A comparison between CORSIA and the EU ETS for Aviation

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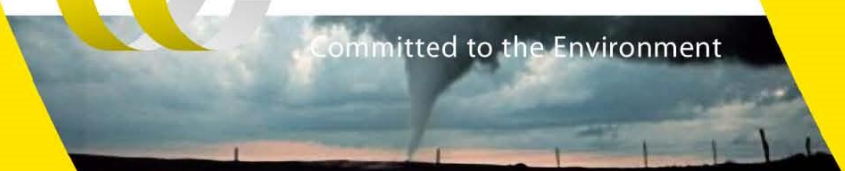

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For this study use is made of the Aviation Emissions and Evaluation of Reduction Options Modelling System (AERO-MS). The European Aviation Safety Agency (EASA) holds the IPR for the AERO-MS. The parties executing the study wish to thank EASA for granting permission for the use of the AERO-MS for this study.

1 Introduction

During the 39th ICAO Assembly in September/October 2016, Member States of ICAO have agreed on a Global Market Based Measure (GMBM) to address CO_2 emissions from aviation and to meet ICAO's aspirational goal of carbon neutral growth from 2020 onwards (CNG, 2020). The measure is called Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA).

The European Union had decided to include all departing and arriving flights in the EU ETS from 2012. In 2012, it decided to temporarily reduce the scope to flights between airports in the EEA+[1] in order to allow ICAO Member States to complete the GMBM negotiations.

Now that the CORSIA has been agreed upon, the EU will review the inclusion of aviation in the EU ETS. It has been announced that after the ICAO Assembly, the European Commission is to provide a report considering options for the coverage of aviation emissions. As specified in the regulation that temporarily reduces the scope of the EU ETS, "the Commission should also give particular consideration to the environmental effectiveness of the European Union Emissions Trading System (EU ETS)".

This study aims to present a comparative analysis of CORSIA and various scopes for the inclusion of aviation in the EU ETS. The study aims to answer the following question:
"How do the covered CO_2 emissions of aviation in CORSIA and three scopes of the EU ETS evolve over time in the period between 2020 and 2035 and how does the amount of CO_2 emissions to be offset in CORSIA compare to the aviation CO_2 emissions covered by the EU ETS?"

Key concepts used in the analysis

The analysis used two key concepts: emissions covered and emissions offset. These are explained below.

Emissions covered are the total emissions on flights between airports in participating countries. Aircraft operators operating these flights should offset, through purchasing credits or allowances, a share of the emissions on these flights, as explained in Section 3.1. Non-covered emissions are emissions to or from airports in states that do not participate in CORSIA. Airlines have no obligation to offset emissions of these flights.

The amount of emissions to be offset are the share of emissions on covered flights for which offsets are required to be surrendered in CORSIA. No share of emissions on non-covered flights is is offset.

The amount of emissions to be mitigated is the number of allowances which airlines have to surrender in the EU ETS for which they have not received or bought EU Aviation Allowances (EUAAs). These allowances will be EUAs.

The amount of emissions to be offset and *the amount of emissions to be mitigated* signify emission reductions in other sector that are paid for by the aviation sector under CORSIA and the EU ETS respectively.

[1] EEA+ denotes Member States of the European Economic Area plus Switzerland.

For the modelling of aviation emissions, use is made of the Aviation Emissions and Evaluation of Reduction Options Modelling System (AERO-MS).
The AERO-MS is an internationally accepted tool for the analysis of policy options for the reduction of international aviation emissions.

In Chapter 2 of this paper the methodology to assess the emissions coverage of CORSIA is described. Chapter 3 addresses the assessment of the emissions coverage of CORSIA, including an overview of the main characteristics of CORSIA. Chapter 4 introduces the various EU ETS scenarios considered and describes the emissions coverage of these scenarios.
A comparison between the emissions coverage of CORSIA and the EU ETS scenarios is provided in Chapter 5. In addition, the chapter considers the projected costs for the aviation industry. Finally the conclusions of the study are presented in Chapter 6.
Annex A contains the tables with AERO-MS computational results.

2 Methodology to assess emissions coverage

For the assessment of the emissions coverage of both CORSIA and the EU ETS, use is made of the AERO-MS. The AERO-MS can assess the economic and environmental impacts of a wide range of policy options to reduce international and domestic aviation GHG emissions. In this study the main focus is on the assessment of emission coverage.

The development of the AERO-MS was initiated by the Dutch Government. The AERO-MS was the first model approved by ICAO's Committee on Aviation Environmental Protection (CAEP) to be used for the assessment of the impacts of GHG reduction policies for international aviation.

In 2009 EASA inherited the property rights of the AERO-MS from the Dutch Government. Since then the AERO-MS has been updated and enhanced. Currently the Base Year of the model is 2010 which is in line with the Base Year for the most recent ICAO/CAEP aviation emission projections. All AERO-MS inputs have been updated and brought in line with the 2010 Base Year. Hereby use is made of EUROCONTROL WISDOM Operations Database as a basis for the AERO-MS Unified Database which contains a detailed record of aviation movements in the Base Year. The Unified Database records 123,025 airport-pairs with 33.1 million civil flights. Airline cost and fare data were updated using IATA and ICAO data. The update of aircraft type input data was based on fleet inventory properties from the EUROCONTROL PRISME Fleet 2, OAG Fleet Databases, ICAO emissions databank as well as the FESG retirement curves. For the specification of aircraft operational characteristics use was made of the EUROCONTROL BADA data. Hence, all AERO-MS data are based on data sources from internationally well-reputed organisations.

The AERO-MS has formed a key part of over 30 international studies where the model results have provided a quantified basis for policy judgement. These studies were executed for a range of other clients like ICAO, the European Commission, EASA, IATA, UNFCCC, WWF and national governments (Germany, UK, the Netherlands).

The AERO-MS enables the computation of alternative emission growth scenarios for global aviation. The results of this study are based on the implementation of the CAEP/9 Most Likely Growth scenario. The main characteristics of this scenario are:

1. CAEP/9 most likely demand growth scenario for the period 2010-2040. The scenario considers 32 route groups for which a forecast is made (23 route groups with respect to international aviation and nine route groups with respect to domestic aviation). There is a clear variation in expected growth between different route groups with generally lower annual growth on more mature markets (North America; Europe) and higher expected growth on emerging markets (Asia; Latin America). For the period 2010-2040 the scenario shows an increase in global passenger demand on international routes of on average 4.8% per annum. For the same period cargo demand on international routes is forecast to grow by 5.2% per annum.
2. CAEP/9 moderate technology improvement scenario: fuel burn improvement of 0.96% per annum for all aircraft entering the fleet after 2010 out to 2040.
3. An increase in load factors over time as specified by CAEP/9 whereby the global average load factor for passenger demand is forecast to increase from 77% in 2010 to 82% in 2040.

4. CAEP assumed increase (in real terms) of the kerosene price to 3 US$ per gallon in 2030/2040 which implies an expected increase of 47% relative to the kerosene price in 2010.

In this study emissions covered by CORSIA and in the three scopes of the EU ETS are analysed. CORSIA and EU ETS scenarios differ in route groups covered. Table 1 summarizes the covered route groups per scenario.
The red route groups are not included; green route groups are included.
n Table 1 a distinction is made between international aviation and domestic aviation. International aviation contains all flights between two different countries. Domestic aviation comprises flights where the airport of departure is in the same country as the airport of arrival (including if a flight is operated by a third country operator). The next two chapters give more detailed information on the scope of the CORSIA and EU ETS scenarios. Note that flights between EEA+ countries are included in all scenarios analysed, while domestic flights in non-EEA+ countries are always excluded, as well as flights between non-participating countries in CORSIA.

Table 1 **Route groups covered in different mechanisms**

Route groups	CORSIA	EU ETS scenarios		
		Original Scope	50/50	Intra EEA+
International aviation route groups				
Between an EEA+ country and another country which is included in CORSIA				
Between an EEA+ country and another country which is excluded from the CORSIA				
Between an EEA+ country and another EEA+ country				
Between two countries outside the EEA+ when both are countries included in CORSIA				
All other routes to and from countries outside EEA+				
Domestic aviation route groups				
Between two airports in the same EEA+ country (domestic)				
Between two airports in the same non---EEA+ country (domestic)				

Note: EEA+ denotes countries in the European Economic Area and Switzerland.

3 Emissions to be offset in CORSIA

3.1 Introduction to CORSIA

During the 39th ICAO Assembly in September-October 2016 the Global Market Based Measures (GMBM) for international aviation was adopted and called Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)[2].

The main characteristics of CORSIA are:

1. CORSIA is valid for the period 2021-2035, whereby three phases are defined: i) pilot phase (2021-2023); ii) first phase (2024-2027); and iii) second phase (2027-2035).
2. Both the pilot phase and first phase are voluntary phases. The second phase is a mandatory phase. The second mandatory phase applies to States (i.e. the participating States) with an individual share of international aviation activities in RTKs above 0.5% of total RTKs in year 2018 or whose cumulative share in the list of States from the highest to the lowest amount of RTKs reaches 90% of total RTKs, except for Least Developed Countries (LDCs), Small Island Developing States (SIDS) and Landlocked Developing Countries (LLDCs).
3. CORSIA applies to all international flights on the routes between the participating States. Hence flights between a participating State and a non-participating State are exempted.
4. For the flights between participating States, aircraft operators need to offset emissions above the baseline emissions level. The baseline emissions level is based on the average of total emissions covered by CORSIA between 2019 and 2020[3].

As per the end of October 2016, 66 States have indicated that they will join the voluntary phases[4]: ECAC44, United States, Canada, Mexico, Guatemala, Costa Rica, Israel, United Arab Emirates, Qatar, China, Indonesia, Thailand, Japan, South Korea, Malaysia, Singapore, Papua New Guinea, Australia, New Zealand, Marshall Islands, Burkina Faso, Kenya and Zambia.
Furthermore AOC RTK data for 2014[5] have been used to assess the countries to join the second phase. The following seven countries (not already included in the voluntary phase) join CORSIA in the second phase: Brazil, Chile, India, Philippines, Russia, Saudi Arabia and South Africa.

The above implies that out of the 191 ICAO States, 118 are exempted for the full period 2021-2035. Figure 1 provides an overview of the ICAO Member States to join CORSIA in the various phases. The analysis of the emissions coverage of CORSIA is based on this overview.

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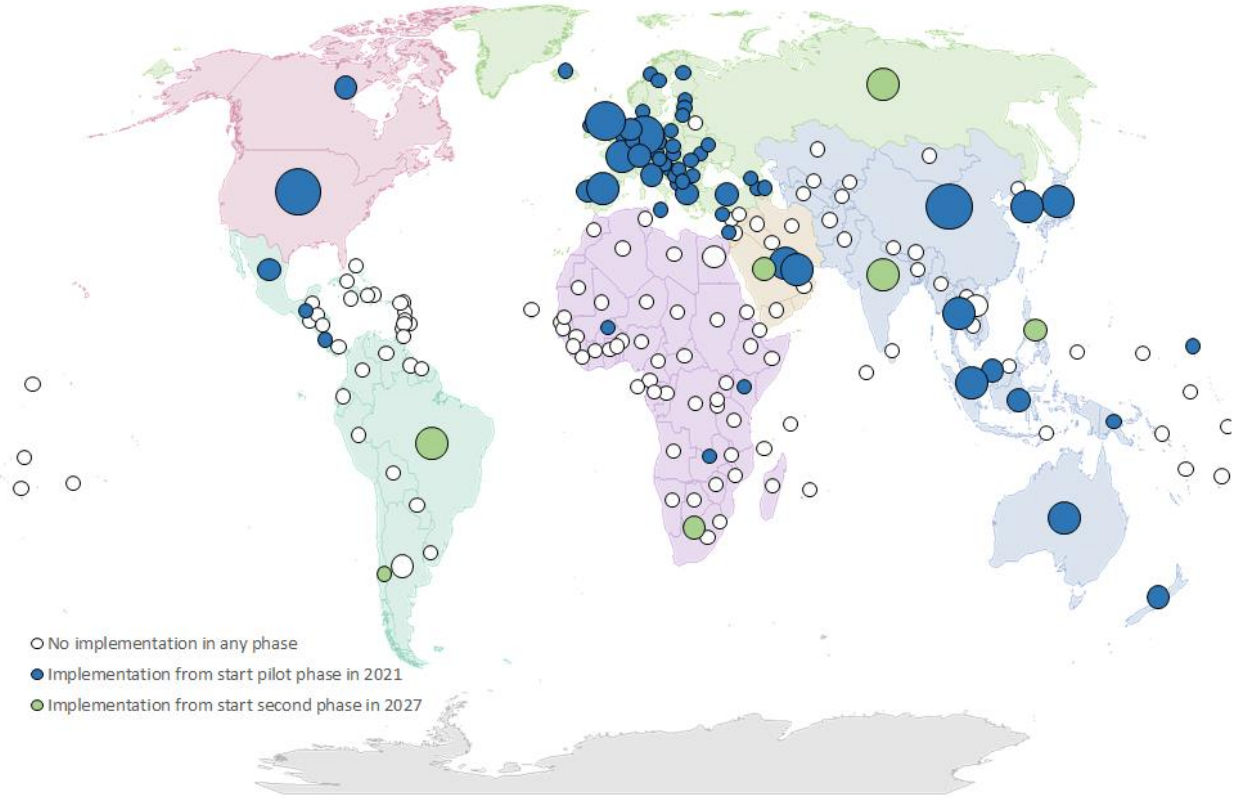
2 A39-WP/530. Assembly – 39th session. Report of the executive committee on agenda item 22 - Section on Global Market-based Measure Scheme.

3 Offset obligations of individual aircraft operators are also affected by the so-called sectoral growth rate and individual growth rate. In the pilot and first phase offset obligations will be based on a 100% sectoral growth rate (and hence 0% individual growth rate). During the second phase the individual growth rate will go up to 70% (i.e. 30% sectoral growth rate). Hereby it is noted that the ratio between sectoral growth rate and individual growth rate does not affect to total offset obligation for the aviation sector (presented in this report) but only the distribution of the offset obligation across (groups of) aircraft operators (not presented in this report).

4 www.icao.int/environmental-protection/Pages/market-based-measures.aspx

5 www.icao.int/Meetings/GLADs-2016/Documents/RTK.pdf

Figure 1 Countries to join the ICAO GMBM (CORSIA) in various phases*



* The size of the bubbles reflects the share in international aviation emissions in 2021-2035 (with 50%/50% allocation of emissions to the country of departure/arrival).
There are five categories:
1. More than 8% (US and China).
2. More than 5% but less than 8% (UK and Germany).
3. More than 2% but less than 5% (12 countries).
4. More than 0.5% but less than 2% (18 countries).
5. Less than 0.5% (remaining countries).

3.2 Emissions coverage and amount of emissions to be offset in CORSIA

The computational results for analysis of CORSIA are presented in Figure 2 through Figure 4. Figure 2 shows that for the period 2021-2035 the AERO-MS computes 12,544 Mt of CO_2 emissions of international aviation. The State Pairs which are subject to CORSIA take account of 9,582 Mt of CO_2 (76% of total). The distribution of these emissions across the different implementation phases is also presented in Figure 2.

The cumulative number of tonnes of CO_2 emissions to be offset under CORSIA in the period 2021-2035 equals 2,711 Mt of CO_2 (see Figure 3). The cumulative non-covered emission growth (i.e. growth relative to the 2020 level of emissions outside the scope of CORSIA) amounts to 614 Mt of CO_2. This implies that 81.5% of the cumulative emission growth after 2020 is covered by offsets (see Figure 4). The distribution of the offsets and non-covered emission growth across the different implementation phases is also presented in Figure 3. Clearly the larger part of the cumulative emission offset takes place in the second phase (2,323 Mt out of the total of 2,711 Mt which is 86%).

This is because, first of all, the offset requirement will increase over the years due to increasing emission growth widening the gap between emission levels in any year and the baseline emissions (average of 2019/2020). Second, in the second phase seven additional countries are included in the offset scheme (see above).

Figure 2 **Total CO_2 emissions international aviation on covered and non-covered State Pairs by CORSIA per implementation phase (in Mt)**

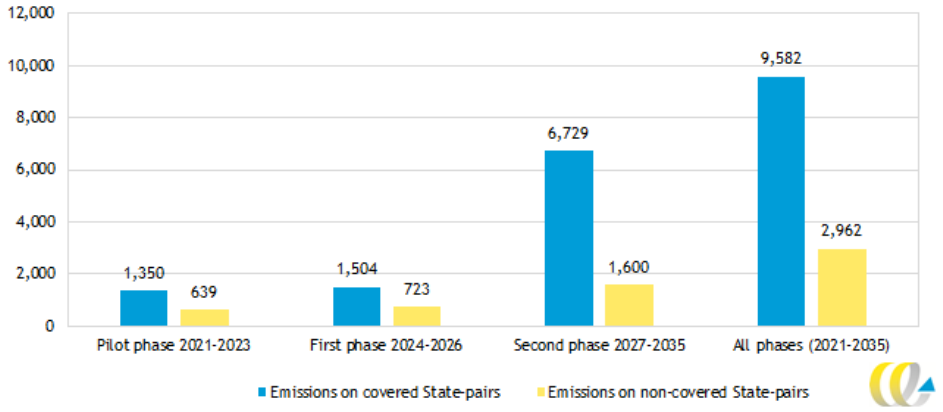


Figure 3 **CO_2 emissions to be offset on covered State pairs and non-covered CO_2 emission growth (in Mt)**

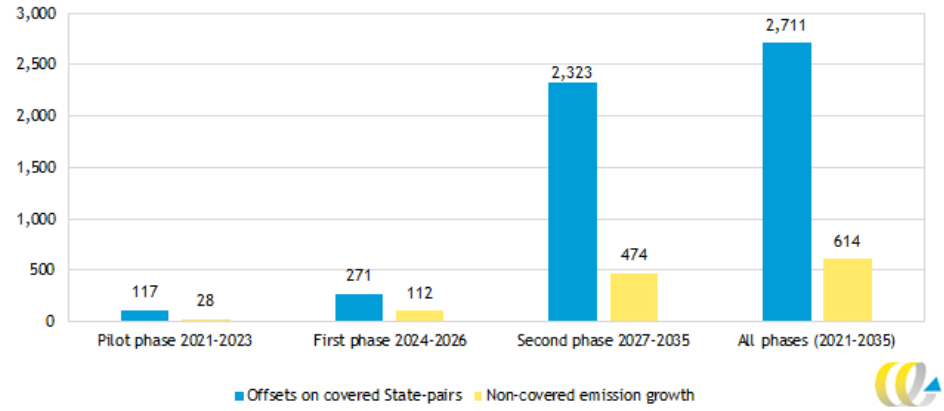
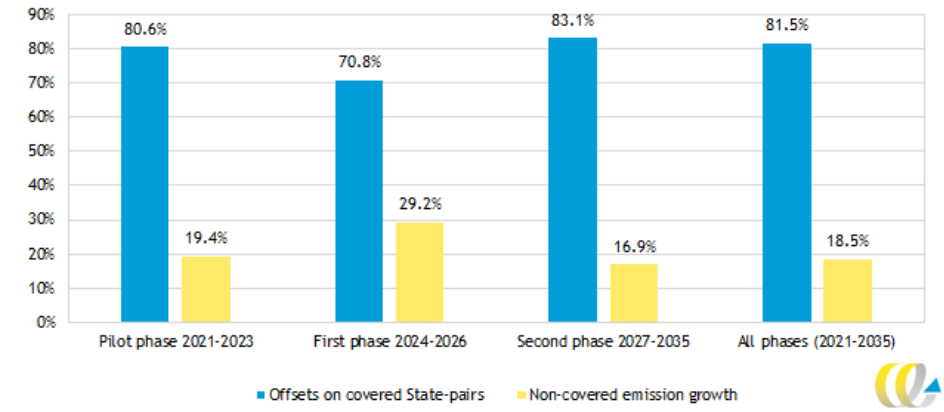


Figure 4 **CO_2 emissions to be offset on covered State pairs and non-covered CO_2 emission growth (in %)**



Though CORSIA has global coverage, one can split out the offset obligation for certain routes. The international flights between the EEA+ countries account for 271 Mt of offsets in CORSIA in the period 2021-2035. This is of relevance for the comparison between CORSIA and the EU ETS scenarios in Chapter 5 of this document.

If all emission growth after 2020 were covered by the CORSIA, 26.5% of the cumulative emissions in 2021-2035 would be offset. However, because not all countries join, 21.6% of the total emissions in 2021-2035 are offset.
Hence with CORSIA about one fifth of the cumulative CO_2 emissions of international aviation in the period 2021-2035 are offset.

4 Emissions to be mitigated under the EU ETS

4.1 Introduction to EU ETS scenarios

The EU ETS scenarios apply to the European Economic Area (EEA) plus Switzerland. The EEA includes EU Member States, Norway, Iceland and Liechtenstein. In the study the UK is assumed to remain part of the EU ETS also after a Brexit. The EEA countries plus Switzerland are referred to as the "EEA+ countries".

The extent of emissions to be mitigated under the ETS are calculated for three scenarios with different geographical scopes:

- Original scope: All flights departing from or arriving at an airport in one of the EEA+ countries, similar to the scope in Directive 2008/101/EC but adding flights to and from Switzerland.
- 50/50 scope: Flights between an EEA+ country and a non-EEA+ country are covered for 50%. Intra EEA+ flights are covered for 100%. This option is very similar to the option where only departing flights from EEA+ countries would be covered.
- Intra EEA+ scope: All flights departing from an airport in one of the EEA+ countries also arriving at an airport in one of the EEA+ countries, similar to the scope of the "Stop the Clock" Decision No 377/2013/EU.

In the European Commissions Proposal to amend the EU ETS Directive, COM(2015) 337 final, a Linear Reduction Factor of 2.2% year for stationary installations under the EU ETS is proposed for the period 2021-2030. In this Directive the LRF does not apply to aviation in the EU ETS. As part of this study we have looked at the extent of emission to be mitigated if the LRF of 2.2% would also be applied to aviation in the EU ETS for the full period 2021-2035 considered in this study. Thus, all three EU ETS scenarios are considered with and without a Linear Reduction Factor (LRF) and a total of six EU ETS scenarios have been analysed.

The caps without the LRF are based on 95% of the average emissions in the years 2004-2006:

- original scope: 214.1 Mt[6];
- intra EEA+ scope[7]: 60.7 Mt[8];
- the cap for the 50/50 option is then simply 60.7 + (214.1-60.7)/2 = 137.4 Mt.

The LRF of 2.2% over the period 2021-2035 can simply be applied to the cap numbers. The LRF means that by 2035 the cap numbers are 2.2%*15=33% lower.

A share of the emissions under the cap are auctioned. Currently this is 15%. For the purposes of calculating ETS costs, in all six EU ETS scenarios we have assumed that the proportion of emissions under the cap to be auctioned increases linearly from 15% in 2020 to 100% in 2035.

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6 http://ec.europa.eu/clima/policies/ets/allowances/aviation/index_en.htm whereby the cap is adjusted to account for Switzerland.

7 This scenario is also referred to as the 'Stop the Clock' scenario.

8 Based on AERO-MS data.

4.2 Emissions coverage and amount of emissions to be mitigated under the EU ETS

The cumulative CO_2 emissions in the period 2021-2035 on the covered routes for the original EU ETS scope amount to 6,535 Mt (see Figure 5). Cumulative emissions on international flights covered by the original scope scenario are 6,114 Mt in 2021-2035. Figure 2 shows that the cumulative emissions of international aviation in 2021-2035 are forecast to be 12,544 Mt. This implies that the original scope EU ETS scope covers international flights which will generate about half of global international aviation emissions in the period 2021-2035.(i.e. 6,114 Mt of 12,544 Mt).

For the cap without the LRF, for the Intra EEA+ (stop-the-clock) scenario amount of emissions to be mitigated in the period 2021-2035 is about 1/4 of the allowances demand of the EU ETS original scope scenario (see Figure 6a). The amount of emissions to be mitigated for the 50/50 scenario is 62% of the EU ETS original scope allowances demand[9].

The LRF causes a lower cap from 2021 onwards and therefore a larger demand for EUAs. For the original scope scenario the LRF implies an additional demand for EUAs of 565 Mt over the 15 year period considered (3,888 minus 3,323 Mt – see Figure 6a).

Figure 6a pictures the demand for EUAs under the EU ETS scenarios for the period 2021-2035 under the assumption that the method for setting the amount of EUAAs does not change after 2030. This is done in order to be able to make a comparison with the emissions coverage of the CORSIA. However, Phase 4 of the EU ETS relates to the period 2021-2030. Figure 6b shows the demand for allowances of the various EU ETS scenarios for the EU ETS Phase 4 period.

Under the assumption of an increasing proportion of emissions under the cap to be auctioned, Figure 7 shows the auctioned allowances versus the allowances granted for free for the period 2021-2035. The auctioned allowances reflect revenues generated. EU policy is that allowances to be auctioned are distributed to Member States and that hence the auctioning revenues are collected by Member States. Hereby the revised EU ETS Directive provides that at least 50% of auctioning revenues should be used by Member States for climate and energy related purposes.[10] Member States have reported that over 80% of the auctioning revenues of ETS allowances (including aviation allowances) were used for these purposes (Transport and Environment 2016).

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9 All 3 EU ETS scenarios (cap: 95% of 2004-2006) include 308 Mt of EUAs for domestic flights within any of the EEU+ countries. These domestic flights are of course not included in the GMBM for international aviation CORSIA.

10 http://ec.europa.eu/clima/policies/ets/auctioning/index_en.htm

Figure 5 CO_2 emissions (2021-2035) on covered routes by EU ETS scenarios (in Mt)

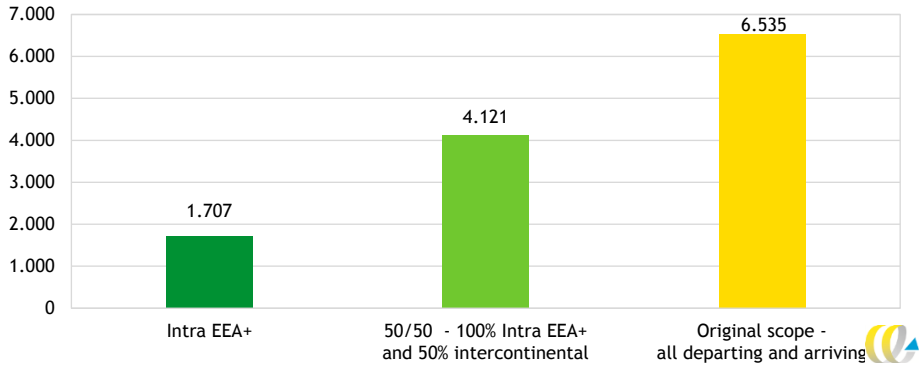


Figure 6a Demand for allowances (EUAs) in 2021-2035 by EU ETS scenario (in Mt)

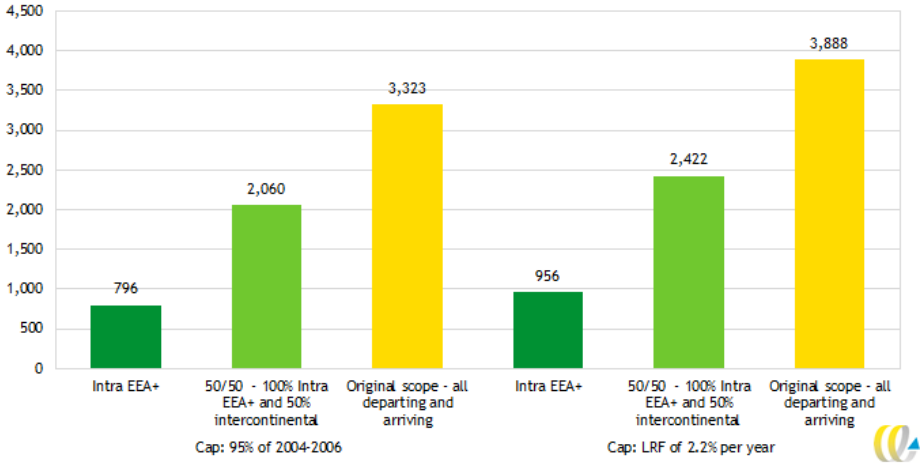


Figure 6b Demand for allowances (EUAs) in Phase 4 EU ETS (2021-2030) by EU ETS scenario (in Mt)

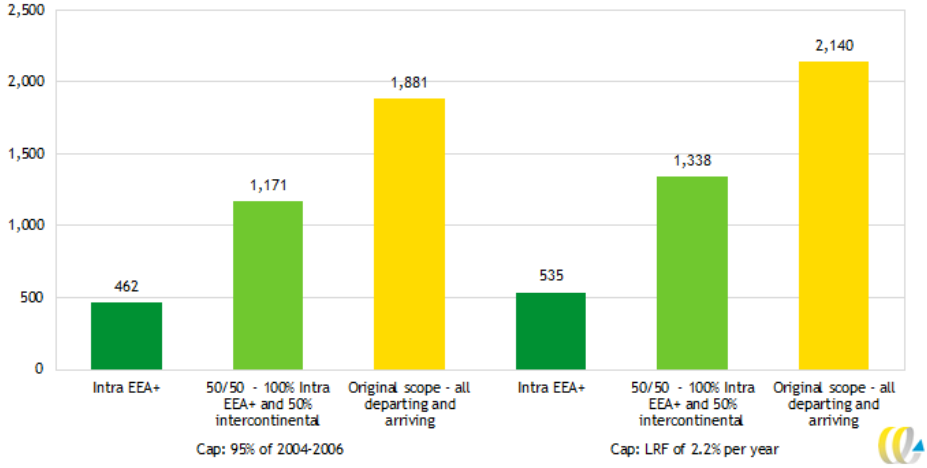
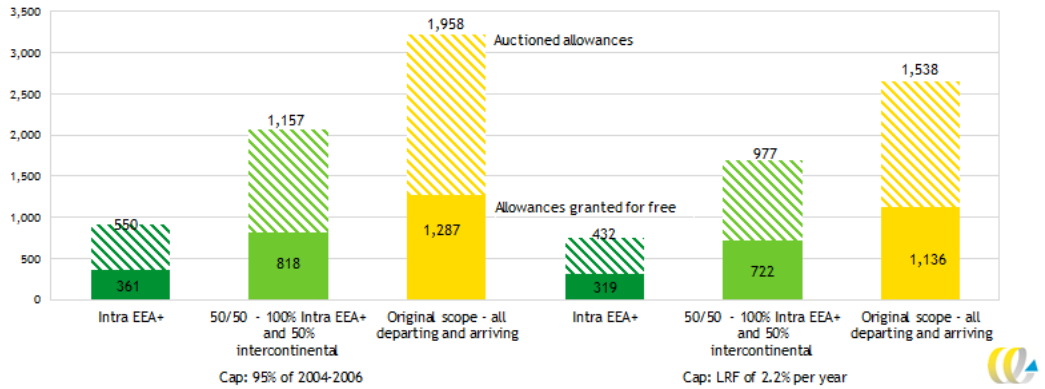


Figure 7 Auctioned allowances and allowances granted for free (2021-2035) by EU ETS scenario (in Mt)



5 Comparison of emissions covered, offset and mitigated under CORSIA and the EU ETS

In comparison to the EU ETS, CORSIA covers more routes, and therefore has more potential for an increased amount of emission to be offset compared to the amount of emission to be mitigated under the EU ETS scenarios. However the EU ETS has a stricter cap. This implies that the total demand for offsets versus the demand for EUAs over the full period 2021-2035 can be rather similar, but the development over time is very different. In order to show this difference, we have made the comparison for CORSIA and the EU ETS scenarios on a yearly basis.

The comparisons between CORSIA and the EU ETS scenarios are presented in Figure 8 through Figure 10 whereby the underlying numbers are presented in Tables A.1 through A.3 in Annex A. Figure 8 clearly shows the larger CO_2-emission coverage for CORSIA because, compared to the EU ETS scenarios, it has a larger geographical scope. The figure also shows how the coverage of CORSIA increases in 2027 because of the start of the second implementation phase with more countries included (see also Figure 1). Table A.1 provides an overview of the numbers behind Figure 8. Table A.1 also shows that according to the CAEP/9 scenario implemented in the AERO-MS, the CO_2 emissions of international aviation are expected to grow by 3.6% per year over the period 2021-2035. The CO_2 emissions covered by CORSIA increase by an average percentage of 4.9% per year over the period 2021-2035. This percentage reflects not only the growth in emissions on covered routes, but also that after 2026 more routes are covered. For the routes subject to the EU ETS scenarios the expected growth is lower especially for the Intra EEA+ scenario (2.4% emission growth per year).

In the initial years of CORSIA the demand for offsets is clearly lower compared to the demand for EUAs for EU ETS scenarios with no LRF (see Figure 9). By 2022 the annual offset demand of CORSIA is larger compared to the demand for EUAs in the Intra EEA+ scenario. In comparison to the 50/50 scenario (cap:95% of 2004-2006) the demand for offsets in CORSIA is larger from the year 2027 onwards, and in comparison to the original scope scenario it takes up to 2032 before CORSIA covers more emissions. (see Table 2). If one compares the cumulative demand for offsets over time versus the cumulative demand for EUAs, it takes longer before CORSIA covers more emissions. For the 50/50 ETS scenario, it takes until 2030 before the cumulative demand for offsets is larger under the CORSIA.

Table 2 **First year for CORSIA to require more emission to be mitigated compared to EU ETS scenarios**

	Annual emissions	Cumulative emissions from 2021 onwards
Cap: 95% of 2004-2006		
Intra EEA+	2022	2023
50/50 - 100% Intra EEA+ and 50% intercontinental	2027	2030
Orginal scope - all departing and arriving	2032	Not in 2021-2035
Cap: LRF of 2.2% per year		
Intra EEA+	2023	2024
50/50 - 100% Intra EEA+ and 50% intercontinental	2027	2033
Orginal scope - all departing and arriving	Not in 2021-2035	Not in 2021-2035

The demand for offsets over the full period 2021-2035 of CORSIA (2,711 Mt – see also Table A.2) is less than the demand for EUAs in the original scope scenario (3,323 Mt – see also Table A.2).

If CORSIA is compared to the EU ETS scenarios with an LRF, the demand for EUAs of the original scope EU ETS scenario in any year remains larger than the demand for offsets in CORSIA (i.e. the light blue CORSIA line in Figure 10 stays below the dark green EU ETS original scope line). Hence the difference between the demand for offsets in CORSIA for the full 15 year period (2,711 Mt – see also Table A.2) and the demand for EUAs in the original scope scenario (3,888 Mt – see also Table A.2) would become significantly larger if an LRF of 2.2 were to be implemented in the EU ETS for aviation.

One can also compare the offsets and EUAs for Intra EEA+ flights between CORSIA and the EU ETS Intra EEA+ scenario. In the case of CORSIA, 271 Mt of offsets are computed for Intra EEA+ flights for the period 2021-2035 (see also section 3.2). The EUAs for the Intra EEA+ scenario, without the LRF, amount to 796 Mt (see Table A.2). The 796 Mt is significantly higher compared to the 271 Mt in CORSIA. Alongside implementation of CORSIA, the continuation of the EU ETS for Intra EEA+ flights would mean significant additional emissions to be mitigated.

Figure 8 **CO_2 emissions on routes covered by EU ETS scenarios and CORSIA per year (in Mt)**

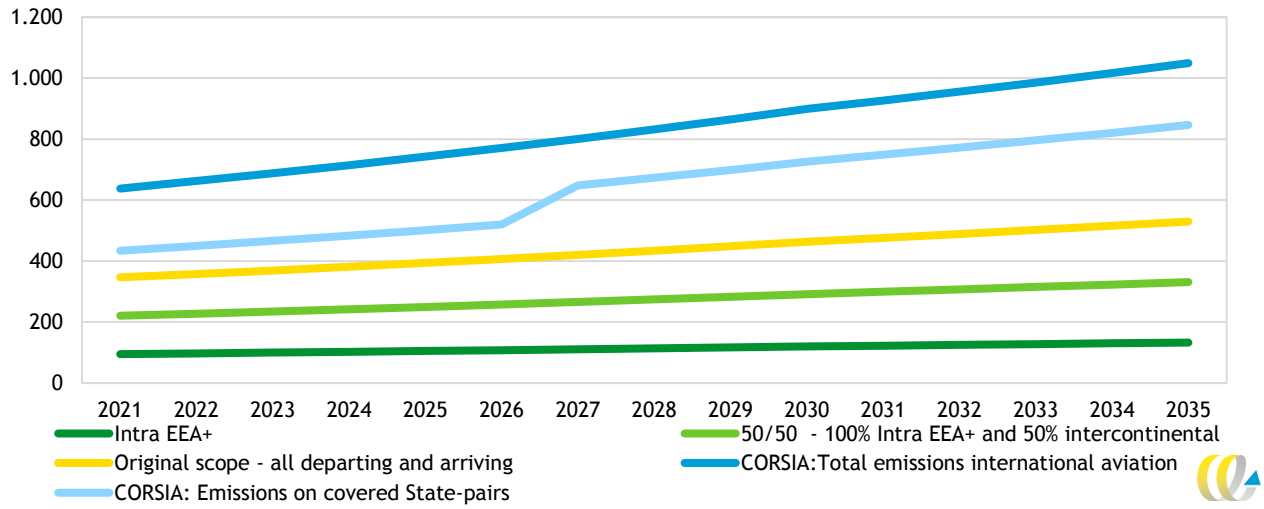


Figure 9 **Demand for allowances (EUAs) in EU ETS scenarios (cap: 95% of 2004-2006) versus demand for offsets in CORSIA per year (in Mt)**

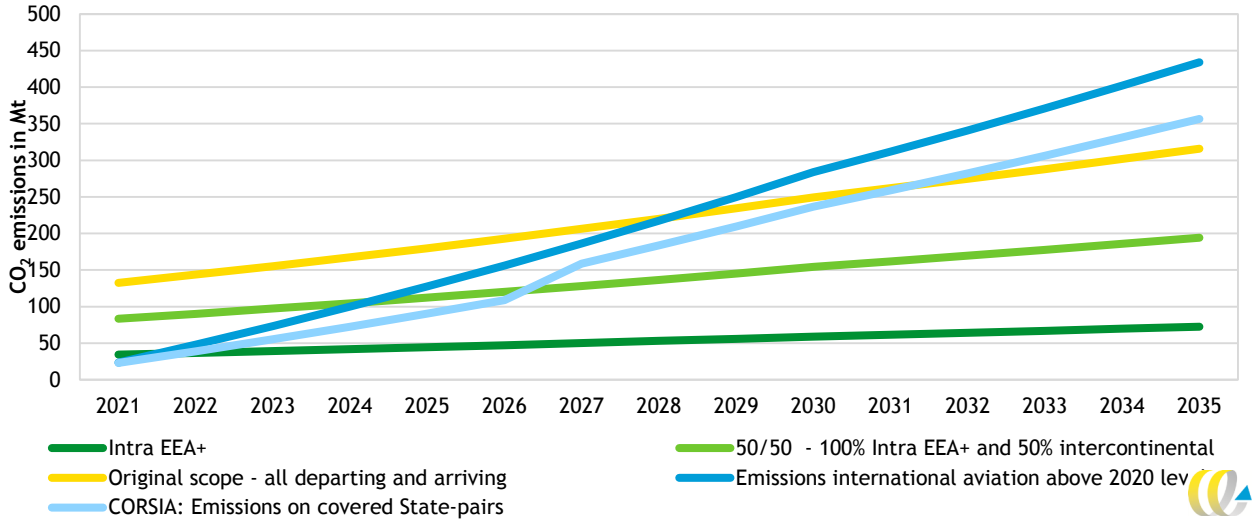
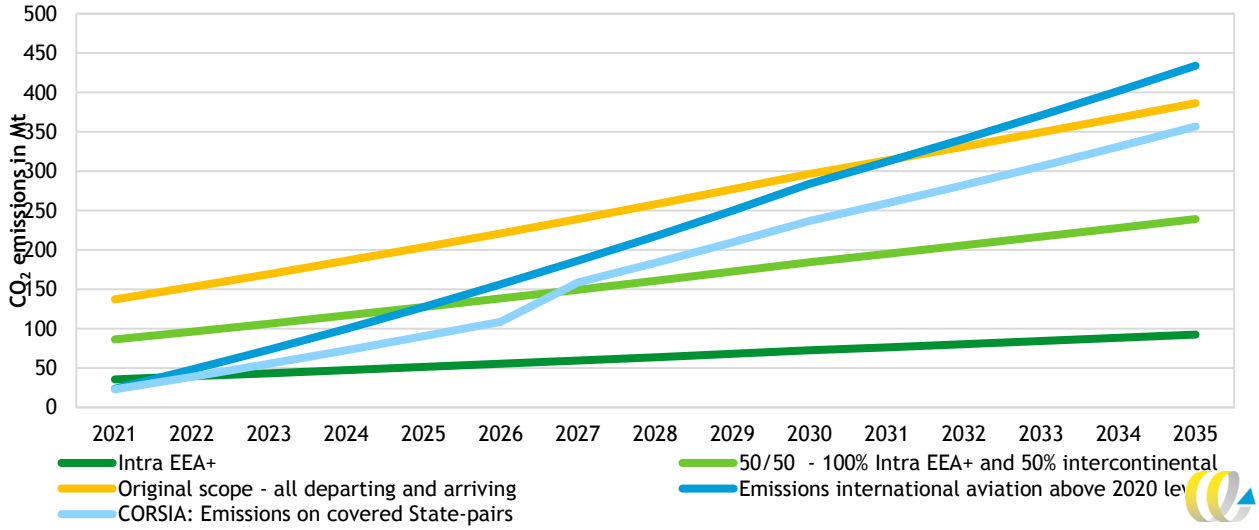


Figure 10 **Demand for allowances (EUAs) in EU ETS scenarios (cap: LRF of 2.2% per year) versus demand for offsets in CORSIA per year (in Mt)**



Finally the estimated total costs for buying allowances (EU ETS scenarios) or offsets (CORSIA) have been compared. For the EU ETS scenarios the PRIMES carbon price has been used and for CORSIA two alternative carbon price scenarios are considered; the first CORSIA carbon price scenario is based on the WEO New Policies Scenario. Because current carbon prices have dropped to levels below 1 € per tonne of CO_2, we have also considered a Low Price Scenario. The Low Price Scenario is very similar to a low price scenario considered by ICAO during preparatory analysis of the CORSIA. The Low Price Scenario takes into account a larger pool of emissions units with lower abatement costs.

The consideration of the two different CORSIA price scenarios reflects the fact that ICAO with the technical contribution of CAEP, still has to develop Emissions Unit Criteria[11]. In this analysis the assumed prices per tonne of CO_2 in $€_{2015}$ are presented in Table 3.

Table 3 **Carbon prices per tonne, $€_{2015}$**

Year	EU ETS scenarios	CORSIA	
	PRIMES carbon price[1)]	WEO - New Policies Scenario[2)]	Low Price Scenario
2020	16.3	18.0	5.4
2030	35.7	33.4	9.0
2040	53.1	45.1	12.6

1. https://ec.europa.eu/energy/sites/ener/files/documents/20160713%20draft_publication_REF2016_v13.pdf
2. IEA World Energy Outlook 2015.

All projected carbon prices are substantially higher than the current prices of CDM credits and voluntary credits which at the end of 2015 traded at around USD 0.4 per tonne of CO_2 and around USD 3 per tonne of CO_2 respectively (World Bank 2016).[12] (In a reversal of the historical trend, CDM credits are currently trading at lower prices than voluntary credits, probably as a result of the collapse of demand from the EU ETS). Still, it can be expected that the Paris Agreement will result in an increase in demand for credits which, in turn, would have a positive impact on prices. Projected EUA prices are also well above current EUA prices which were about EUR 4 per tonne of CO_2 in 2016.

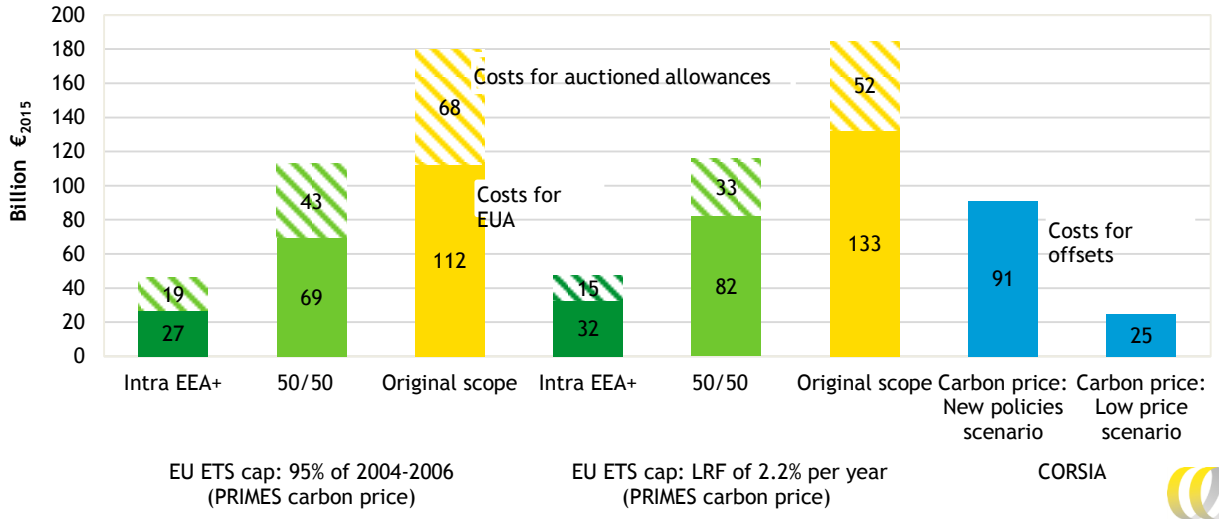
The total estimated costs per year for CORSIA for the two alternative carbon prices considered are presented in Table A.4 in Annex A. The total costs per year for the six EU ETS scenarios are presented in Table A.5. For the EU ETS scenarios a distinction is made between the total costs for allowances to be purchased by the aviation sector in order to cover the growth above the cap (costs for EUAs) and the costs for auctioned allowances (costs for EUAAs) under the cap. The totals costs for the full period 2021-2035 are presented in Figure 11. The costs are a function of the price of offsets (CORSIA) or allowances (EU ETS). If these prices are for example 10% of the price listed in Table 3 (more like the current prices), the costs are a factor of 10 lower. Conversely, if they are two times higher, the costs would increase by 100%.

Relative to the total fuel costs for international aviation, the estimated costs for offsets are about 2.5% (new policies) and 0.7% (low carbon price).

11 Article 20 of the CORSIA resolution states that this should be done as soon as possible but not later than 2018.

12 https://openknowledge.worldbank.org/bitstream/handle/10986/25160/9781464810015.pdf?sequence=3&isAllowed=y

Figure 11 Total estimated costs (2021-2035) for buying allowances/offsets for EU ETS scenarios and CORSIA



6 Conclusions

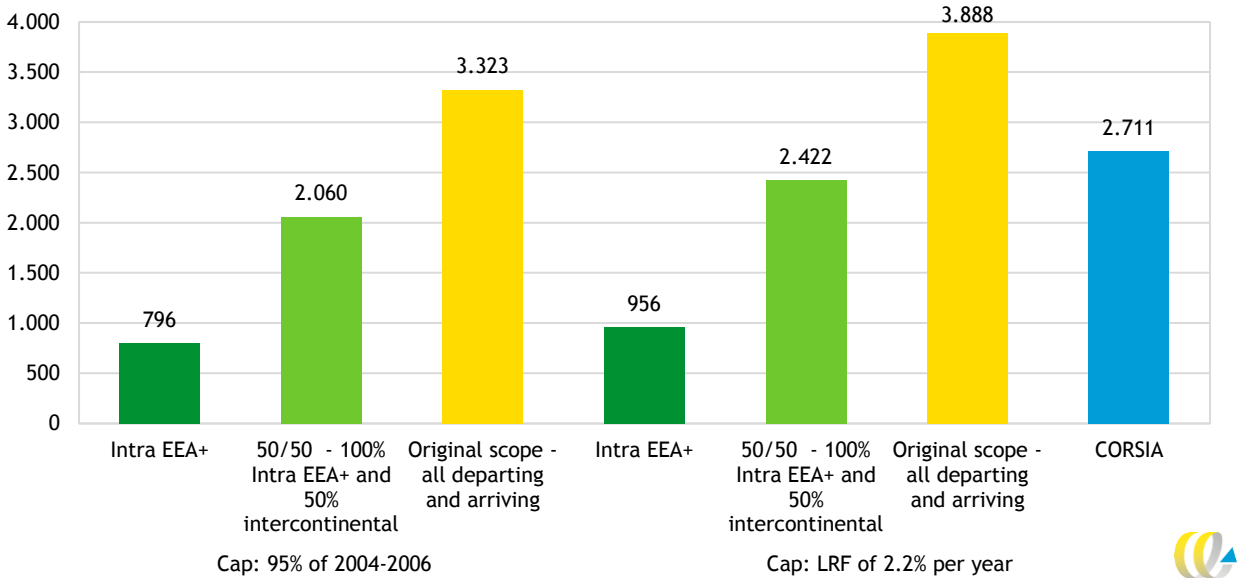
The main conclusions from the analysis in this study are:

1. On the basis of the current CORSIA resolution, with a mandatory scheme for the period 2027-2035, and 66 countries having announced that they will join the voluntary phases (2021-2026), the demand for offsets in the period 2021-2035 equals 2,711 Mt of CO_2. This implies that 81.5% of the emission growth of international aviation above 2020 levels will be required to be offset. Hence CORSIA does not result in full Carbon Neutral Growth after 2020. Because CORSIA only requires emissions above the baseline (2019/2020) to be offset and because not all countries join in the period 2021-2035, about one fifth of the cumulative CO_2 emissions of international aviation in the period 2021/2035 is offset.

2. Assuming the current cap for the EU ETS will be kept constant, the demand for allowances (EUAs) in the period 2021-2035 varies between 796 Mt when intra/EEA~flights are subject to EU ETS to 3,323 Mt when all flights departing from or arriving at EEA+ airports are included. If the Linear Reduction Factor of 2.2% year which is proposed for the stationary EU ETS were also applied to aviation, the demand for EUAs would increase to 956 Mt for the Intra EEA+ scenario and 3.888 Mt for the original scope scenario.

3. Because of the larger geographical scope of CORSIA, it covers more CO_2 emissions than any of the EU ETS scenarios. However, if the demand for offsets in CORSIA is compared with the demand for allowances from outside the aviation sector in the EU ETS scenarios the picture is quite different. This is because the EU ETS has a much stricter cap (95% of average 2004-2006 emissions) in comparison to the baseline for CORSIA (100% of average 2019-2020 emissions). Therefore the cumulative demand for allowances from outside the aviation sector for the original scope ETS scenario is larger compared to the demand for offsets in CORSIA (3,323 Mt versus 2,711 Mt). With a stricter cap for the EU ETS (LRF of 2.2%), the difference will become even larger (see Figure 12).

Figure 12 Total estimated costs (2021-2035) for buying allowances/offsets for EU ETS scenarios and CORSIA



4. In the initial years of CORSIA the demand for offsets is clearly lower compared to the demand for allowances from outside the aviation sector in any of the EU ETS scenarios. From 2022 onwards the demand for offsets in CORSIA is larger than the demand for allowances from outside the aviation sector in the Intra EEA+ scenario (current cap). In the case of the 50/50 ETS scenario, the demand for offsets in CORSIA is larger from 2027 onwards, and in the original scope ETS scenario it takes up to 2032 before CORSIA requires more emissions to be mitigated.

The results of the study allow for an ex-ante evaluation for various policy scenarios for the future of the inclusion of aviation in the EU ETS in the presence of CORSIA. One scenario would be to exclude aviation from the EU ETS and include all EU ETS flights (including domestic flights) in CORSIA. Another scenario would be to retain the domestic and intra-EEA+ flights in the EU ETS and exempt these flights from CORSIA. Yet other scenarios would include all flights within the original scope of the EU ETS in the EU ETS and exempt them from CORSIA. This study can be used to evaluate the demand for offsets and allowances of these scenarios:

5. If all international flights that are currently under the EU ETS would be included in CORSIA from 2021 onwards, the demand for offsets in CORSIA (as described in the study) remains unchanged while the demand for allowances (EUAs) from outside the aviation sector would be lower. If the EU ETS were to be retained for intra-EEA+ flights and all other flights would be included in CORSIA then the reverse obviously applies. In the period 2021-2035 the cumulative difference in the demand for offsets (under CORSIA) and EUAs (in the EU ETS) between the two scenarios would amount to 525–685 Mt CO_2, depending on the EU ETS cap. This is 22-28% of the cumulative amount of emissions to be offset under CORSIA in that period.

6. If either the original scope of the EU ETS were restored (and all these flights were to be exempted from CORSIA) or 50% of the emissions on flights to and from EEA-airports would be included in the EU ETS (and these emissions were to be exempted from CORSIA), the sum of the demand for offsets and allowances from outside the aviation sector would be even larger than in the scenario presented in the former conclusion.

Annex A Tables with AERO-MS results

A.1 CO_2 emissions covered by EU ETS and ICAO GMBM per year (in Mt)

Year	EU ETS scenarios			GMBM	
	Intra EEA+	50/50 - 100% Intra EEA+ and 50% intercontinental	Original scope - all departing and arriving	GMBM:Total emissions international aviation	GMBM: Emissions on covered State-pairs
2021	95	221	346	638	434
2022	97	228	358	663	450
2023	100	235	369	688	466
2024	103	242	381	714	483
2025	105	250	394	742	501
2026	108	257	407	771	520
2027	111	266	420	801	648
2028	114	274	434	832	673
2029	117	283	449	865	699
2030	120	292	464	898	726
2031	122	299	476	927	749
2032	125	307	489	956	772
2033	128	315	502	986	796
2034	130	323	516	1,017	820
2035	133	331	530	1,049	846
Total	**1,707**	**4,121**	**6,535**	**12,544**	**9,582**
Annual CO_2 emission growth (2021-2035)					
Growth	2.4%	2.9%	3.1%	3.6%	4.9%*

* This percentage does not only reflect increasing emissions on the covered routes but also that after 2026 more routes are covered.

A.2 Demand for allowances (EUAs) in EU ETS scenarios (cap: 95% of 2004-2006) versus demand for offsets in GMBM per year (in Mt)

Year	EU ETS scenarios (cap: 95% of 2004-2006)			GMBM	
	Intra EEA+	50/50 - 100% Intra EEA+ and 50% intercontinental	Original scope - all departing and arriving	Emissions international aviation above 2020 level	GMBM: Emissions on covered State-pairs
2021	34	83	132	23	23
2022	37	90	144	48	39
2023	39	97	155	73	55
2024	42	105	167	100	72
2025	44	112	180	127	90
2026	47	120	193	156	109
2027	50	128	206	186	158
2028	53	137	220	217	183
2029	56	145	234	250	209
2030	59	154	249	284	237
2031	62	162	262	312	259
2032	64	169	275	341	282
2033	67	177	288	371	306
2034	70	186	302	402	331
2035	72	194	316	434	357
Total	**796**	**2,060**	**3,323**	**3,325**	**2,711**

A.3 Demand for allowances (EUAs) in EU ETS scenarios (cap: LRF of 2.2% per year) versus demand for offsets in GMBM per year (in Mt)

Year	EU ETS scenarios (cap: LRF of 2.2% per year)			GMBM	
	Intra EEA+	50/50 - 100% Intra EEA+ and 50% intercontinental	Original scope - all departing and arriving	Emissions international aviation above 2020 level	GMBM: Emissions on covered State-pairs
2021	36	86	137	23	23
2022	39	96	153	48	39
2023	43	106	169	73	55
2024	47	117	186	100	72
2025	51	127	203	127	90
2026	55	138	221	156	109
2027	59	149	239	186	158
2028	64	161	258	217	183
2029	68	172	277	250	209
2030	72	184	297	284	237
2031	76	195	314	312	259
2032	80	206	331	341	282
2033	84	217	349	371	306
2034	88	228	368	402	331
2035	92	239	386	434	357
Total	**956**	**2,422**	**3,888**	**3,325**	**2,711**

A.4 Yearly estimated costs for buying offsets for GMBM for different WEO carbon price scenarios (in billion €$_{2015}$)

Year	WEO carbon price scenario	
	New Policies scenario	Low price scenario
2021	0.4	0.1
2022	0.8	0.2
2023	1.2	0.4
2024	1.7	0.5
2025	2.3	0.7
2026	3.0	0.8
2027	4.6	1.3
2028	5.6	1.5
2029	6.7	1.8
2030	7.9	2.1
2031	8.9	2.4
2032	10.1	2.7
2033	11.3	3.1
2034	12.6	3.5
2035	14.0	3.9
Total	**91.1**	**25.0**

A.5 Yearly estimated costs for buying allowances for EU ETS scenarios based on PRIMES carbon reference price scenario (in billion €$_{2015}$)

Year	Cap: 95% of 2004-2006								
	Intra EEA+			50/50 - 100% Intra EEA+ and 50% intercontinental			Original scope - all departing and arriving		
	Costs for EUA	Costs for auctioned allowances (EUAA)	Total	Costs for EUA	Costs for auctioned allowances (EUAA)	Total	Costs for EUA	Costs for auctioned allowances (EUAA)	Total
2021	0.6	0.2	0.9	1.5	0.5	2.0	2.4	0.8	3.2
2022	0.7	0.3	1.1	1.8	0.7	2.6	2.9	1.1	4.0
2023	0.9	0.4	1.3	2.2	1.0	3.1	3.4	1.5	5.0
2024	1.0	0.6	1.6	2.5	1.2	3.8	4.0	1.9	6.0
2025	1.2	0.7	1.8	2.9	1.6	4.5	4.7	2.4	7.1
2026	1.3	0.8	2.2	3.4	1.9	5.2	5.4	2.9	8.3
2027	1.5	1.0	2.5	3.8	2.2	6.1	6.2	3.5	9.7
2028	1.7	1.2	2.9	4.3	2.6	7.0	7.0	4.1	11.1
2029	1.9	1.4	3.2	4.9	3.1	8.0	7.9	4.8	12.7
2030	2.1	1.6	3.7	5.5	3.5	9.0	8.9	5.5	14.4
2031	2.3	1.8	4.1	6.1	4.0	10.0	9.8	6.2	16.0
2032	2.5	2.0	4.5	6.6	4.5	11.1	10.8	7.0	17.7
2033	2.7	2.2	4.9	7.3	5.0	12.3	11.8	7.8	19.6
2034	3.0	2.4	5.4	7.9	5.5	13.5	12.9	8.6	21.5
2035	3.2	2.7	5.9	8.6	6.1	14.7	14.0	9.5	23.5
Total	**26.7**	**19.2**	**45.9**	**69.4**	**43.5**	**112.9**	**112.2**	**67.7**	**179.9**

Year	Cap: LRF of 2.2% per year								
	Intra EEA+			50/50 - 100% Intra EEA+ and 50% intercontinental			Original scope - all departing and arriving		
	Costs for EUA	Costs for auctioned allowances (EUAA)	Total	Costs for EUA	Costs for auctioned allowances (EUAA)	Total	Costs for EUA	Costs for auctioned allowances (EUAA)	Total
2021	0.6	0.2	0.9	1.6	0.5	2.1	2.5	0.8	3.3
2022	0.8	0.3	1.1	1.9	0.7	2.6	3.1	1.1	4.2
2023	1.0	0.4	1.4	2.4	0.9	3.3	3.8	1.4	5.2
2024	1.1	0.5	1.6	2.8	1.1	3.9	4.5	1.8	6.3
2025	1.3	0.6	1.9	3.3	1.4	4.7	5.3	2.1	7.4
2026	1.5	0.7	2.3	3.9	1.6	5.5	6.2	2.5	8.7
2027	1.8	0.8	2.6	4.5	1.9	6.4	7.2	3.0	10.1
2028	2.0	1.0	3.0	5.1	2.2	7.3	8.2	3.4	11.6
2029	2.3	1.1	3.4	5.8	2.5	8.3	9.4	3.8	13.2
2030	2.6	1.2	3.8	6.6	2.7	9.3	10.6	4.3	14.9
2031	2.9	1.3	4.2	7.3	3.0	10.3	11.8	4.7	16.5
2032	3.1	1.5	4.6	8.1	3.3	11.4	13.0	5.1	18.1
2033	3.4	1.6	5.0	8.9	3.6	12.4	14.3	5.5	19.9
2034	3.8	1.7	5.5	9.7	3.8	13.6	15.7	6.0	21.7
2035	4.1	1.8	5.9	10.6	4.1	14.7	17.2	6.4	23.5
Total	**32.4**	**14.7**	**47.2**	**82.5**	**33.3**	**115.8**	**132.5**	**51.9**	**184.5**