reported for the EU28, Norway and Iceland for the year 1990 [4]. These data reflect emissions from all departing flights (both Intra EEA and Outbound EEA flights). Total aviation emissions in 1990 reported to the UNFCCC by the 31 EEA countries were 84.9 Mt. A reduction of 40% relative to 1990 would imply a level of about 51 Mt of aviation CO_2 emissions. The inferred aviation target for EEA countries of 112.7 Mt is clearly higher. Aviation is allowed to increase emissions by 33% compared to 1990. In other words, the indicative aviation target of 112.7 Mt is over twice as high compared to the -40% relative to 1990 level of aviation emissions. This implies that in order to reach the overall EU target of a 40% reduction relative to the year 1990, other economic sectors have to reduce more emissions to compensate for the indicative aviation target being above the -40% compared to 1990 level of emissions.

D.3 Aviation emissions forecast for 2030

In 2016 ICAO published an aviation demand growth forecast for the coming decades [6]. This forecast is included in the ICAO baseline scenario for 2030, on the basis of which CO_2 emissions on flights departing from the EEA for 2030 are computed with the AERO-MS[13]. The ICAO demand forecast distinguishes 59 global route groups for which a forecast is made in terms of the growth in passenger km and cargo tonne-km. The forecast for Intra EEA flights shows an annual demand increase of 2.5% for passenger demand. For Outbound EEA flights, the annual passenger demand growth varies between route group, with an average demand growth of 3.2% per year.

CO_2 emissions in 2030 are forecast to grow to 75.4 Mt for Intra EEA flights and 141.1 Mt for Outbound EEA flights (see table 1).

Table 10: CO_2 emissions in 2016 and 2030 on flights departing from the EEA.

	CO_2 emissions 2016 (Mt)	CO_2 emissions 2030 (Mt)	Annual growth rate (CAGR)
Intra EEA flights[14]	61.5	75.4	1.5%
Outbound EEA flights	106.2	141.1	2.0%
All EEA departing flights[15]	167.7	216.5	1.8%

Source: EU ETS data viewer and UNFCCC (reported data for 2016) and AERO-MS (2030 computational results).

Table 10 also includes the CO_2 emissions for the latest year - 2016 - for which registered emission data are available. The table shows that the expected annual growth rate of CO_2 emissions for the period 2016-2030 is 1.5% for Intra EEA flights and 2.0% for Outbound EEA flights. The ICAO baseline scenario as implemented in the AERO-MS assumes an improvement of the fuel burn characteristics of new aircraft entering the fleet up to 2030. Also, in line with ICAO specifications, it is assumed that load

[13] The IPR for the AERO-MS is with EASA. Information regarding the model can be found on: https://www.easa.europa.eu/easa-and-you/environment/impact-assessment-tools

[14] Data for 2016 are reported in the EU ETS data viewer [5].

[15] Data for 2016 are reported to UNFCCC [4].

factors will go up over time. As a result, the fuel-efficiency per RTK will improve by 1.0% to 1.5%, depending on the route. The expected technology improvements and higher load factors are insufficient to stop the growth in CO_2 emissions on flights departing from the EEA.

D.4 Emission coverage of EU ETS and CORSIA in relation to the indicative aviation emission target

In the latest regulation of December 2017 the EU has prolonged the Intra EEA scope of the EU ETS for aviation [7]. There is no specific date for a further review of the scope so that there is flexibility to review progress on CORSIA. Intra EEA flights thus remain subject to the EU ETS. However, under the new regulation the linear reduction factor (LRF) of 2.2% per year is also applied to the aviation cap from 2021 onwards.

Presently it is not clear how both CORSIA and the EU ETS will work together after 2020. We assume that both the EU ETS and CORSIA will be applied to international Intra EEA flights in such a way that EEA Member States comply with international law (i.e. international flights between EEA countries are subject to CORSIA) and that the EU ETS aviation cap in the latest EU regulation is also respected (see Table 11).

Intra EEA flights are predominantly operated by aircraft operators registered in EEA states. Assuming that under CORSIA states are allowed to set higher criteria for units that aircraft operators have to surrender, EEA states could require airlines registered in their states to surrender EUAs for the emissions above the CORSIA baseline on Intra EEA flights. This would mean that for international Intra EEA flights emissions above 2020 levels are formally subject to CORSIA and emissions between the EU ETS cap and the 2020 level are formally subject to the EU ETS, but that in practice airlines have to surrender EUAs under both regimes.

For Outbound EEA flights, operated by airlines registered in both EEA and non-EEA states, only CORSIA would apply whereby international credits need to be surrender for emissions above the CORSIA baseline. Domestic flights within EEA Member States are not subject to CORSIA and will remain under the EU ETS as in the current situation. A summary of the assumptions on the EU ETS and CORSIA for 2030 is provided in Table 11.

At present it is unknown whether the United Kingdom will remain in the EU ETS after Brexit. The UK white paper on the future relationship between the UK and the EU states that a consistent approach to carbon pricing is necessary for the market to function, which could be delivered by remaining in the EU ETS [8]. For the analysis in this paper we assume that the United Kingdom is still part of the EU ETS in 2030. Hence, in this analysis the EEA also in 2030 relates to the current EU28 plus Norway, Iceland and Liechtenstein.

For Outbound EEA flights the emissions above the CORSIA baseline need to be offset by international credits. Given the growth in international aviation emissions following from the ICAO baseline scenario, the CORSIA offset rate in 2030 is computed to 28%. However, not all Outbound EEA flights will be covered by CORSIA. At present 42 States from outside the EEA have voluntary signed up to CORSIA [1] and it has been assessed that another 7 States have to mandatory join the second phase of CORSIA from 2027 onwards16. About 85%of the emissions on the Outbound EEA flights are on flights to States which are currently expected to have joined CORSIA in 2030. Hence 15% of the emissions on the Outbound EEA flights will be on flights to States not participating in CORSIA. These emissions will not be subject to any Market Based Measure. All in all, it is estimated that by 2030 about 24% of the

[16] Brazil, Chile, China, India, Philippines, Russia and South Africa.

emissions on Outbound EEA flights will be offset by international credits. This equals 33.6 Mt (see Figure 12)

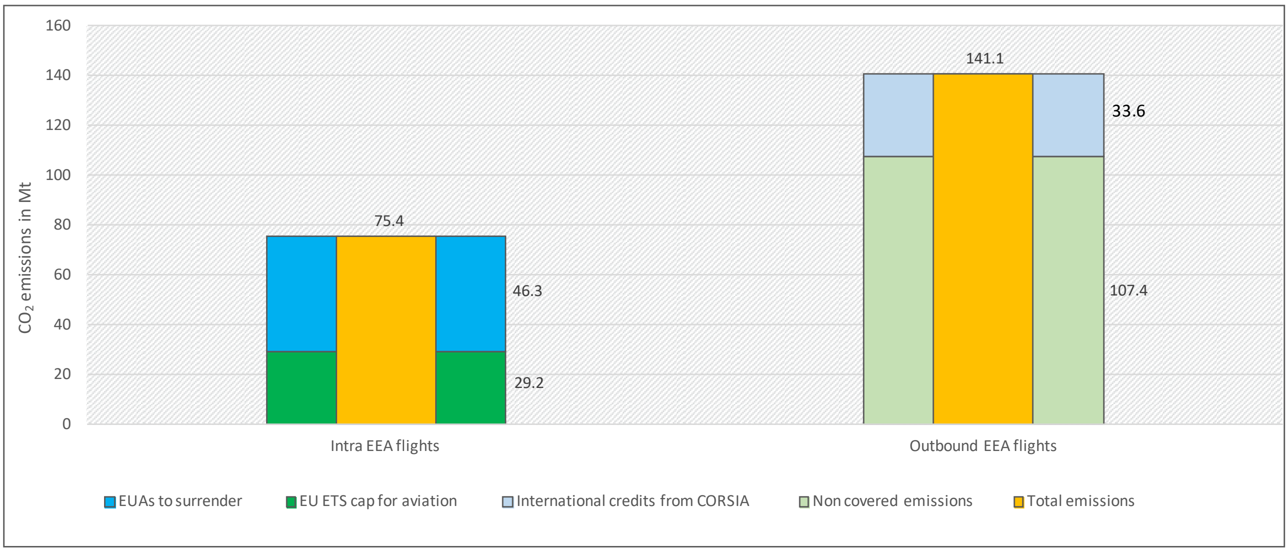
Table 11: Assumptions on EU ETS and CORSIA in 2030

Feature	EEA domestic flights	International Intra EEA flights	Outbound EEA flights covered by CORSIA
Cap/Baseline	EU ETS cap (95% of 2004-2006 with LRF of 2.2% per year in 2021-2030)	EU ETS cap (95% of 2004-2006 with LRF of 2.2% p.a. in 2021-2030) minus emissions above 2020 level; CORSIA baseline (2020 level)	CORSIA baseline
Surrendering requirements	Emissions above the EU ETS cap (EU ETS)	Emissions above the EU ETS cap but below the CORSIA baseline (EU ETS); Emissions above the CORSIA baseline (CORSIA)	Emissions above the CORSIA baseline (CORSIA)
Eligibility of units	EUAs	EUAs for emissions above the EU ETS cap but below the CORSIA baseline; EUAs for emissions above the CORSIA baseline (additional requirement set by EEA States)	International credits eligible under CORSIA
Notes		International EEA flights fall under two regimes but in practise only EUAs need to be surrendered	Outbound EEA flights covered by CORSIA are between EEA Member States and non-EEA States participating in CORSIA
Policy	Additional contribution to target	Remaining shortfall	Legal, economic and political barriers to the implementation of the policy
No issuance of EUAAs under the EU ETS (cap for aviation is 0)	Up to 29.2 Mt	At least 28.3 Mt	Would require an amendment of Directive 2008/101/EC
Require airlines to surrender EUAs for non-CO2 climate impacts of intra-EEA flights	Up to 75.4 Mt (multiplier of 2)	Nil (multiplier of 2)	Would require a new directive. Uncertain what the multiplier would be.
Require EEA-airlines to surrender EUAs in CORSIA for Outbound flights	Up to 16.8 Mt	At least 40.7 Mt	Distortion of markets where airlines from EEA States and non-EEA States compete
Introduce an aviation tax of	Up to 57.5 Mt (at 35 €/EUA)	Nil	Would require EEA-wide coordination on taxes

Feature	EEA domestic flights	International Intra EEA flights	Outbound EEA flights covered by CORSIA
8 €/pax for Outbound flights in order to acquire EUAs			Earmarking may not be acceptable for all EEA-Member States
Require aircraft at EU airports to uplift 50% sustainable aviation fuels for Outbound flights	Up to 57.5 Mt (if sustainable fuels with 80% lower carbon emissions)	Nil	Would require a new directive. Uncertain whether sufficient amounts of sustainable aviation fuels are available. High costs of sustainable aviation fuels

Source: Own compilation

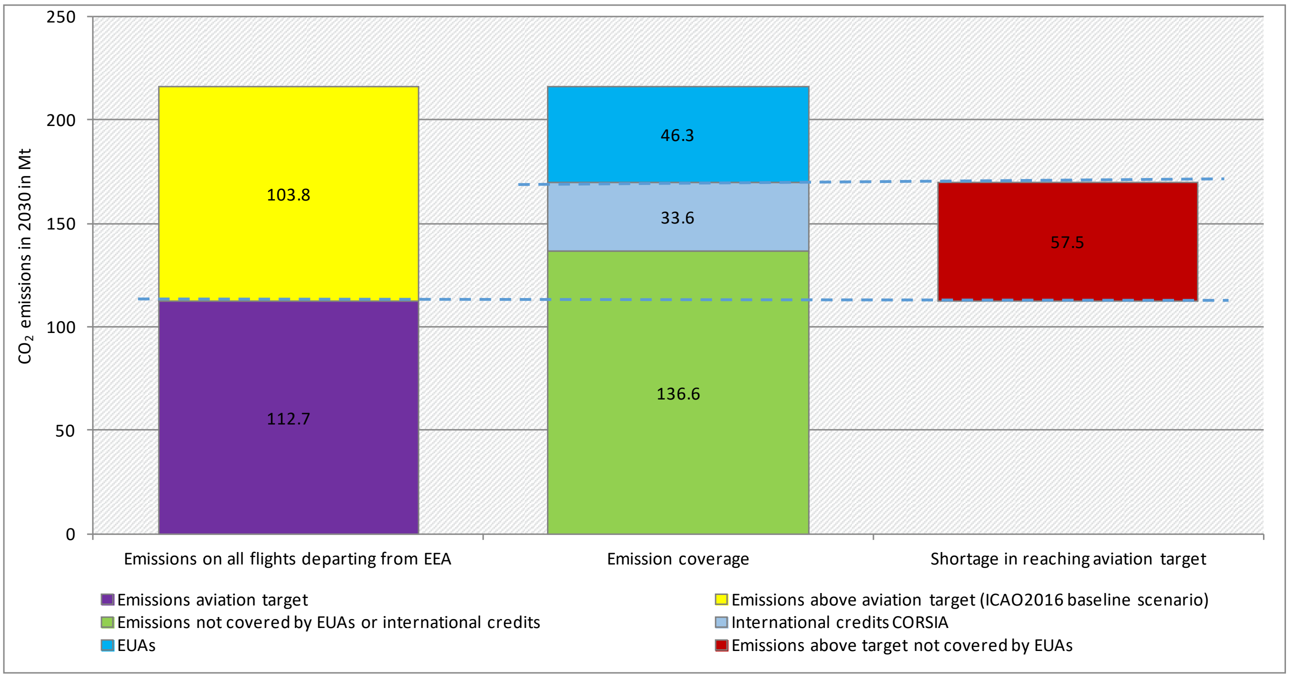
Figure 12: Aviation emissions in 2030 on flight departing from the EEA and emission coverage by Market Based Measures



Source: AERO-MS

In a next step we have looked to what extent the EU aviation emissions target for 2030 will be reached with both the EU ETS and CORSIA in place. Hereby it is of importance that EUAs represent reductions in other EU ETS sectors and contribute to reaching the EU target. International credits, though, are expected to stem from countries outside of the EEA and thus not contribute to reaching the EU target. Figure 13 shows the shortage in reaching the aviation emissions target in 2030. This shortage is estimated to 57.5 Mt and is mainly because at present no Market Based Measures are foreseen for Outbound EEA flights which contribute to reaching the EU aviation emissions target.

Figure 13: Contribution of Market Based Measured to reaching the aviation emissions target in 2030



Source: AERO-MS

D.5 Possible ways to reach the indicative aviation emission target

The first obvious way to reach the EU aviation emission target in 2030 would be to lift the derogation for flights departing or arriving at airports outside the EEA from the EU ETS. If the derogation would be lifted, aircraft operators would have to also surrender EUAs for Outbound EEA flights. If for Outbound EEA flights a similar cap would be applied as for Intra EEA flights (95% of 2004-2006 with an LRF of 2.2% from 2021 onwards) the EU aviation emission target would be reached. However, about half of the Outbound EEA flights is operated by airlines from non-EEA countries. Given the international disputes with the original EU ETS scope for aviation in 2012, it does not seem feasible to get non-EEA countries to accept their operators being subject to the EU ETS for flights between EEA and non-EEA countries. This also because from 2021 onwards CORSIA will be in place as the internationally agreed MBM to address global international aviation emissions.

In an UBA paper various option in which CORSIA and the EU ETS can co-exist have been explored [9]. We have taken elements of these options which could be added to the EU ETS and CORSIA option described in Table 11. In fact, these represent supplemental policy measures which could be taken in order to reach the aviation emissions target. Possible supplemental policy measures are:

1. Lower the EU ETS cap for Intra EE flights.
2. Additional EUAs to surrender for Intra EEA flights for non-CO_2 climate impacts.
3. Additional requirements for EEA airlines for their operations on Outbound EEA flights.
4. Introduce tax for Outbound flights and use proceeds to buy EUAs.
5. Require airlines to use sustainable aviation fuels on Outbound EEA flights.

In the first policy measure the EU ETS cap for Intra EEA flights is further adjusted downwards to ensure that the demand for EUAs from the aviation sector increases. In the default option the cap is 29.2 Mt (see Figure 12). Hence the maximum potential of this measure is to reach an additional annual demand for EUAs of 29.2 Mt. This in case airlines would have to surrender EUAs for all their emissions on Intra EEA flights. Note that the additional demand for EUAs is lower compared to the shortage in reaching the aviation target in 2030 (see Figure 13).

The non-CO_2 impacts of aviation account for about half of the climate impact of aviation in terms of radiative forcing. Despite provisions in the recital of an EU Directive [10] no action has been taken so far to address these impacts. It is possible to include non-CO_2 climate impacts of aviation in the EU ETS, provided that a CO_2-equivalence can be established [11]. The non-CO_2 impacts account for about 25% - 50% of the total climate impact of aviation. The range results from the fact that there is scientific uncertainty about the contribution of aviation to cloudiness [12]. Hence, an EU ETS requirement could be that 1.3 - 2 EUAs needs to be surrendered for each ton of CO_2 emitted on Intra EEA flights (multiplier of 1.3 - 2). For the year 2030, this would mean an additional demand of EUAs of 22.6 - 75.4 Mt from the aviation sector. The disadvantage of this option would be that it requires new regulation and that there is uncertainty about the size of the non-CO_2 climate impact of aviation.

It would also be possible to reach the aviation target in 2030 by combining the first two policy measures. The above options would mean that Intra EEA flights would fully take account of reaching the EU aviation emissions target. Market Based Measures for Outbound EEA flights would not contribute at all to reaching the target. Therefore, we have also identified a number of policy measures which address the Outbound EEA flights.

One policy measure is that under CORSIA EEA States set additional requirements to the eligible units for Outbound flights operated by EEA airlines. This could be that EEA states require the airlines registered in their States to surrender EUAs for the emissions above the CORSIA baseline for also Outbound flights (note that we have already assumed this will be the case for the Intra EEA flights in the default option – see Table 11). Hereby we assume that for EEA states it will not be feasible to set additional requirements to the eligible units to be surrendered for emissions on Outbound EEA flights operated by airlines which are registered outside the EEA. About half of the emissions and required credits on Outbound EEA flights is related to EEA airlines. The additional demand for EUAs will therefore be around 16.8 Mt (half of 33.6 Mt –see Figure 12), which is insufficient to fully compensate for the shortage in reaching the target. The additional requirements will possibly imply a larger CORSIA related costs for EEA airlines for their operations on Outbound EEA flights relative to the cost increase for non-EEA aircraft operators. Therefore, there might be a competitive issue.

A fourth option is to introduce an additional policy instrument for Outbound EEA flights to ensure that these flights contribute to meeting the EU emission objectives, viz. a tax of which the proceeds could be used to buy EUAs. The tax can be an environmental departure tax per aircraft flight or a ticket tax per passenger. The environmental aircraft departure tax can be linked to the CO_2 certification of aircraft which will be introduced as part of the ICAO CO_2 emission standard. Both a passenger ticket tax and environmental aircraft departure tax could be introduced for all Outbound EEA flights.

We have estimated what the tax per passenger would have to be to reach the target. It is expected that the EUA price in 2030 will be about 35€ per ton of CO_2 [13]. Hence, in order to buy 57.5 Mt of EAUs (shortage in reaching the target in 2030 – see Figure 13) in 2030 about 2 billion € is required. According to the ICAO baseline scenario there will be around 250 million passengers on Outbound EEA flights (for 2016 this number was about 175 million [14]). This implies a required tax level per departing passenger on Outbound EEA flights in 2030 of about 8€[17]. Because the tax would be applicable to airlines registered in both EEA and non-EEA countries, no competitive issues are foreseen. Also, the required tax level per passenger will not imply a significant impact on demand for airlines. Presently several EU countries (Germany, France and the UK) already have a passenger departure tax in place for intercontinental flights. Hence it is legally feasible to introduce such a tax.

[17] If cargo would also be taxed, the tax level can be somewhat lower.

There are however a number of drawbacks with this policy measure. In principle, each Member States can decide on how to use the tax proceeds. Several EEA Member States will possibly object to earmarking the revenues for specific emissions reduction purposes. Moreover, using tax revenues to buy EUAs and thus influence the market would probably be politically controversial. Also, non-EEA States might see it as an indirect way of including operations of their airlines into the EU ETS.

A final option is to require aircraft that uplift fuel at EEA-airports to lower the carbon emission factor of the fuel so that the target will be met. The carbon emission factor can be lowered by using blends of fossil fuels with fuels that have low or zero net carbon emissions over their lifecycle, such as advanced biofuels or synthetic power-to-liquid fuels generated with renewable electricity. In order to meet the shortfall of 57.5 Mt of CO_2, emissions on Outbound EEA flights would need to be reduced by this amount. The emissions are estimated to amount to 141.1 Mt, so the carbon emissions would need to be reduced by 57.5/141.1 = 41%. If the advanced fuels have 80% lower emissions over their lifecycle than fossil fuels, the fuels uplifted for Outbound flights would need to contain 50% of sustainable aviation fuels.

The main disadvantage of this option is that it is not clear whether sufficient amounts of sustainable aviation fuels can be produced by 2030. Currently, biofuels are the only sustainable aviation fuel used in the aviation sector, and the amount used is negligible compared to the total emissions [15]. Also, at present sustainable aviation fuels are significantly more expensive compared to fossil fuels.

Table 12: Overview of policy options to enhance the contribution of aviation to meeting the EU 2030 climate target

Policy	Additional contribution to target	Remaining shortfall	Legal, economic and political barriers to the implementation of the policy
No issuance of EUAAs under the EU ETS (cap for aviation is 0)	Up to 29.2 Mt	At least 28.3 Mt	Would require an amendment of Directive 2008/101/EC
Require airlines to surrender EUAs for non-CO_2 climate impacts of intra-EEA flights	Up to 75.4 Mt (multiplier of 2)	Nil (multiplier of 2)	Would require a new directive. Uncertain what the multiplier would be.
Require EEA-airlines to surrender EUAs in CORSIA for Outbound flights	Up to 16.8 Mt	At least 40.7 Mt	Distortion of markets where airlines from EEA States and non-EEA States compete
Introduce an aviation tax of 8 €/pax for Outbound flights in order to acquire EUAs	Up to 57.5 Mt (at 35 €/EUA)	Nil	Would require EEA-wide coordination on taxes Earmarking may not be acceptable for all EEA-Member States
Require aircraft at EU airports to uplift 50% sustainable aviation fuels for Outbound flights	Up to 57.5 Mt (if sustainable fuels with 80% lower carbon emissions)	Nil	Would require a new directive. Uncertain whether sufficient amounts of sustainable aviation fuels are available. High costs of sustainable aviation fuels

Source: Own compilation

Table 12 summarizes the options for enhancing the contribution of aviation to meeting the EU 2030 climate target. The table includes the main legal, economic and political barriers to the implementation of the various policy measures.

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E Promoting transition through an aviation innovation fund (AIF)

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Abstract

In this paper we assessed how low- or zero-carbon fuels and other new and improved technologies which facilitate the transition of the aviation sector to a pathway compatible with the Paris Agreement can be fostered by establishing an Aviation Innovation Fund (AIF). There are three main strands of technological developments geared towards full decarbonisation of the aviation industry by 2050: biofuels, synthetic fuels (e-fuels) and electric aircraft. The main reason why all three of these developments should be eligible for funding is that the technologies are not mutually exclusive and are at different stages of development. However, given the different stages of these technologies, it would be appropriate to establish separate windows for each of the main technological strands.

As an example, we analyzed how the window for synthetic fuels could potentially be implemented by establishing a drop-in quota flanked with a subsidy for each litre of e-fuel which covers on average the price difference between fossil and synthetic kerosene so that e-fuel providers can compete with fossil kerosene suppliers. The subsidies would be paid for a period of 10 or 12 years upon the delivery of the product. These subsidies would be auctioned repeatedly to ensure competition between different e-fuel suppliers and to allow for the gradual expansion of e-fuel production capacity in line with the increase of the drop-in quota. We conclude that establishing an AIF would promote the uptake of innovative technologies in the aviation sector. Since aviation is an international operating sector to a large extent, such a fund would be most effective if implemented at the global level. However, there are options to establish a fund unilaterally or with a group of more ambitious countries to facilitate similar developments at the global level at a later stage.

Kurzbeschreibung

In diesem Papier haben wir untersucht, wie kohlenstoffarme oder kohlenstoffarme Kraftstoffe und andere neue und verbesserte Technologien, die den Übergang des Luftverkehrssektors zu einem mit dem Pariser Abkommen kompatiblen Weg erleichtern, durch die Einrichtung eines Aviation Innovation Fund (AIF) vorangetrieben werden können. Es gibt drei Hauptstränge technologischer Entwicklungen, die auf eine vollständige Dekarbonisierung der Luftfahrtindustrie bis 2050 abzielen: Biokraftstoffe, synthetische Kraftstoffe (E-Kraftstoff) und Elektroflugzeuge. Der Hauptgrund, warum alle drei dieser Stränge förderfähig sein sollten, ist, dass sich die Technologien nicht gegenseitig ausschließen und sich in unterschiedlichen Entwicklungsstadien befinden. Angesichts der unterschiedlichen Phasen dieser Technologien wäre es jedoch angebracht, für jeden technologischen Hauptstränge separate Fenster einzurichten.

Als Beispiel haben wir analysiert wie das Fenster für synthetische Kraftstoffe möglicherweise umgesetzt werden könnte, indem eine Drop-In-Quote festgelegt wird, die von einer Subvention pro Liter E-Kraftstoff flankiert wird, die im Durchschnitt den Preisunterschied zwischen fossilem und synthetischem Kerosin abdeckt, so dass e Kraftstoffanbieter können mit Lieferanten fossiler Kerosin konkurrieren. Die Subventionen würden für einen Zeitraum von 10 oder 12 Jahren bei Lieferung des Produkts gezahlt. Diese Subventionen würden wiederholt versteigert, um den Wettbewerb zwischen verschiedenen E-Kraftstoff-Anbietern zu gewährleisten und die schrittweise Erweiterung der E-Kraftstoff-Produktionskapazität im Einklang mit der Erhöhung der Drop-In-Quote zu ermöglichen. Wir kommen zu dem Schluss, dass die Einrichtung und der AIF die Einführung innovativer Technologien im Luftverkehrssektor fördern würden. Da die Luftfahrt weitgehend ein internationaler

operierender Sektor ist, wäre ein solcher Fonds am effektivsten, wenn er auf globaler Ebene eingerichtet würde. Es gibt jedoch Möglichkeiten, einseitig oder mit einer Gruppe von ambitionierteren Ländern solch einen Fonds einzurichten, um später ähnliche Entwicklungen auf globaler Ebene zu erleichtern.

List of Abbreviations

AIF	Aviation Innovation Fund
BAFA	Bundesamt für Wirtschaft und Ausfuhrkontrolle (Federal Office for Economic Affairs and Export Control)
CAAFI	Commercial Aviation Alternative Fuels Initiative
CCfD	Carbon Contract for Difference
CCS	Carbon Capture and Storage
CCU	*Carbon Capture and Utilisation*
CO2	Carbon Dioxide
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
DAC	Direct Air Capture
EEG	Erneuerbare-Energien-Gesetz (Renewable Energy Law)
EGKF	Energie- und Klimafonds (Energy and Climate Fund)
EIF	European Investment Fund
EIF	European Investment Fund
EU	European Union
EU ETS	European Union Emissions Trading System
EUAA	European Aviation Allowances
FRL	Fuel Readiness Level
FRL	Fuel Readiness Level
GHG	Greenhouse Gas
HEFA	Hydroprocessed Esters and Fatty Acids
ICAO	International Civil Aviation Organization
IF	Innovation Fund (established under the EU ETS)
IKI	International Climate Initiative
KfW	Kreditanstalt für Wiederaufbau (Credit Institute for Reconstruction)
NKI	National Climate Initiative
PCF	Private Sector Facility
PtL	Power-to-Liquid
R&D	Research and Development
R&P	Rules and Procedures
TRL	Technology Readiness Level
UNFCCC	United Framework Convention on Climate Change
VAT	Value Added Tax

E.1 Introduction

Aviation accounts for more than 2% of global CO_2 emissions and the share is increasing due to a strong growth in emissions despite efficiency improvements. Radical technological change is required for the de-carbonization of international aviation. In order to be in line with the Paris

Agreement temperature goals, full decarbonization by 2050 should be pursued (IPCC 2018). Since many conventionally fuelled aircraft which are currently on order may still fly around that time, and because climate-neutral technologies are not available on the market (e.g. battery-electric aircraft), low- or zero-carbon drop-in fuels need to enter the fuel mix in increasing shares between now and 2050.

Low- or zero-carbon fuels can be biofuels or synthetic fuels, so called electro- or e-fuels, generated from renewable electricity (power-to-liquid or PtL). Both fuel types are currently available in very small quantities so the transition fund should aim to increase production capacity, thus lowering the unit costs of production through economies of scale and learning. Neither the EU ETS nor CORSIA will provide sufficient incentives to make climate-neutral fuels competitive (CE Delft 2015).

However, despite post-fossil fuels many other new and improved technologies will be required to reduce and finally eliminate aviation's impact on the global atmosphere. This includes improved airframes and engines and potentially operational improvements such as climate-friendly routing to avoid non-CO_2 impacts of aviation.

In this paper we assess how such technological developments which facilitate the transition of the aviation sector to a pathway compatible with the Paris Agreement can be fostered by establishing an Aviation Innovation Fund (AIF). An AIF should basically be open to addressing technical improvements of other (environmental) issues as well. We first examine experiences gathered with similar funds and instruments (chapter E.2) and then the more fundamental aspects of such a fund, addressing questions such as its purpose, its core focus, how the transitional momentum can be ensured and what actors the fund should address (chapter E.3). In a second step we focus on more administrative issues such as sources of funding, how the budget should be spent and who and where such a fund should be established (chapter E.4). Finally, we draw conclusions and provide initial recommendations (chapter E.5).

This paper should not be understood as a blue print for how such a fund should precisely be implemented but should rather serve as a discussion starter. Before establishing such an AIF, an in-depth discussion with stakeholders, particularly from the addressed industries (airlines, aircraft manufacturers, fuel producers and suppliers, airports and other providers of fuel infrastructure) should be initiated, mainly with the view to refining the design of the fund in such a way that it is as effective as possible in fostering the transition of the aviation sector to a pathway compatible with the Paris Agreement.

E.2 Experience gathered with similar funds and instruments

There are a number of funds in a broad range of sectors and countries or bodies which aim to foster innovation or transition towards a fundamental different environment. The list below is by no means complete but illustrates the variety of initiatives in which the instrument can be applied:

- Innovation fund of the German Federal Ministry for Health (G-BA 2019): It was established in 2015 and spent 300 mil €/year between 2016 and 2019 and aims to promote telehealth, improving the provision of medical services in underdeveloped regions, extension of geriatric services and increasing drug safety. Currently there are discussions about extending this fund beyond 2019 (GKF 2019). Even though the purpose of this fund is entirely different than the one considered in this paper, it illustrates that there are already positive experiences with such funds in Germany. In addition, some of the administrative designs such as the expert advisory body as well as the rules of procedures should be scrutinised if such a fund were established in Germany.[18]

- Innovation fund of the GIZ (2019): The financial resources were provided by the German Federal Ministry for Economic Cooperation and Development; the fund supported some 250 projects in several developing countries between 2016 and 2019.
- Eiffel Energy Transition Fund (EIG 2019): This fund aims at supporting the energy transition by being an active lender to renewable energy developers and energy efficiency operators. It provides short-term credits and is endowed with 400 mil €.
- Private sector facility (GCF 2019): The Green Climate Fund was established under the United Framework Convention on Climate Change (UNFCCC) and aims to mobilize 100 bn US$/year from 2020 onwards to be used to finance adaptation and mitigation efforts. The private sector facility (PCF) provides loans for private entities. However, encouraging innovation is only one goal among others (small projects, capacity building, public-private partnership, etc.).
- Investments in infrastructure and environmental funds (EIF 2019): This initiative of the European Investment Fund (EIF) does not directly focus on innovation. However, it invests in equity and debt funds which are focused on projects dealing with climate action and/or infrastructure. It could be considered, therefore, as an example for sources of co-funding or co-financing.
- NER300 (EC 2010):[19] It was the first fund established under the EU ETS geared to innovation. The NER300 received its name from the 300 mil EUAs of the new entrants' reserve. It was devoted to promoting the development of carbon capture and storage (CCS) and innovative renewable energy technologies. The lessons learned from this experience were considered in the design of the innovation fund (next item).
- Innovation Fund (EC 2019a):[20] This fund is endowed with revenues of 450 mil EUAs for the period of 2020 to 2030 plus the unspent resources from NER300. Depending on the EUA price, this may amount to financial resource of some 10 bn €. The innovation fund (IF) focuses on 5 technology areas: 1) low-carbon technologies in energy intensive industries such as steel, cements, pulp & paper; 2) carbon capture and utilisation (CCU); 3) carbon capture and storage (CCS); 4) innovative renewable generation; 5) energy storage (EC 2019b). The selection criteria include greenhouse gas emissions avoidance, degree of innovation, project maturity, scalability and cost efficiency (Doubrava 2019). Compared to the NER300, it is open to more projects, provides support in more flexible ways, has a simpler selection process and makes use of synergies with other funding programmes. The first call for proposals is expected to be published in mid-2020.

[18] https://innovationsfonds.g-ba.de/innovationsausschuss.

[19] https://ec.europa.eu/clima/policies/innovation-fund/ner300_en.

[20] https://ec.europa.eu/clima/policies/innovation-fund_en.

From this short overview, a few conclusions can be drawn for the design and establishment of an AIF:

- The instrument of an innovation fund has been used in the past and is being used both at national and at international/multilateral levels to foster climate-related innovations. Since aviation is an international sector, such an AIF would be most effective if implemented at international level, e.g. at a global or EU level. However, since such developments are usually slower than those at national level, such an AIF could be initially established at national level with the view to expanding it to the EU level and finally to a global one. If such a strategy is pursued, the design and implementation can build on experiences gathered with the fund in Germany, even if such experiences are made in other sectors.
- The AIF should be implemented in such a way that it allows use of synergies with other funding instruments such as the fund of the EIF or Horizon 2020 and with all types of financing instruments including grants, loans, credits and equity.
- Although the IF under the EU ETS focuses on other technology sectors, it seems to be the closest 'neighbouring' instrument to the AIF, at least at the EU level. Lessons learned from the NER300, the IF's 'predecessor', should be taken into account when designing and implementing the AIF.

Duwe and Ostwald (2018) have analysed the design of the IF in more detail. Some of their conclusions and recommendations are also relevant to the design and implementation of the AIF. If the AIF is orientated to more than one technology, e.g. post-fossil synthetic fuels for renewable energy source, it may be necessary to divide the fund into different technology windows to ensure that all technologies are boosted and not just the one which seem to be the most promising in the medium term. In addition, they recommend setting ambitious selection criteria which include the emission reduction potential but should also "take into account possible long-term business opportunities, to increase the likelihood that the technology is indeed commercialised after the successful demonstration project" (Duwe and Ostwald 2018).

As the experience gathered with past innovations has shown, it is usually a long way from the initial innovation to a new technology achieving significant market penetration. One important lesson learned from these experiences is that not only the initial phase after a new invention is important to ensure a reliable further development towards market maturity but that important progress can be made with learning-by-doing once a technology is already beyond the pilot phase. Against this background, it is important that the AIF focuses not only on the initial phases of innovation but also supports new technologies as long as required, i.e. until they are competitive with traditional technologies. Obviously, the financial support should decrease at the same pace as the progress made by the new technology towards market maturity.

E.3 Conceptual design

E.3.1 Purpose of the fund

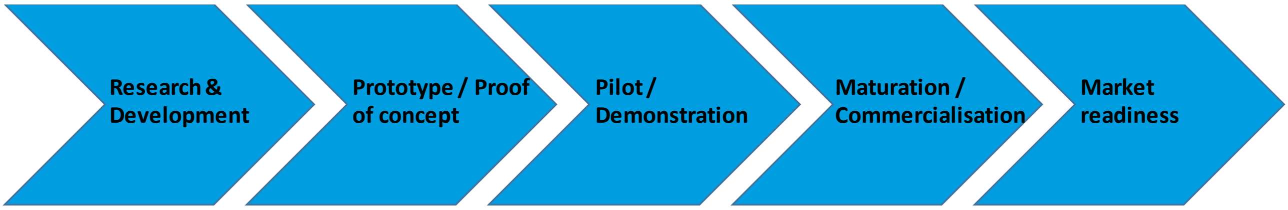
As current and future planned initiatives to enhance the sustainability of the aviation sector are clearly insufficient to guarantee widespread use of climate-neutral fuels and/or fully-electric propulsion by 2050, additional measures are required. The measure proposed in this paper is an

AIF. The goal of the AIF is to support technological breakthroughs for low-carbon innovations in the aviation sector, thereby enhancing the speed with which climate-neutral fuels and techniques are deployed in the market. This is required to ensure full decarbonisation of the aviation industry by 2050.

The stages of innovation

If new and disruptive technologies are to become successful innovations, they will have to pass through all steps of the innovation sequence. There are many ways in which the innovation sequence can be defined, e.g. through a simple linear innovation model (e.g. Ford et al. 2007), or more complicated models with more stages (e.g. Mankins 2009; 1995) and/or feedback loops (Branscomb and Auerswald 2002; Auerswald and Branscomb 2003). Regardless of the exact innovation model used, five main stages can be identified. These are shown in figure 14.

Figure 14: Stages of innovation



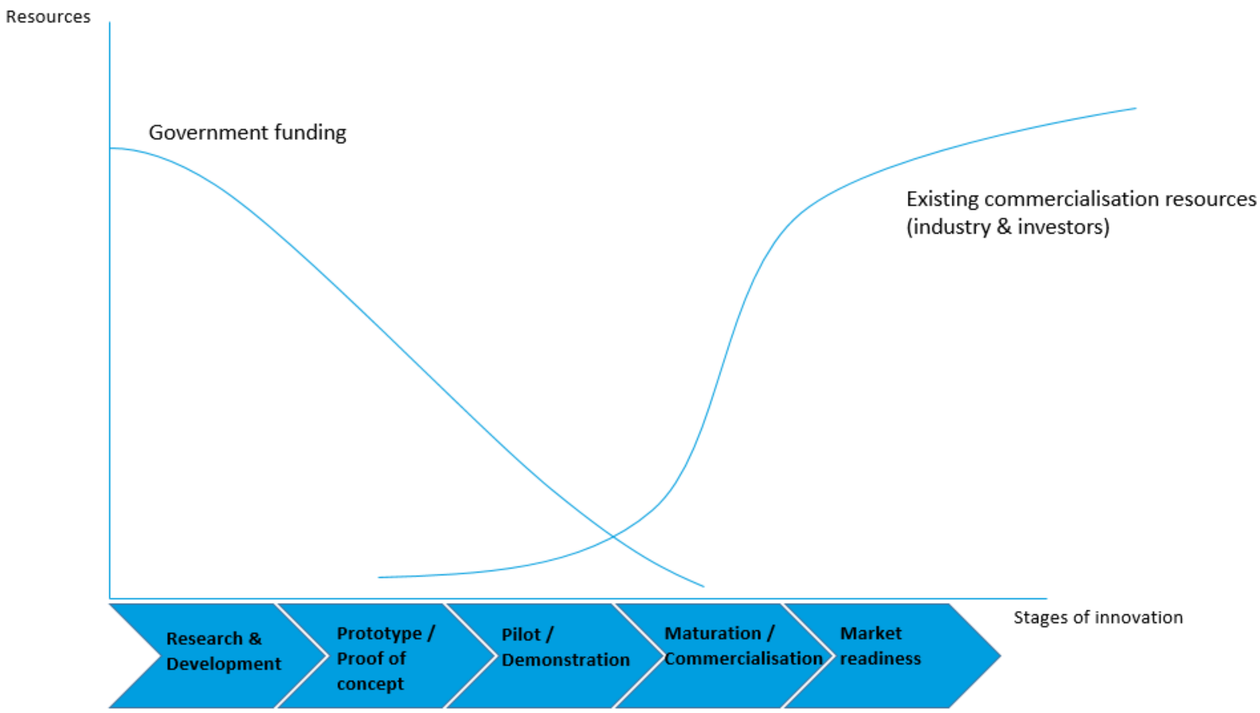
Source: Own compilation

For each innovation to become successful, the innovation is required to pass through all five stages:

- The **first stage** is the research and development stage. This stage, which often takes place at universities, or at the research and development (R&D) departments of high-tech companies, is when ideas are first pitched. The innovations are triggered based on good ideas or a challenge to a constraint that was taken for granted up to now, which is formulated as a hypothesis.
- The **second stage** leads to the creation of a prototype or proof of concept, where proof is found, and the hypothesis is either proven or denied.
- The result of the **third stage** a pilot product or service. At the end of this stage, a small-scale final product should be operational.
- The **fourth stage** centres on the upscaling of the fabrication of the product, ideally with a compelling business case. Any bugs are to be removed and the product should be near market readiness.
- By the time the product reaches the **fifth and final stage,** it should be fully ready for market. After this last stage, the product is diffused, adopted and spread amongst users.

Successful innovations pass through all five stages, however, many innovations strand in the so-called 'valley of death'. This valley separates discoveries from commercialisation and is caused by a funding disparity. In the earlier stages, funding is often provided by existing research resources. These resources can either be provided by governments for research carried out at universities, or by private companies investing in the R&D sectors. In the latter stages, commercialisation resources are provided to products. The 'valley of death' occurs where the final tail of the research resources is used up, but the commercialisation resources have not yet come about, and usually occurs between the pilot stage and the maturation/commercialisation stage.

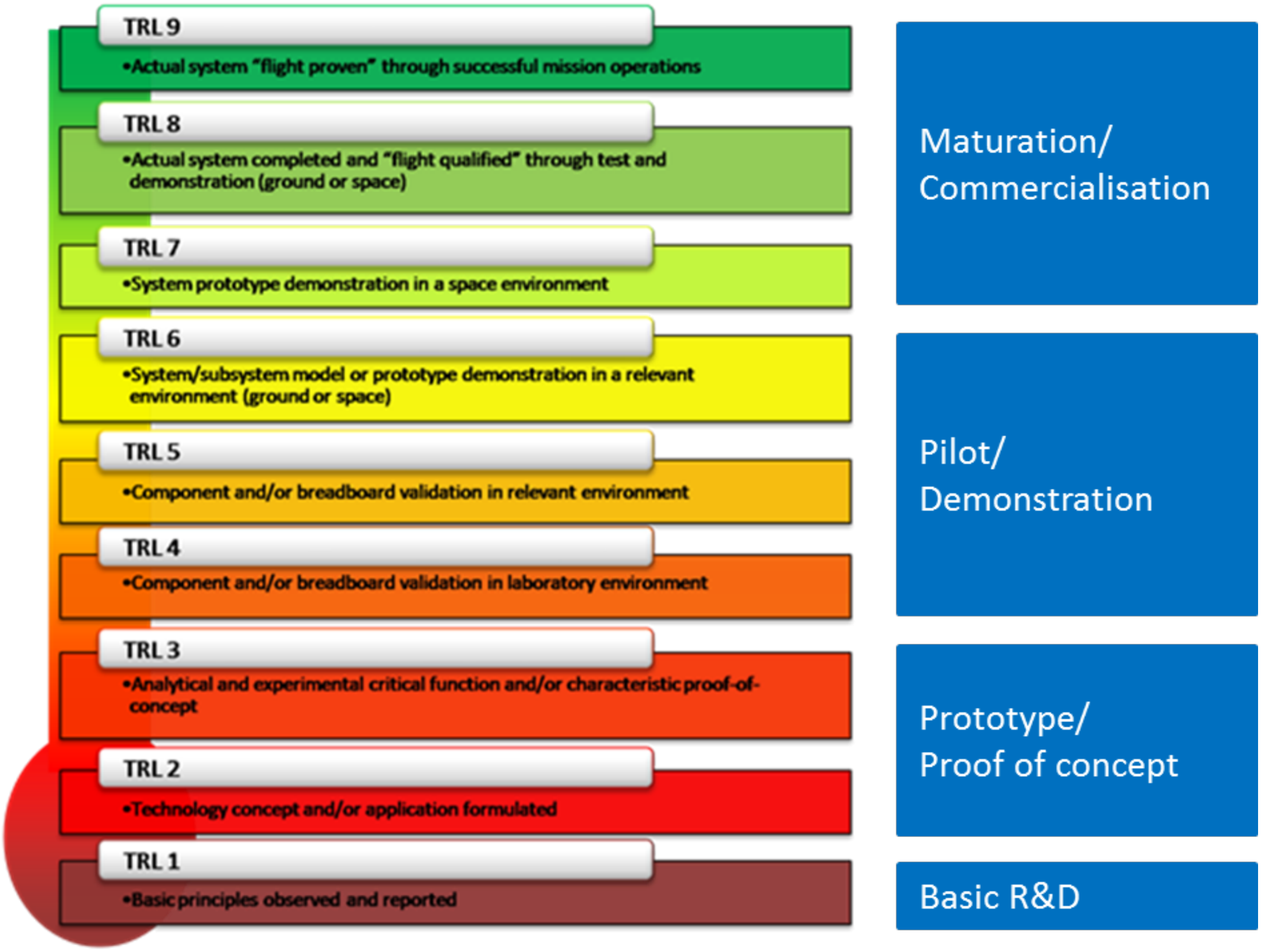
Figure 15: 'Valley of death'



Source: Based on Markham (2002) and Jackson (2011)

A more detailed way of classifying innovations is the use of Technology Readiness Levels (TRL). The concept of TRL was first coined by NASA and is a type of measurement system used to assess the maturity level of a particular technology. There are 9 TRLs of which TRL 1 is the initial and TRL 9 is the final stage. Figure 16 below illustrates the 9 TRLs and the stages of innovation they roughly correspond to. The TRLs are clearly more comprehensive and nuanced than the stages of innovation and therefore provide a more detailed walk-through of the different stages of the 'valley of death'.

Figure 16: Technology readiness levels



Source: Own compilation based on NASA (2012) and Napp et al. (2017)

Which initiatives should be funded?

The goal of the AIF is to aid the development of low-carbon innovations in aviation technologies. The design should take account of the fact that there are currently already many types of European funding in place that are geared to promoting new and disruptive technologies (e.g. Horizon2020/Horizon Europe, InvestEU, Enhanced European Innovation Council pilot, InnovFin Energy Demo Projects and Connecting Europe Facility). For specific projects aimed at the developments of synthetic kerosene, additional funding initiatives may be found within the framework of more general synthetic fuel projects. The AIF will therefore need to provide added value compared to the existing funds. Horizon2020/Horizon Europe funds are usually orientated to the earlier stages of innovation up to the proof of concept/pilot stage. Other funds such as InvestEU and Connecting Europe Facility are usually aimed at upscaling and commercializing products. Thus, there could be a funding gap precisely in the stages that are known for being the 'valley of death'.

For the AIF to have added value, its focus could therefore be on innovations currently in the 'valley of death', particularly in the pilot/demonstration stage and the maturation/commercialization stage (TRL 4 – 9). When an innovation is close to being marketable, parties with a commercial interest can generate funding. This design, purpose and structure of the AIF would resemble the IF and its predecessor the NER 300 (chapter E.2).

Based on lessons learned from the IF and given the enormous challenge of full decarbonisation by 2050, the main focus of the AIF could also be on radical and novel approaches. Analysis of the IF revealed that currently most of the available technologies for emissions reductions in industrial sectors are largely focused on the existing technology stock and marginal improvements, rather than more radical and novel approaches or new business options (Duwe and Ostwald 2018). When funding is directed to those more developed technologies in the latter stages of innovation which are largely focused on the existing technology stock and marginal improvements, the emissions reduction achieved by these more developed technologies may be insufficient to deliver the magnitude of emissions reductions required (Duwe and Ostwald 2018).

A combination of the two aims is also possible: one could use the AIF in two different ways for technologies depending on their stage of innovation. New disruptive technologies that are still in their pilot/demonstration phase could apply for grants from the AIF, whereas technologies in the maturation/commercialisation stages could apply for either grants or loans/equity guarantees from the AIF, depending on the maturity of the product and market readiness. Please see chapter E.4 for discussion of the structure of the fund.

In the above paragraphs we have tried to narrow down the focus of the AIF and the stages of initiatives that should be funded. However, we recommend conducting further research as to current funding schemes and their focus in order to ensure the added value of the AIF. In addition, it is possible that certain percentages of the fund would be dedicated to certain innovation stages. For instance, if the focus is on the pilot/demonstration and maturation/commercialisation stages (TRL 4 – 9), the vast majority of the funds in the AIF could be dedicated to innovations in this stage (e.g. 75%). The remaining 25% of the funds could then be used also to support innovations in other stages (TRL 1 – 3). These percentages should be seen as indicative; the true focus of the AIF will largely be shaped by political will. The allocation of percentages of the funding of the AIF to certain innovation stages is therefore yet to be decided.

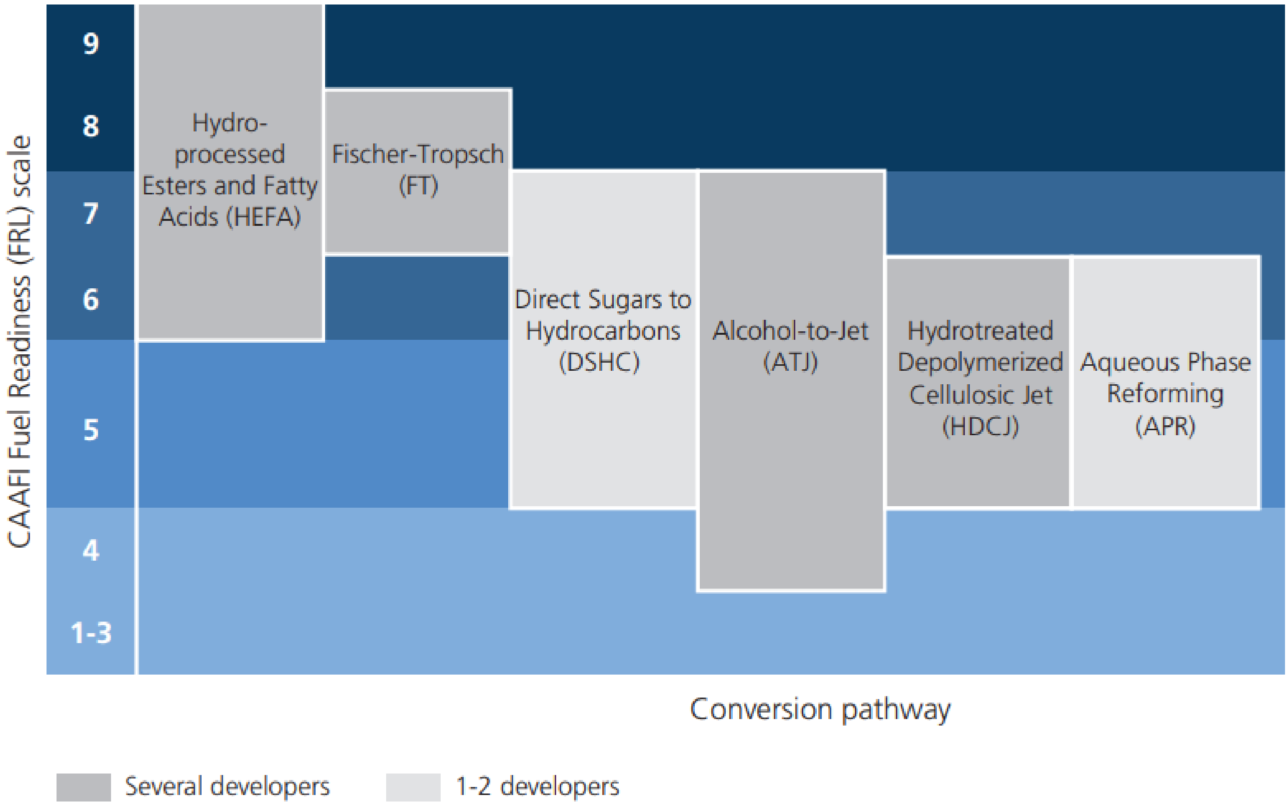
E.3.2 Focus

There are three main strands of developments geared towards full decarbonisation of the aviation industry by 2050. These are **biofuels**, **synthetic fuels** and **electric aircraft** (using renewable electricity). The first two strands focus on the fuels used by aviation, whereas the latter strand centres around aircraft/engine design. Developments of each of these strands, both fuel-related and aircraft design-related, should be eligible for funding by the AIF.

In contrast to fossil fuels, **biofuels** are produced from biomass. First-generation biofuels are derived from sugar, starch and vegetable oils contained in food crops, whereas the feedstocks used in second-generation biofuels are not derived from food crops. Biofuels were already used in the aviation industry, at airports in Oslo, Los Angeles and Stockholm, in 2016 (CE Delft 2019a). IATA (2015) distinguishes 4 main groups of feedstocks that can be used in the production of bio kerosene: residual flows from forestry, residual flows from agriculture, organic waste flows (e.g. used deep-frying fat) and cultivated biomass.

There are multiple production routes to create biofuels, depending on the feedstock used. Because of these multiple production routes, it is difficult to identify the stage of innovation in which biofuels are located overall. The 'Fuel Readiness Level' (FRL) was developed by the Commercial Aviation Alternative Fuels Initiative (CAAFI) to classify the status of production routes. They are adapted from the TRLs described above: the FRLs overlap with the stages of innovation outlined in paragraph E.3.1. The FRLs of different production routes of bio kerosene are shown in Figure 17.

Figure 17: Fuel readiness levels of production routes of bio kerosene



Source: Jong et al. (2017)

Despite the fact that there are certain production routes (e.g. HEFA or Fischer-Tropsch) that are at or close to the commercialisation stage, the use of biofuels in aviation is currently not widespread. There are three main reasons for this. Firstly, there is a price disparity between fossil kerosene and bio kerosene. In 2017, bio kerosene was two to three times more expensive than fossil kerosene (CE Delft 2017). The second main reason is related to this: there is a shortage of large-scale production capacity. Bio kerosene is currently only produced on a large scale in Los Angeles (World Energy 2018), although from 2022 onwards Europe will also have a factory in the Netherlands (SkyNRG 2019). Thirdly, biofuels are currently only verified to be blended with fossil fuels and the maximum blending limit is 50% at the moment (depending on the production route). Funds from the AIF could be used to help bring more production routes closer to the commercialisation stage, which will enhance global production capacity.

Arguably, first-generation biofuels are a sensitive issue as diverting farmland or crops from food production for biofuel production is controversial. It should therefore be carefully considered whether or not first-generation biofuels should be eligible for funding from the AIF. In addition, strict sustainability criteria for the feedstocks should be developed and applied with priority.

Synthetic fuels can be produced from hydrogen generated with renewable energy and CO_2 ideally captured from the air. By using CO_2 captured from the air, no additional CO_2 is emitted over the lifecycle of the fuel, although a flight which uses only these fuels would still not be entirely climate-neutral as aviation also causes non-CO_2 climate impacts (e.g. NO_x-emissions and contrails). Synthetic fuels have a number of advantages compared to biofuels. Firstly, they can achieve more air mileage per hectare of land (UBA 2016b; Lehmann 2018). This is regardless of which renewable energy source is used on the land (wind or photovoltaics) as the biomass grown on the same area will result in a lower amount of fuel. A second advantage that synthetic fuels use less water during the production process (UBA 2016b; Lehmann 2018). According to the UBA, synthetic fuel produced from concentrated CO_2 sources are at technological readiness level 8-9 (i.e. similar to certain types of biofuels, e.g. HEFA); however, extracting CO_2 from less concentrated sources like the air is still at the level of development and demonstration (Lehmann 2018). In addition, synthetic kerosene is much more expensive than fossil kerosene; even taking into account current developments, this price disparity is likely to remain even in 2050 when projections suggest that the cost of synthetic kerosene will be at least 50% higher than fossil kerosene in 2050 (Lehmann 2018). Funding from the AIF could be used to further synthetic fuel innovations using less concentrated CO_2 and help to upscale production and to reduce costs for synthetic fuels in general.

Electric aircraft are powered by electric motors. The electricity used can be supplied by a number of methods, e.g. batteries, solar cells and fuel cells. Hybrid electric aircraft combine electric and internal combustion motors. Much like road vehicles, the greater the share of the flight that is flown electrically, the smaller the range. Therefore, hybrid electric aircraft will have a larger range and can carry heavier weight (more passengers or freight) than a full electric aircraft can. The fact that vast amounts of energy are needed to lift and propel aircraft combined with the lower energy density in e.g. batteries will result in a slower movement towards electric aircraft for larger long-haul flights. However, medium haul and short haul aircraft may be able to transition more swiftly towards electric aircraft. Much like the developments at automobile level hybrid electric aircraft will arrive before full electric aircraft.

According to Thompson (2018), there are currently almost 170 electrically propelled aircraft being developed around the world. This number is expected to have risen to over 200 by the end of 2019 (Thompson 2019). Only a limited number of them are geared to current commercial aviation purposes, as roughly half are designed as urban air taxis (with vertical take-off and landing) while only 70 are designed for general aviation. Many electric aircraft innovations are still in the R&D stage. However, at the 2019 Paris Air Show Eviation presented a prototype of Alice, an aircraft designed to take 9 passengers up to 650 miles at a cruise speed of 240 knots and expected to enter service in 2022. Such short haul aircraft (for flights up to 800 kilometres) with a limited number of passengers would likely be the first category of aircraft to be developed with a (hybrid) electric powertrain. According to Roland Berger's panel of aerospace experts, the first >50 seat hybrid-electric aircraft will enter fare-paying passenger service by 2032 (Thompson 2018), although others have argued that this could occur as early as the late 2020s (Bowler 2019; Risen 2019). Funds from the AIF could enhance research efforts geared to the development of aircraft suitable for commercial passenger and freight aviation and help to speed up the process of electrifying larger aircraft suitable for longer distances.

Overall, the main reason why all three of these developments should be eligible for funding is that the technologies are not mutually exclusive and are at different stages of development. Therefore, each technology will have a role to play in the transition to full decarbonisation by 2050. Biofuels are currently available on a small scale, mainly produced from used cooking oil with a HEFA process. New processes with different, more widely available feedstocks require further development. Synthetic fuels are not yet commercially available but may become available in the next decades, while electric aircraft are probably a more distant technology.

E.3.3 How could transitional change be ensured?

There are numerous ways in which transitional change could be ensured. As mentioned in the previous paragraph, all three tracks (biofuels, synthetic fuels and electric aircraft) may be necessary to achieve full decarbonisation of the aviation industry by 2050. Each of the technologies may have a role to play over the time period between now and 2050.

A universal problem towards achieving full decarbonisation across the entire economy is the fact that carbon emissions are not accurately priced and as result many products, including fossil fuels, are too cheap. Aviation is currently already priced under EU ETS and will soon also be priced under CORSIA, a global market mechanism established under ICAO geared to offsetting and reducing the *growth* in emissions from the base years 2019-2020. However, the prices at which EU Emission Allowances are currently purchased are too low to fully internalise the external climate change costs of aviation and to achieve transitional change. In 2018, the average price of aviation emission allowances (EUAA) was 18.40 €/tCO_2 (EEA 2019), far below the climate change avoidance costs of 100 €/tCO_2-equivalent mentioned in the Handbook of External Costs of Transport (CE Delft; infras; Ricardo 2019). Furthermore, airlines only need to hand over emission allowances or offsets for the CO_2 emitted, non-CO_2 impacts are fully ignored. CORSIA will start with a voluntary phase from 2021 onwards. It is currently unclear with what criteria the offsets in CORSIA will need to comply, but it is unlikely that the price of CORSIA will approach the 100 €/tCO_2-equivalent. In fact, research conducted by the NCI (2019) revealed that 3.8 bn offset units will be available for less than 1.00 €/t CO_2 each.

One option in bringing about the required transitional change is to gradually increase the price of fossil kerosene, e.g. by tightening the cap of the EU ETS and phasing out free allocation of allowances or a fuel tax. There may be legal obstacles to taxes arising from air service agreements. However, it is possible to implement a fuel tax on national flights and to agree on a bilateral basis to tax fuels on flights between countries. The US, for example, already levies taxes on fuel used on domestic flights (CE Delft 2018). Also, the EU Energy Taxation Directive allows for an excise duty on aviation fuels for flights between Member States if the Member States concerned agree to do so (CE Delft, 2018). This gradual transition towards more expensive fossil fuels is a crucial step towards decarbonisation as it implies a financial incentive to reduce fossil fuel consumption. Similarly, it reduces the price disparity between fossil and non-fossil kerosene, which will aid in the further deployment of non-fossil fuels.

A second option is to levy taxes on aviation tickets or on flights (CE Delft 2019b). This option does not have any of the legal obstacles of fuel taxes, but it has the disadvantage that a ticket tax does not constitute a carbon price since flights would be taxed regardless of what fuel they use.

An additional benefit of the options is that they create revenues for financing the AIF. As a result, the sector itself, and the people using the service, raise funds for the AIF. If general tax revenues were used to fund the AIF instead, individuals who do not use the service would also indirectly contribute to the fund.

The funds raised are subsequently available to be spent on innovations in any of the three main tracks. For technologies still in their infancy stage, such as electric aircraft, funding could be available in the form of grants. Based on the lessons learned from the IF, Duwe and Ostwald (2018) provided recommendations for an improved design of the fund, which are also useful for ensuring transitional change triggered by the AIF. These recommendations include the clear establishment of a maximum amount of funding per project as an absolute amount, rather than a percentage, providing higher co-financing rates and avoiding strict performance-based criteria as conditions for payment, but using milestones instead (Duwe and Ostwald 2018).

For those types of biofuels that are closer to market readiness and for which the price is the last hurdle that needs to be overcome, the AIF could provide loans rather than grants. In this way, the money returns to the AIF and can subsequently be re-used as other loans or grants. It is advisable that a large portion of the funding is spent on grants (technologies in their infancy stage) than loans, in order to ensure breakthrough technologies reach maturity and deliver the magnitude of emission reduction required.

E.3.4 Which actors would profit from the fund?

Which actors would profit from the fund dependents on the track of innovation? Ultimately all parties in the aviation industry would profit from the fund, but the parties which would be eligible for the funding differ, depending on whether the innovation is focused on aircraft design or fuels.

To further electric aircraft innovations, the companies designing and building the aircraft should be eligible to apply for funding from the AIF. The main research and development take place at these companies.

If applying the AIF for the fuel-based innovations, it is not as clear which actors would profit from the fund. Large airports like Amsterdam Schiphol, tend to have one refuelling station at which a number of oil and gas companies work together in a partnership to supply kerosene. In the case of Schiphol this involves Shell, BP, Esso, Q8, Statoil, Texaco and Total, next to Air France-KLM. These refuelling stations at airports could be eligible for funding, which they could use to enhance the percentage of biofuels or synthetic fuels in the mix offered to airlines. However, the AIF could provide support to companies producing biofuels or synthetic fuels. This would include directly or indirectly supporting other process steps in the production process of these fuels such as hydrolysis, direct air capture (DAC) or fuel synthesis.

E.4 Administrative design

E.4.1 How could the budget be raised and maintained?

This question includes at least two main dimensions: first, at which level, e.g. international, European or national level, should the budget be raised and second, by which instruments.

Since all countries would profit from breakthrough innovations in the aviation sector, particularly since this sector is even more international than many other sectors, it would be reasonable to source the budget at the international level or at least at European level. However, the time period required for establishing such a fund at the AIF is longer, the more multilateral the initiative is advanced. However, if countries do not want to wait until other countries join their initiative, they can start such a fund at national level with a smaller coalition of countries with similar ambitions. Based on this consideration, we focus the further considerations on the initial establishment of the AIF by Germany.

Several instruments could be considered in deciding how a budget is raised and maintained in Germany. The three main approaches are discussed below:

- Contribution (Umlagebeitrag): the budget would be kept separate from the government's general budget and the financial resources required would be charged to those who profit from the AIF in the long run, i.e. the passengers. This approach is similar to the one applied for the promotion and development of renewable energy technologies in Germany through the Renewable Energy Law (EEG). The cost of subsidising the increase in generation from renewable sources is financed by a mark-up on the electricity price.

- Taxes: the required budget could also be sourced by establishing new taxes, rising rates of existing taxes or abolishing tax exemptions. Since the aviation sector is, compared to other modes of transport, 'undertaxed',[21] there may be options to use this route and at the same time contribute to levelling the playing field between various modes of transport. However, taxes go directly into the general government budget and can usually not be earmarked for certain purposes. Nevertheless, additional spending by the government usually requires financing by reducing expenditure for other budget items or the identification of additional funding sources. In this sense, taxing can also be applied to raise the budgets for the AIF.
- Revenues from allowances: So far 85% of the allowances allocated to the aviation sector are allocated free of charge, which corresponds to roughly 50% of the total allowance demand of the aviation sector in 2018. Since phase III of the EU ETS, allocation free of charge has mainly been limited to sectors which face carbon leakage through the relocation of production sites outside the EU territories, it could be argued that aviation does not face such risks and that allocation free of charge should be phased-out as soon as possible. As with taxes, these additional revenues could be used to finance the budget of the AIF even if they were not directly earmarked for this purpose. Moreover, this change would require a respective change in the EU ETS directive, which could be envisaged at the next review of the directive in 2020/2021.

Against this background, pursuing the tax approach seems to be most promising, particularly if the AIF should be initially established at national level and sooner rather than later. Assuming that introducing an additional tax for this purpose is the least complicared option, we focus on existing taxes and or tax exemptions. Three taxes may be considered:

- Value added tax (VAT): It is currently only raised on domestic flights. International flights are entirely exempted, even the share for flying over German territory. UBA (2016a) estimates that the revenues foregone amounted to almost 5 bn € in 2012. However, legal analysis suggests that raising VAT on international flights is virtually impossible.
- Ticket tax: Roughly depending on the distance flown, tickets for flights starting in Germany are taxed at different rates, which amount to about 1.2 bn € per year. The ticket tax was introduced in 2011 to close the budget deficit. It could be argued that the revenues should be devoted to environmental purposes in the aviation sector such as those of the AIF. However, it could also be argued that the rates are increased with a view to generating additional sources of funding for establishing an AIF.
- Kerosene tax: Kerosene is included the Energy Tax Directive with a minimum rate of 0.33 €/l. In Germany the tax rate for kerosene is 0.6545 €/l. However, taking into account the provisions of the ICAO Chicago Convention, the directive allows for the exemption of

[21] UBA (2016a) estimates that in 2012 more than 50% of the environmentally damaging subventions of some 57 bn € stem from the transport sector of which again 42% stem from aviation (12 bn €).

kerosene from taxation and currently all EU Member States do so. UBA (2016a) estimates that in Germany alone more than 7 bn € of tax revenues were forgone in 2012 through these exemptions. Kerosene could be taxed through bilateral agreements if both countries agreed. Based on an initiative of the Dutch Finance Ministry, several Member States (e.g. the Netherlands, Sweden, Finland, Belgium and France) are currently considering how the exemption of kerosene from taxation could be abolished at least for the flights between the Member States concerned.

Since raising VAT on international flights seems impossible, the generation of an additional budget for the AIF needs to focus on the kerosene and the ticket tax. One conceivable option is abolishing the kerosene exemption for all domestic flights and raising at least the EU minimum rate of 0.33 €/l on these flights. This would generate about 250 mil € of additional revenue per year. In addition, the ticket tax could be reconstructed as a tax that mimics the VAT. In the long term, about 5 bn € a year could be raised via this route until a level playing field with other transport modes is achieved. However, in a first approach the tax rates for international flight could be increased (and diversified) in such a way that about 750 mil € of additional revenue would be generated each year. Overall both changes would generate some 1 bn € per year or 10 bn € over a period of 10 years. The starting budget is comparable with the financial resource, which were available at the start of the EEG in the year 2000. However, the budget to promote the development grew by an average rate of almost 25% per year up to 2010. Aggregated over the period of the first 10 years, more than 36 bn € were devoted to the development of renewable energy sources in Germany (Netztransparenz 2019). Against this background, a continuous increase of the rates could be envisaged, though perhaps only after the initial start of the AIF.

E.4.2 How should the budget be spent?

The rules and procedures (R&P) for the implementation of the fund would be different if the AIF is geared to the promotion of post-fossil e-fuels alone or if it addressed all technological improvements in the aviation industry. Given the varying maturity of innovative technologies (section E.3.2), establishing several windows, for example for the provision with biofuels or with e-fuels, for breakthrough technologies in airframes and engines and for radical operational improvements to ensure that not only one branch of potential innovation pathways is promoted.

For spending the budget, the R&P should include a set of criteria, which may partly be antagonistic. The selection criteria could, for example, build on the criteria established for the IF under EU ETS (Doubrava 2019):

- long-term greenhouse gas emissions avoidance potential;
- degree of innovation;
- project maturity;
- scalability;
- cost efficiency.

Moreover, the experiences gathered in driving down the cost of renewable energy sources should be taken into account. Some of the important lessons learned are:

- important insights for reducing the cost and for scaling up a technology are made during their deployment thorough learning by doing;
- investors need certainty that they can make use of their investment over a minimum period of time;
- subsidising the investments may not be sufficient to ensure a continuous use of the capacities and to ensure learing by doing;
- if the revenues over a sufficiently long period of time are ensured, subsidising the investment may not be required at all;
- establishing fixed subsidy rates per unit of output (Einspeisevergütung) may result in windfall gains if the costs fall faster than they can be adapted by the government;
- competition among investors and awarding those investors, who required the lowest subsidy per unit, can address this caveat.

Quite naturally, the criteria and R&P would be somewhat different for each window if the AIF included more than one window, mainly because the technologies are quite different in terms of their current stage of innovation, shares of initial investments and operational costs in the total costs of a technology but also in terms of which actors may be addressed (fuel suppliers, aircraft manufactures, airlines, etc.).

Given the limited space in this paper, we focus our further deliberations on only on one of the AIF's potential windows and elaborate in more detail how the window for post-fossil e-fuels could be designed while taking into account the considerations made above.

Nemet et al. (2016) describe six elements of strategies to overcome the 'valley of death' (section E.3.1) including "Prioritizing learning and tolerating failures", "Iterative upscaling and supporting diversity" and "Robust demand pull". Based on these elements we develop a concept for the promotion of e-fuels through the AIF. Obviously, this concept is just an initial design of such an AIF window. If it were pursued, several more detailed issues would have to be discussed, adjusted and addressed.

To establish a demand for post-fossil e-fuels, a minimum drop-in quote will be established, which will be continuously increased to finally arrive at 100% post-fossil fuels, for example in 2050. It will start very low with a share of 0.5% or 1% because it takes time to build the production capacities.

As a support for this pull instrument, the production and provision of post-fossil fuels will be subsidized through the AIF. Producers of such fuels should be in a position to sell their products for the same price as fossil kerosene (currently some 0.60 €/l).[22] Similar to the tenders for renewable energies established in Germany since 2017, the AIF could publish an auction tender in which producers of post-fossil e-fuels could compete for the lowest subsidy.

The terms of reference for this tender would include the amount of post-fossil e-fuels to be produced. This amount could easily be calculated from the demand established through the drop-in quota. To ensure that at least two or three providers compete with their technologies, the maximum offers could be capped in terms of capacity (e.g. max. one third of the demand

[22]If the kerosene tax exemption were (partly) abolished, it would implicitly provide additional support to make these fuels competitive with fossil kerosene.

generated through the quota). Suppliers must guarantee the production of a certain amount over a minimum period of time, e.g. 10 or 12 years.

The subsidy would not be handed out at the beginning of the investment or of the production but only ex-post when the product is actually delivered. This would provide an incentive not only to invest in production facilities for post-fossil e-fuels but to run them efficiently from a long-term perspective and to look continuously for further improvements.

Those producers would win the bid which can provide post-fossil e-fuel that complies with strict environmental criteria and ensures significant GHG reductions and facilitates the transition to a post-fossil aviation sector at the lowest subsidy per litre.[23] Producers of post-fossil e-fuels would, similarly to electricity producers under the EEG, have two streams of revenues: on the one hand, from selling the product at 'normal' market prices and, on the other hand, the subsidy from the AIF, which would ensure that they could recover their higher cost of production.

Such subsidy auctions should be conducted on a regular basis, e.g. every one or two years, to both ensure that the amount required by the quota can be provided at market prices and to make use of efficiency gain in the production of e-fuels through lower per litre subsidies.

While the auction may be initially limited to generation of e-fuels in Germany, removing this limitation at a later point in time could be considered since it may be difficult to ensure the additional renewable energy required in Germany. However, this strategy could ensure that the technological know-how for the generation of post-fossil e-fuels is advanced in Germany (first mover advantages) and that the technology may be successfully exported at a later point in time.

Establishing only a drop-in quote could be considered. From an economic theory perspective, this approach may bring about the same result and contribute to upscaling the e-fuels production. However, this applies only in the case of a global approach where the quota is harmonised at least among all major aviation hubs. In a unilateral approach of the EU or some of its Member States, the economic incentives are different: As long as the quota is very small, the quota would have a limited impact on kerosene prices. But as soon as it induces a significant price difference, airlines will apply tankering strategies to evade the additional cost induced through the drop-in quota. By combining the quota (push) with a subsidy this incentive can be reduced or even eliminated.

Duwe and Ostwald (2018) found in their analysis of existing innovation funds under the EU ETS Directive (section E.2) that the lack of upfront financing was a potential barrier for the implementation or the success of innovative projects. Against this background, at least a part of the subsidy may need to be made available at the implementation phase of new production capacities rather than only upon delivery of the e-fuel. However, as long as there is a reliable stream of subsidies, justified by a respective government notice, banks should have no major problem with financing such projects. Several thousand of cases of wind or photovoltaic installations also receive their feed-in tariff only upon delivery of the electricity but this is not a barrier to finding private banks for financing these investments. Another aspect to be considered is that the production of e-fuels requires comparatively large amounts of renewable electricity, which are operational expenditure from an e-fuels producer perspective (Oeko-Institut 2019; Perner et al. 2018). These expenditures will also be paid upon delivery rather than upfront, so that a larger share of the total costs of e-fuels producers accrue during the production phase rather than upfront. Based on these considerations, it does not seem to be

[23]Instead of a fixed subsidy per litre, the concept of symmetric carbon contract for difference (CCfD) could be applied Richstein (2017). In this case, the producer receives the difference to the auctioned strike price as subsidy if the market price for fossil kerosene is lower; the difference has to be returned if the market price is higher than the strike price. However, since e-fuels are far from the current market prices for kerosene, the introduction of these contracts could be postponed for several years.

necessary to provide upfront finance under an AIF e-fuels window. However, a smaller share of upfront finance could be funded from other public sources. If so, this needs to be taken into account during the auction of the production subsidy to avoid double funding.

In summary, we conclude that the above-described approach for an e-fuel window of the AIF would allow for a diversity of technological approaches, promote learning and upscaling and provide a robust combination of demand-pull and demand-push elements and could therefore contribute to overcoming the innovation 'valley of death' described in section E.3.1.

E.4.3 Which body should oversee the AIF in Germany?

Generally, it is at the government's discretion in which an AIF is situated. Several considerations should be taken into account when identifying which body may be best suited. It could be located according to the purpose, to where the revenues are arriving or where experience with similar instruments already exists. However, even with such heuristics, the questions may not be answered easily.

The main purpose, for example, is innovation and transition to an aviation sector compatible with the Paris Agreement. Obviously, the purpose involves issues which are addressed in the departments for the environment, for research and development, for transport, for economic affairs and, last but not least, in the Treasury. Therefore, this criterion provides little guidance.

If we focus on where the revenues arrive, the Treasury is clearly the most appropriate, at least if the budget is soured through taxes. However, even if it were sourced through revenues from auctioning allowances, the revenues would arrive in the Treasury.

Examining experiences gathered with similar instruments again provides several options:

- The Energy and Climate Fund (EGKF[24]) was established in 2010. It is fed by the revenues from auctioning EU ETS allowances and spends at least 300 mil € per year for energy efficiency, renewable energies, energy storage and network technologies, energetic renovation of building, electromobility as well as for national and international climate protection. However, the promotion of innovation is not included in the target areas of this fund. It is administered by the Treasury although certain windows, such as the national and international climate initiatives (NKI and IKI) are administered by the environment ministry.
- The mFUND[25] is a modernisation fund of the Ministry of Transport. Since 2016 it has spent 200 mil € per year on research and development projects in the area of data-based applications for mobility 4.0. It is specifically focused on IT and cloud-based technologies and devoted to R&D rather than to deployment and transition.
- The Federal Office for Economic Affairs and Export Control (BAFA[26]) is a subordinate agency of the Ministry for Economic Affairs. Among other tasks, it administers certain procedures such as exemptions from the German Renewable Energy Sources Act (EEG), which are somewhat related to innovation and the transition towards renewable energies.

[24] https://www.gesetze-im-internet.de/ekfg/EKFG.pdf.

[25] https://www.bmvi.de/DE/Themen/Digitales/mFund/Ueberblick/ueberblick.html.

[26] https://www.bafa.de/EN/Federal_Office/Tasks/tasks_node.html.

- The Credit Institute for Reconstruction (KfW) is a state-owned development bank jointly chaired by the Treasury and the Ministry for Economic affairs. It recently established a specific window for the promotion of innovation with a commitment volume of 1.54 bn € (KfW 2019).

These considerations illustrate that there is not an obvious option for situating the administration of the AIF. Ultimately, this question may be of secondary importance if selection criteria and the rules of procedures are designed in such a way which ensures that diverging perspectives of affected stakeholders are reflected.

E.5 Conclusions and recommendations

In this paper we assessed how low- or zero-carbon fuels and other new and improved technologies which facilitate the transition of the aviation sector to a pathway compatible with the Paris Agreement can be fostered by establishing an Aviation Innovation Fund (AIF).

We assessed experiences gathered with similar funds or instruments and found that not only the initial phase after a new invention is important in ensuring a reliable further development towards market maturity. Important progress can be made through learning-by-doing once a technology is already beyond the pilot phase. It is therefore important that the AIF does not focus on the initial phases of innovation alone but also supports new technologies as long as required until they are competitive with traditional technologies. Obviously, the financial support should decrease at the same pace as the new technology makes progress towards market maturity. The main purpose of the AIF would be to overcome the so-called innovation 'valley of death', where the final tail of the research resources is used up, but the commercialisation resources have not yet emerged. It usually occurs between the pilot stage and the maturation/commercialisation stage of an innovative technology.

There are three main strands of technological developments geared towards full decarbonisation of the aviation industry by 2050: **biofuels**, **synthetic fuels** (power-to-liquid) and **electric aircraft** (using renewable electricity). The main reason why all three of these developments should be eligible for funding is that the technologies are not mutually exclusive and are at different stages of development. Therefore, each technology will have a role to play in the transition to full decarbonisation by 2050. Biofuels are currently available on a small scale, mainly produced from used cooking oil with a HEFA process. New processes with different, more widely available feedstocks require further development. Synthetic fuels are not yet commercially available but may become available in the next decades, while electric aircraft are probably a more distant technology. However, given the different stages of these technologies, it would be appropriate to establish separate windows for each of the main technological strands.

To ensure that AIF unfurls its full capacity in promoting technological change, it needs to be embedded in a policy which ensures a gradual transition towards more expensive fossil fuels so that their prices ultimately reflect their climate change avoidance costs. Such a policy would provide financial incentives to reduce flying and fossil fuel consumption, reduce the price disparity between fossil and post-fossil kerosene and raise financial resources to replenish the fund. These policies basically include strengthening the ambition of the EU ETS, reducing or abolishing exemptions of fossil kerosene from the European fuel tax, charging VAT on international flights and establishing or increasing ticket taxes. All policies have advantages and disadvantages, particularly in terms of the likelihood of implementing them soon and/or unilaterally by one EU Member State or a group of mutually agreeing Member States. Against this background, a combination of applying at least the EU minimum fuel tax rate and introducing/increasing ticket taxes seems to be the most promising option to raise the financial resources to feed the AIF.

As an example, we assessed how the window for synthetic e-fuels could potentially be implemented. To overcome the 'valley of death', the AIF should, among other goals, allow for learning promote upscaling and provide a robust demand pull. Against this background, we suggest establishing a drop-in quota which starts at very low rates but ultimately arrives at 100% in 2050. To advance the development of e-fuels production capacities, this quota would be flanked by a subsidy per litre of e-fuel which covers the average price difference between fossil and synthetic kerosene so that e-fuel providers can compete with fossil kerosene suppliers. Similarly, to support schemes for renewable energies, the subsidies would be paid for a period of 10 or 12 years and only upon the delivery of the product to ensure that production installations are actually used and to facilitate learning-by-doing. These subsidies would be auctioned repeatedly to ensure competition between different e-fuel suppliers and to allow for the gradual expansion of e-fuel production capacity in line with the increase of the drop-in quota. The approach described above for an e-fuel window of the AIF would allow for a diversity of technological approaches, promote learning and upscaling and provide a robust combination of demand pull-and-push elements and could therefore contribute to overcoming the innovation 'valley of death'.

Based on the analyses in this paper, we conclude that the establishment of an AIF would promote the uptake of innovative technologies in the aviation sector such as biofuels, synthetic e-fuels or electric aircraft. Since aviation is an international operating sector to a large extent, such a fund would be most effective if implemented at the global level. However, there are options for establishing a fund unilaterally or with a group of mutually agreeing countries to facilitate similar developments at the global level.

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