Full scope EU ETS for aviation

Instruments to prevent carbon leakage

Committed to the Environment

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Content

Summary

In its current form, the EU ETS covers all flights between European Economic Area (EEA) airports, with exemptions for flights between the mainland and peripheral areas (outermost regions) within the same member state. Since the 'stop the clock' derogation in 2012, flights between airports located in the EEA to airports located outside the EEA are temporarily exempted from surrendering emission rights. This derogation has recently been extended until 2026 with the requirement of the implementation of CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation) in each respective country. To reduce the emissions from intercontinental aviation (faster), European Federation for Transport and Environment A.I.S.B.L. (T&E) supports an extension of the EU ETS scope to all flights departing at airports within the EEA. An important counterargument of the aviation sector to the EU ETS scope extensions is the occurrence of carbon leakage. T&E has commissioned this study to answer the following questions:

1. What will be the effect of the EU ETS scope extension on costs and emissions?
2. Which types of routes are at risk of carbon leakage, and what are the effects on ticket prices on alternative travel options on these routes?
3. Which instruments at EU or national level could reduce carbon leakage caused by a scope extension of the EU ETS?

Effect of the EU ETS scope extension on costs and emissions

A scope extension of the EU ETS would increase the costs of airlines on routes between EEA and non-EEA airports, since EU ETS allowances are more expensive than the costs for CORSIA offsets, which in addition only have to be paid for emissions above the 85% emission baseline from 2019. The additional costs will affect the ticket prices of passengers (depending on the applied cost-pass through rate of airlines) and result in a reduction in demand and emissions by 6.6 Mt CO_2 in 2030 and 7.4 Mt CO_2 in 2035. As a first order approximation, the costs increase of the EU ETS scope extensions scales linear with the flight distance. An indication of the order of magnitude in 2030 for economy class tickets from Amsterdam is € 19 extra for a flight to Istanbul and € 40 extra for a flight to Hong Kong.

Ambiguity around carbon leakage definition

The European Commission has no legal definition of carbon leakage in the EU ETS Directive. In the view of the authors, carbon leakage of the EU ETS should be defined as the increase in aviation CO_2 emissions outside the scope of the EU ETS as a reaction to cost increases caused by the EU ETS. However, in the literature and by stakeholder, often estimates are labelled as carbon leakage, which are based on changes in market shares on route or airport level without considering whether the shifted emissions remain within or outside the EU ETS system. In many cases also a link is suggested that these are additional emissions due to longer flight routes. The latter only occurs to a very limited extent.

Routes at risk of carbon leakage

Shifts in market shares between airlines and carbon leakage are likely to occur if the EU ETS scope extension leads to different cost increases on potential routes. This occurs in cases where (parts) of the routes would be covered by the EU ETS scope extensions, whereas others remain (partly) outside the scope of the EU ETS. This study discusses four cases that are representative for types of routes at risk of carbon leakage. Expected cost differences for 2030 are indicated:

- direct long-haul flight: Amsterdam to Hong Kong (+€ 22) compared to transfer at Istanbul;
- indirect long-haul flight: Nice to Bangkok, via Amsterdam (+€ 25) compared to route via Istanbul;
- intercontinental transfer: Toronto to Mumbai, via Amsterdam (+€ 60) compared to direct flights and routes via hubs outside the EEA;
- (non-)EEA destination choice at Mediterranean coast: Amsterdam to Fez (+€ 17) compared to Malaga.

Instruments at EU or national level to reduce carbon leakage

All five assessed countermeasures to prevent carbon leakage have potential to work. However additional research (e.g. full work out of the instruments, legal analysis, effect analysis) is needed to definitely reject or approve countermeasures.

Instruments based on solutions for carbon leakage in other sectors, the Shipping EU ETS instrument and CBAM, are found to be not applicable in a direct way but could with some alterations also potentially work for aviation. For both measures, a solution would be to increase the costs on flights to non-EEA hubs with a high risk of carbon leakage. To define such a hub, inspiration could be found in the separate implementing regulation that is introduced for maritime shipping. The idea is to introduce a buffer zone around the European Union, using several criteria, to define 'non-EEA hubs with high carbon leakage risk'. Additional research would be needed, also to determine whether all flights to these hubs should be targeted, or only a selection, and what the extra charge should be.

Another approach could be to decrease the costs of the extended EU ETS for destinations with a high risk of carbon leakage, by introducing free allowances specifically for these destinations.

Using 'SAF allowances' to reduce carbon leakage could also work. Both the zero emission factor of SAF and the SAF allowances could help discourage flights to non-EEA airports at high risk of carbon leakage, while encouraging direct flights.

National levies or destination-based charges could work, as they focus on passengers instead of flights, therefore allowing to charge a full passenger journey. A challenge would be the harmonisation of national departure taxes in Europe. A tax at European level requires unanimity of EU member states, making it unlikely to be implemented.

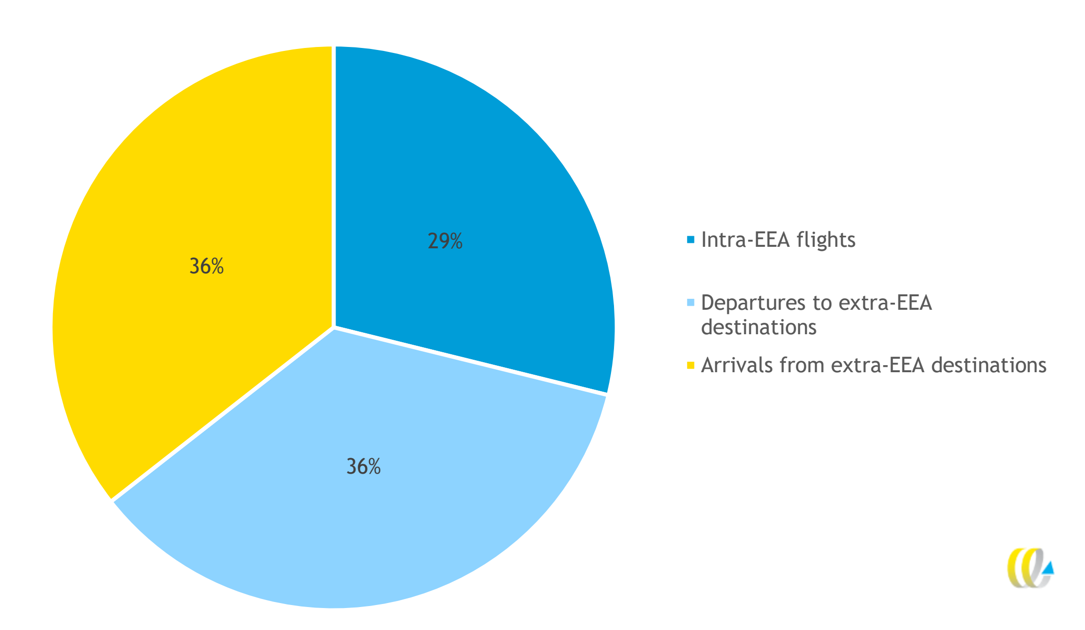
1 Introduction

1.1 Background

In its current form, the EU ETS covers all flights between European Economic Area (EEA) airports, with exemptions for flights between the mainland and peripheral areas (outermost regions) within the same Member State. Since the 'stop the clock' derogation in 2012, extra-EEA flights (flights between airports located in the EEA to airports located outside the EEA) are temporarily exempted from surrendering emission rights. This derogation has recently been extended until 2026 with the requirement of the implementation of CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation) in each respective country.

In its current scope, the EU ETS covers 29%[1] of the CO_2 emissions from departing and arriving flights at European airports (see Figure 1 for 2019). The remaining 71% of aviation CO_2 associated with intercontinental flights are excluded and currently part of CORSIA, which has a much lower CO_2 price and only requires compensation above a baseline (85% of 2019 emissions from 2024 until the end of the scheme in 2035).

Figure 1 - Share of different flight segments for aviation emissions in 2019



In order to reduce the emissions from intercontinental aviation (faster), European Federation for Transport and Environment A.I.S.B.L. (T&E) supports an extension of the EU ETS scope to all flights departing at airports within the EEA.

[1] Note, that in the past, airlines did not pay for all EU ETS allowances, since they received free allowances. The free EU ETS allowances are set to be phased out gradually starting in 2024 and will be fully eliminated by 2026 as part of the Fit for 55 package.

With this scope extension the EU ETS would cover 100% of the emissions of the departing flights at EEA airports and 64% when comparing to departing and arriving flights[2].
An important counterargument of the aviation sector to the EU ETS scope extensions is the occurrence of carbon leakage.

1.2 Objective and research questions

Carbon leakage describes the increase in emissions outside a region as a direct result of the policy to cap emission in this region. For aviation this implies a shift from aircraft movements, passengers and freight from routes via EEA airports to routes via non-EEA airports. In order to prevent carbon leakage, additional instruments could be introduced. The goal of this study is to put together a comprehensive overview of different cases of carbon leakage and instruments that could be used at EU or national level to limit the risk of carbon leakage. The following research questions are answered:

1. What will be the effect of the EU ETS scope extension on costs and emissions?
2. Which types of routes are at risk of carbon leakage, and what are the effects on ticket prices on alternative travel options on these routes?
3. Which instruments at EU or national level could reduce carbon leakage caused by a scope extension of the EU ETS?

1.3 Outline of the report

In Chapter 2, a general overview of the EU ETS scope extension is given. This includes an overview of the overall impact on CO_2 emissions and a literature overview of studies that have assessed carbon leakage for aviation. Since carbon leakage depends strongly on the specific routes and alternative travel options, we discuss effects on ticket prices and carbon leakage for four specific cases in Chapter 3. For the individual travel options the effects of the European Fit For 55 package (including CORSIA) on ticket prices is assessed, with specific attention to the additional costs of the EU ETS scope extension.

In Chapter 4, potential instruments to prevent carbon leakage are described. The analysis consists of a general discussion of potential measures to reduce carbon leakage and an individual assessment of potential countermeasures. We conclude with a systematic comparison of the measures on the most important criteria.

[2] This in more than 50% due to the fact that intra-EEA flights have all emissions in scope and for extra-EEA flights only the emissions of departing flights are subject to the EU ETS.

2 EU ETS scope extension

2.1 The EU ETS for aviation

Aviation was brought into the EU ETS in 2012. Originally, the EU ETS covered all flights to and from airports in Member States of the European Economic Area (EEA). A number of countries from outside the EEA strongly disagreed that aircraft operators which are not based in the EEA were also subject to the EU ETS for the flights between non-EEA and EEA Member States. In 2013, the EU decided to 'stop the clock' and to temporarily reduce the scope of flights subject to the EU ETS to flights between and within EEA Member States (referred to as 'intra EEA flights'). The European Court of Justice stipulated that the EU was within its right to apply the EU ETS to flights outside the EU (Court of Justice of the European Union (CJEU), 2011). The reduction of scope was also adopted in order to provide time for ICAO to agree on a global market based mechanism (TAKS, 2022).

During the ICAO Assembly in October 2016, a resolution was adopted to implement a global Market Based Measure to address CO_2 emissions from international aviation as of 2021. As a result, the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) was introduced (ICAO, 2016). CORSIA aimed to stabilise CO_2 emissions at 2020 levels by requiring airlines to offset the growth of their emissions above these levels. CORSIA is being implemented in three phases:

1. **Pilot phase (2021-2023):** offsetting requirements are only applicable to flights between States that have volunteered to participate in CORSIA offsetting (115 States have volunteered to participate in 2023).
2. **First phase (2024-2026):** offsetting requirements will still be applicable only on routes between volunteering States.
3. **Second phase (2027-2035):** CORSIA should apply to all ICAO contracting states, with certain exemptions.

The CORSIA baseline of 2020 emissions was meant to be established as an average of reported emissions from 2019 and 2020. However, following the significant reduction of aviation activities due to the COVID-19 pandemic, the baseline for the pilot phase was re-defined as the level of 2019 emissions. This, combined with the rebound of the aviation sector, resulted in no offsetting obligations under CORSIA for aeroplane operators in 2021 and 2022. After the first periodic review of CORSIA, ICAO countries agreed on a new CORSIA baseline from 2024 onward, defined as 85% of CO_2 emissions in 2019. The 2021 revision of the EU ETS directive appropriately implements CORSIA for the EU. This will be applied to international flights departing from or arriving at airports within the EEA. For flights within the EEA, only the EU ETS applies.

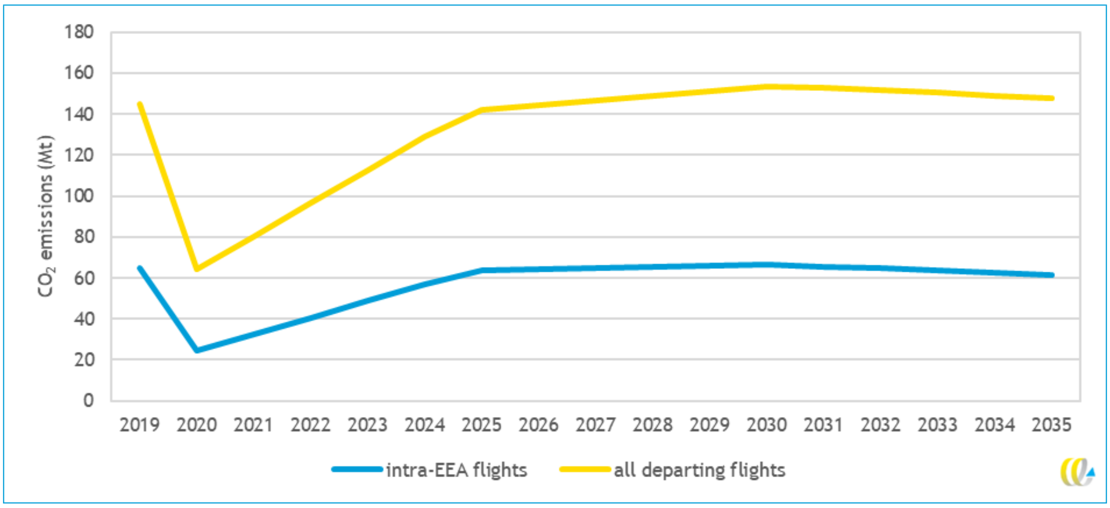
In 2026, the European Commission will carry out an assessment of CORSIA to determine whether it is sufficiently delivering on the goals of the Paris Agreement. Subject to the outcome of this assessment, the Commission will make a legislative proposal to possibly phase out the EU ETS exemption for flights to extra-EEA destinations. This proposal could extend the scope of the EU ETS to departing and incoming flights like in the original proposal or only target departing flights from EEA airports (half scope) (EC, ongoing-c).

2.2 Effects of an EU ETS scope extension

A scope extension of the EU ETS would increase the costs for airlines on routes between EEA and non-EEA airports, since EU ETS allowances are more expensive than the costs for CORSIA offsets, which in addition only have to be paid for emissions above the 85% baseline from 2019. The additional costs will affect the ticket prices of passengers (depending on the applied cost-pass through rate of airlines) and result in a reduction in demand and emissions.

Figure 2 shows projections for the aviation CO_2 emissions for EEA related flights estimated in 2022 (TAKS, 2022).The main assumptions are full recovery from COVID in 2025 relative to 2019 emissions, post COVID-19 growth according to the ICAO traffic forecast (ICAO, 2018) and SAF blending following Regulation (EU) 2023/2405 on ensuring a level playing field for sustainable air transport (hereafter referred to as ReFuelEU Aviation), which leads to the decreasing emissions at the end of the period. Note, that the numbers in Figure 2 deviate from a recent study of Transport and Environment (T&E, 2023), estimating the emissions of all departing flights from EU27, Norway, Iceland, Switzerland and the UK airports in 2019 (187.43 Mt) and 2023 (164.85 Mt). However, these differences are not relevant for the conceptual discussion on carbon leakage within this study.

Figure 2 - Aviation CO_2 emissions for intra-EEA flights (current EU ETS scope) and all EEA departing flights (possible scope extension)

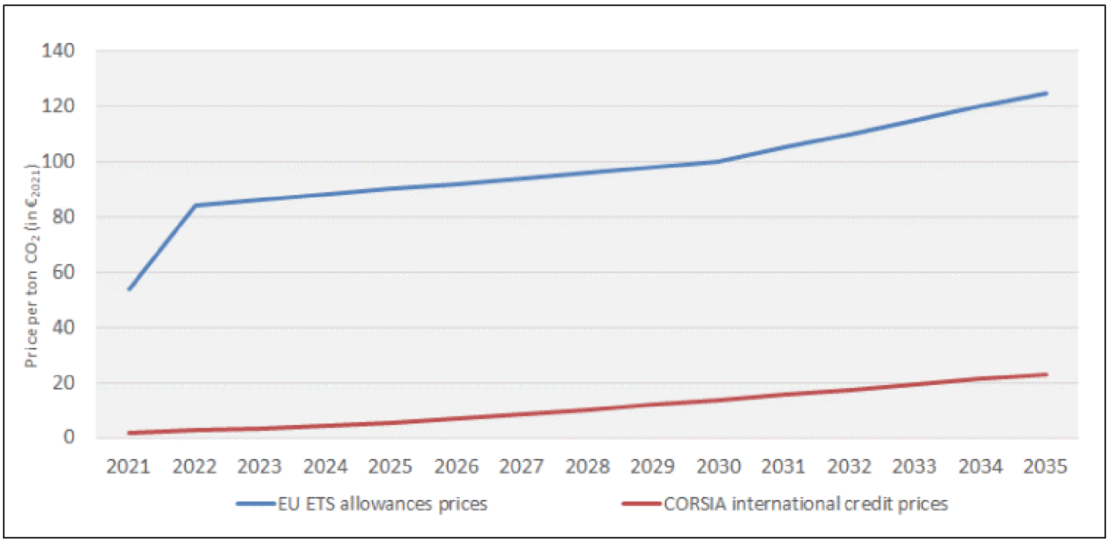


Source: AERO-MS modelling of different EU ETS scenarios in TAKS (2022).

The current scope of the EU ETS covers the intra-EEA flights, represented by the blue line in Figure 2, which in 2019 covered 29% of the aviation CO_2 emissions from all departing and incoming flights. The 2026 assessment by the Commission mentions a possible extension to include all intra/extra-EEA departing flights and exempt incoming flights. This would cover 64% of aviation CO_2 emissions (with respect to all incoming and departing flights to EEA airports) and is represented here by the yellow line.

The projected prices for EU ETS allowances and CORSIA credits used in the study TAKS (2022) are shown in Figure 3. Note, that airlines have to purchase CORSIA credits only for emissions above the baseline, which is 85% of 2019 emissions. Since the emissions in the period 2025 to 2035 are expected to be similar to 2019 levels, this implies costs for only 15% of the emissions, reducing the effective costs by 85%.

Figure 3 - Projected EU ETS allowance prices and CORISA international credit prices

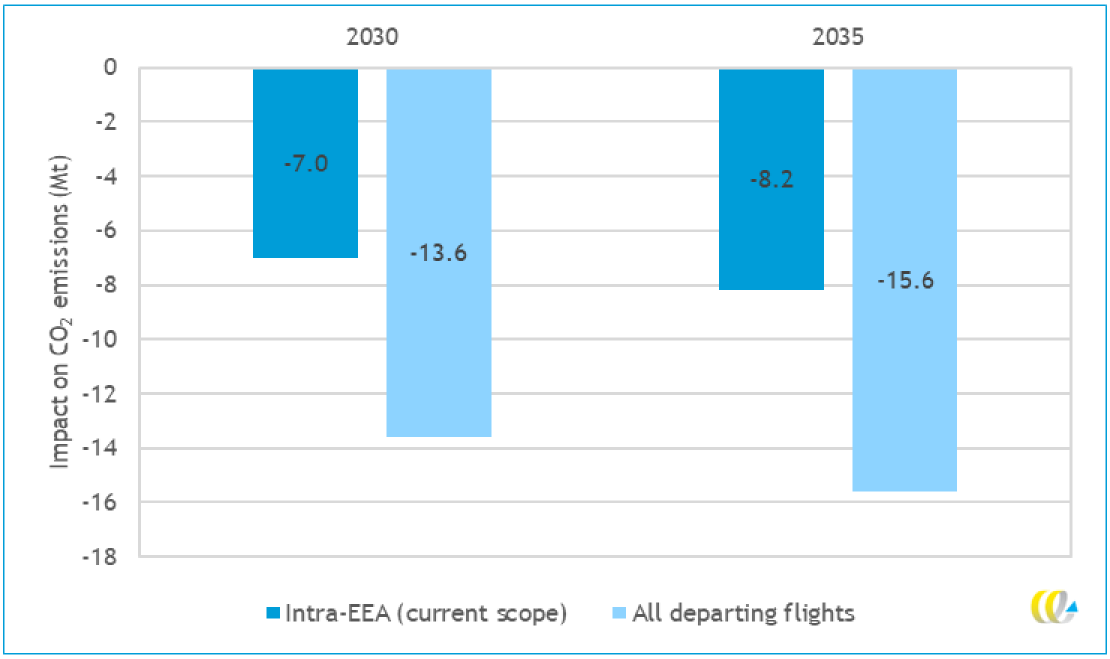


Source: TAKS (2022).

The higher costs for airlines will be passed through in the ticket prices or freight rates. This leads to emissions reduction in two ways:

1. Decrease in demand for flights and;
2. Improvements in efficiency earlier than in the baseline. Figure 4 shows the resulting emissions reduction. An EU ETS scope extension to all departing flights will decrease the aviation CO_2 emissions by 6.6 Mt in 2030 and 7.4 Mt in 2035 according to TAKS (2022).

Figure 4 - Emission reduction due to an EU ETS extension



Source: AERO-MS modelling of different EU ETS scenarios in TAKS (2022).

2.3 Carbon leakage

However, the cost increase for flights departing at EEA airports as a consequence of an ETS scope extension may not only lead to a reduction in demand but also to a potential evasion to routes via airports outside the EEA, if these routes have less strict climate policies and hence lower prices. The European Commission has no legal definition of carbon leakage in the EU ETS Directive. However, in EC (ongoing-b), the European Commission defines carbon leakage as:

"*Carbon leakage refers to the situation that may occur if, for reasons of costs related to climate policies, businesses were to transfer production to other countries with laxer emission constraints. This could lead to an increase in their total emissions.*"

The International Energy Agency (IEA) and the international Panel of Climate Change (IPCC) use slightly different explanations:

- **IEA:** Carbon leakage is defined as the increase in emissions outside a region as a direct result of the policy to cap emission in this region (IEA, 2008).
- **IPCC:** Carbon leakage is defined as the increase in CO_2 emissions outside the countries taking domestic mitigation action divided by the reduction in the emissions of these countries (IPCC, 2007).

The IEA and IPCC definitions are clear. Carbon leakage is the increase in emissions outside a region taking policy measures. In the IEA definition it is this absolute value, in the IPCC definition it is a relative value compared to the reduction of emissions in the region.
The European Commission definition is, however, less clear. The first sentence seems to use the same definition as the IEA definition. However, the second sentence "*This could lead to an increase in their total emissions*", seems to focus specifically on an increase in the total emissions. Note that this would lead to different numbers of carbon leakage.

We will explain the difference between these definitions by using an example (see Figure 5). A passenger travelling from Amsterdam (AMS) to Shanghai (SHA) would be facing additional costs for the outgoing flight AMS-SHA. To avoid part of the additional CO_2 costs, the passenger purchases a transfer ticket via Istanbul (IST), since only the short part AMS-IST would be covered by the EU ETS scope extension and the IST-SHA part of the journey would be out of scope of the EU ETS. Now there are three options in what to define as carbon leakage:

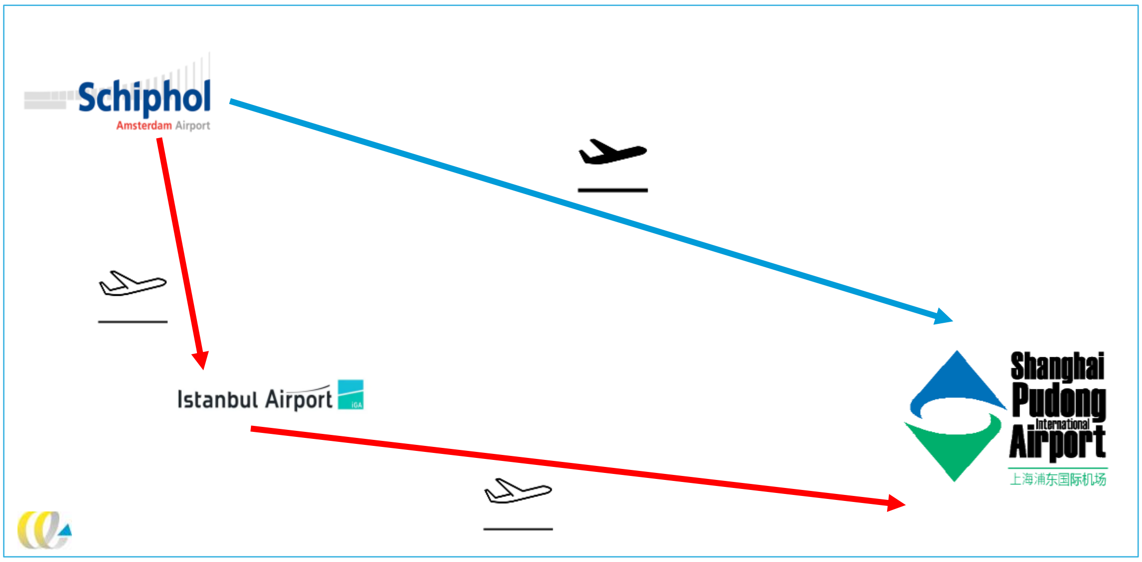
1. Total emissions from the indirect route (AMS-IST-SHA).
2. Emissions from the part of the indirect route outside the EU ETS (IST-SHA).
3. Additional emissions from the indirect route compared to the direct route (AMS-IST-SHA minus AMS-SHA).

The IEA and IPCC definitions are clear. It should be Option 2, as carbon leakage is described as the increase in emissions outside the EU ETS region. The EC definition could either be interpreted as also stating Option 2 according to the first sentence. The second sentence, however, suggests an increase in total emissions, which is in line with Option 3. On the other hand, Option 1 is about shifts of flights and therefore shifts of emissions. These shifts are important for airlines, airports and all stakeholders related to air traffic activities at a specific airport for reasons of competitiveness and connectivity. In this example, there is a probability that for instance KLM (home carrier of Amsterdam Schiphol) would lose market share to Turkish Airlines (home carrier of Istanbul Airport). This is a valid argument, especially in the discussion around a level playing field.

However, carbon leakage should be about effects on carbon. Therefore, in this study we will define carbon leakage in line with the IEA and IPCC definitions (Option 2), as the increase in emissions outside a region as a direct result of the policy to cap emission in this region. Carbon leakage means that the region's climate mitigation policy is less effective and more costly in containing emission levels, a legitimate concern for policy-makers.

Option 3 defines the additional global GHG emissions. An important note is that carbon leakage and additional global GHG emissions are not the same. Carbon leakage is the share of emissions that is moved to the region outside the EU, while the change in global GHG emissions can be defined as the additional emissions from changes in flight patterns or SAF blending from a global perspective. Carbon leakage does therefore not necessarily lead to additional global GHG emissions, when flight patterns change such that the total flight length decreases, it could even lead to a reduction in global GHG emissions.

Figure 5 - Example route options from Amsterdam to Peking either via a direct flight or with a transfer at Istanbul airport



In this study, no new modelling is performed to estimate the total amount of carbon leakage due to a scope extension of the EU ETS. It is obvious that the probability of carbon leakage has a strong dependence on the specific routes. Therefore, we discuss the effects of the EU ETS scope extension for 4 example routes in detail in Chapter 3. However, in the next section we will give an estimate of what the total carbon leakage is based on a literature review.

2.4 Carbon leakage estimation based on literature

We found three recent studies that have assessed carbon leakage for aviation.
It is important to note that these studies define carbon leakage as the above-mentioned Option 1: total emissions of flights that shift to non-EEA hubs. Hence, the amount quantified in these studies is higher than what is expected for a method in line with the definitions of the European Commission, IEA and IPCC.

The three studies are:

1. SEO and NLR (2022) calculated that for the Fit For 55 policies, whereby the Refuel EU Aviation blending obligation has the same scope as the EU ETS scope extension namely all departing flights, 6% of the emissions reduction is ‘leaked’ due to a shift of flights to non-EEA hubs.
2. A follow-up study by T&E (2022), based on data of the SEO study, concludes that this ‘carbon leakage’ risk is limited to 3% of total emissions savings by the Fit For 55 measures in 2035.
3. SEO (2022) did an assessment of the EU ETS scope extension in combination with the other aviation related Fit For 55 measures. In this study ‘carbon leakage’ for the combined scope extension and Fit for 55 measures could become 12% in 2035.

For some specific routes however, these studies find ‘carbon leakage’ figures that could become much larger. To show the difference between the definition used in these studies (Option 1) compared to Options 2 and 3, we analyse the case Hamburg – Bangkok from SEO (2022) as shown in Figure 6.

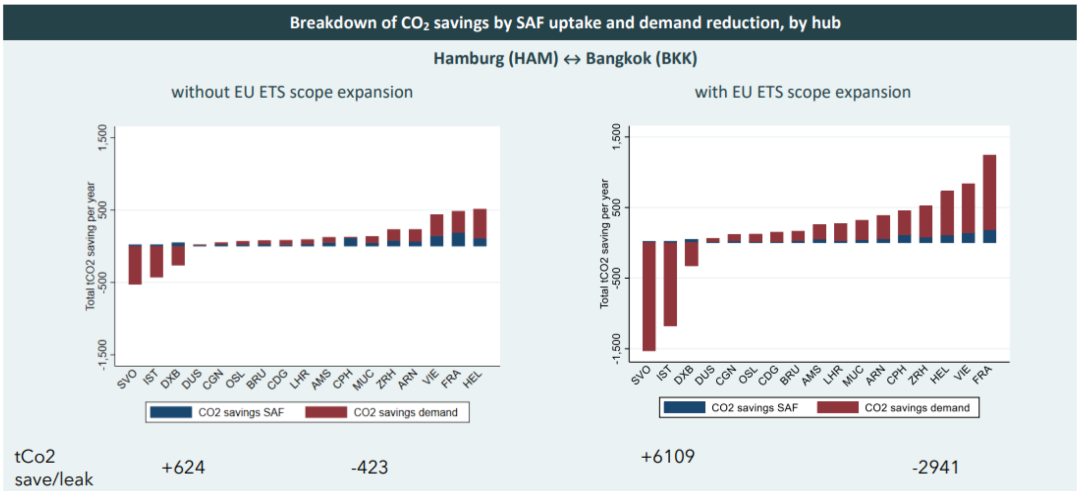
As a consequence of the EU ETS scope extension, routes via European hubs incur more additional costs than routes via non-European hubs. Therefore, the SEO report finds a decrease in emissions from routes via European hubs as Frankfurt (FRA), Vienna (VIE) and Helsinki (HEL) and an increase in emissions via non-European hubs as Moscow (SVO), Istanbul (IST) and Dubai (DBX). It argues that the carbon leakage here is the increase in emissions via non-European hubs for the total route, which is 2,941 tonnes of CO_2. The saved emissions by decreases in routes via European hubs are 6,109 tonnes. Therefore, the relative carbon leakage for this route is 48%, this is for the EU ETS with scope extension and other Fit For 55 measures combined.

Figure 6 - Case example of a carbon leakage estimation for Hamburg – Bangkok from the SEO study on the EU ETS scope expansion

CO₂ impact and carbon leakage for Hamburg – Bangkok

For the route example Hamburg – Bangkok, in 2030 and with the EU ETS scope expansion, we find that carbon leakage is 2941 tons CO_2, while CO_2 savings are 6109 tons (see C.3). This means that carbon leakage can add up to 48.1% for this route.

Figure C.3. Ticket cost example for the Hamburg – Bangkok route with cost and CO_2 savings in % (2030)



Source: SEO Amsterdam Economics (2022).

Source: SEO (2022).

However, this is calculated using the Option 1 method to calculate carbon leakage. The drawback of this definition is that a part of these emissions is still inside the scope of the EU ETS, namely all emissions of flights departing from airports within the EEA. The IEA and IPCC definitions make clear that only the increased emissions outside the EU ETS should be counted as carbon leakage. We performed an additional analysis based on the data in the SEO study, using the ratio of the distance of the second leg to the total route length. We find that carbon leakage according to this definition is 2,260 tonnes or 37% for this specific Hamburg – Bangkok route. This is significantly lower than estimated by SEO.

As mentioned, carbon leakage is something different than additional global GHG emissions. To understand the effect on net global emissions, we estimate the increase in total emissions according to Option 3 based on the SEO case. The method[3] uses the increase in route length of routes via non-European hubs compared to routes via European hubs (note that this calculation does not take into consideration potential carbon leakage caused by less SAF being uplifted at non-EU airports). Table 1 shows the total length, using Great Circle Distance, of the Hamburg – Bangkok example route via European and non-European hubs. Our first finding is that the routes that are currently mostly used, via European hubs, are not necessarily the shortest routes. For example, the routes via London Heathrow and Amsterdam Airport Schiphol are significantly longer than the route via Istanbul. The route via Moscow is actually the shortest route in this case example. Therefore, a shift of routes via European to non-European hubs would not necessarily lead to additional emissions.

Table 1 - Total flight length of possible indirect routes from Hamburg to Bangkok in Great Circle Distance (GCD)

Via hub	Length (km)
European hubs	
Frankfurt	9,403
Vienna	9,212
Helsinki	9,071
Zurich	9,741
Copenhagen	8,911
Stockholm	9,116
Munich	9,392
London Heathrow	10,315
Amsterdam	9,580
Brussels	9,735
Paris, CDG	10,171
Oslo	9,397
Cologne	9,425
Düsseldorf	9,407
Non-European hubs	
Dubai	9,780
Istanbul	9,463
Moscow	8,882

Source: ICAO (ongoing).

[3] This method is an approximation since we use distances to scale the emissions instead of an emission model and weight by savings instead of modelling the number of flights. However, that is sufficient to give a good estimate.

Table 2 shows the weighted average route length via European hubs, using the emissions saved in this example as weights, compared to the route length via the non-European hubs. We find that the route via Dubai is about 4% longer, Istanbul 1% longer and via Moscow is actually 5% shorter than via the weighted average European hub. Multiplying these route length differences with the extra emissions via non-European hubs, we find that there actually is a decrease in total emissions by 1%.

Since it is currently not possible to fly from Europe to Moscow due to the sanctions against Russia, the net result would be slightly different. Using the simple assumption that the increase to Moscow now flies via Istanbul we find a 0.5% increase in total emissions, and if it shifts to Dubai we find a 1.4% increase in total emissions. This indicates that these shifting routes via European hubs to non-European hubs have a very small effect on total emissions from aviation, far from the 48% 'leakage' as defined by SEO. For routes that originally have direct flights, there will be more additional emissions with a shift to indirect routes.

Table 2 - Total length of routes via non-European hubs compared to the weighted average route length via European hubs

Via hub	Length (km)	Delta to w. avg. EU hub (km)
European hubs w. average	9,391	
Dubai	9,780	4.1%
Istanbul	9,463	0.8%
Moscow	8,882	-5.4%

2.5 Conclusions

This chapter shows that the extension of the scope of the EU ETS to all departing flights leads to cost increases for flights departing at EEA airports, causing a reduction in demand which leads to CO_2 emissions reductions of 6.6 Mt in 2030 and 7.4 Mt in 2035. However, the cost increases for flights at EEA airports could also partly lead to evasion via airports outside the EEA, where less strict carbon prices apply, causing carbon leakage. This carbon leakage may partly offset the emissions reduction.

This report uses a definition of carbon leakage in line with the IEA and IPCC definition: "Carbon leakage is defined as the increase in emissions outside a region as a direct result of the policy to cap emission in this region". This definition differs from some previous studies, where also parts of the increase in emissions inside the region are included.
For example the SEO (2022 study calculates 12% carbon leakage with this definition (for the scope extension and Fit for 55 measures combined in 2035). Using the definition in line with IEA and IPCC, the carbon leakage will likely be lower.

Next to this, some reports or definitions seem to suggest that carbon leakage also concerns additional emissions. However, note that carbon leakage and additional global GHG emissions are not the same. Carbon leakage is the share of emissions that is moved to the region outside the EU, while the change in global GHG emissions can be defined as the additional emissions from changes in flight patterns or SAF blending from a global perspective. Carbon leakage does therefore not necessarily lead to additional global GHG emissions, when flight patterns change such that the total flight length decreases, it could even lead to a reduction in global GHG emissions. For the example route Hamburg – Bangkok examined, we find 37% carbon leakage and only ~1% additional global GHG emissions.

3 Possible cases of carbon leakage

3.1 Introduction

Since carbon leakage has a strong dependence on the specific routes, this chapter will focus on four cases which represent the most likely types of carbon leakage that would occur if the EU ETS would cover all departing flights from EEA airports. Other routes with a high risk of carbon leakage are comparable with the chosen cases.

Section 3.1 explains the case selection, including a discussion on the representativeness of the four cases. For these cases, the impact of the EU ETS scope extension on ticket prices in 2030 are described in Section 3.2. A comparison of the CO_2 emissions for the different route options is presented in Section 3.3. In the analysis, emissions within the EU ETS and outside the EU ETS are disentangled to reflect on carbon leakage. Section 3.4 presents a qualitative analysis for the total amount of carbon leakage. In Section 3.5 a detailed analysis of the impacts of the relevant EU policies (EU ETS and ReFuel EU Aviation) and CORSIA on ticket prices in 2030 and 2035 is presented for Case 1. We distinguish between the current scope of the EU ETS (only intra-EEA flights) and a scope extension to all departing flights. The corresponding figures for the other cases in 2030 and 2035 are depicted in Annex C. To place the costs of the EU ETS scope extension in perspective, the effects on the total ticket prices is estimated for current ticket prices on routes. The results are shown in Section 3.6.

3.2 Typical cases of carbon leakage

To illustrate carbon leakage, four cases have been selected, each demonstrating a different kind of carbon leakage. The intention of the cases and the chosen examples are explained below. In Textbox 1 some considerations with respect to the representativeness of the cases are summarized. For Cases 1 to 3 the origin and destination are fixed and different route choices are discussed, in Case 4 different destination choices are compared.

Case 1: Direct long-haul flight

Amsterdam to Hong Kong: This case illustrates the potential effects for direct long-haul flights to extra EEA destinations departing from EEA airports. As alternatives for these direct flights, passengers can choose options with a transfer at either a hub within or outside the EEA. The intention of the case is to show that a transfer via a hub just outside the EEA becomes relatively more attractive, as only the first (relatively short) outbound flight falls under the EU ETS scope extension, while for the other two route options the entire outbound route is subject to the EU ETS. We selected a case for which the direct and several indirect travel options are available. For Amsterdam to Hong Kong the options are a direct flight, but also routes with transfers at Frankfurt, Istanbul, Doha or Beijing.

Case 2: Indirect long-haul flight

Nice via hub to Bangkok: The second case illustrates the competition for flights from Europe to long-haul destinations outside the EEA, for routes without direct connections. The required transfer can either take place at a hub within or outside the EEA. The first outbound flight for the route with a transfer at an EEA hub is already subject to the current EU ETS scope, making it currently a less attractive option compared to a transfer at a non-EEA hub. Therefore, one could argue that there is already a possibility for carbon leakage in the intra-EEA scope of the EU ETS. By extending the EU ETS scope, the current carbon leakage could be further amplified or reduced depending on the location of the hub and the final destination and hence the distances of the first and second flight. The scope extensions lead to additional costs on the second flight leg for transfers at the EEA-hub, while for transfers at non-EEA hubs this will be on the first flight leg. The chosen example is the case Nice to Bangkok with transfer options at Munich, Copenhagen, Amsterdam, Istanbul and Dubai.

Case 3: Intercontinental transfer

Toronto via hub to Mumbai: The third case is an intercontinental connection between two non-EEA destinations, either direct or with a transfer at a (non-)EEA-hub. In this case, a stopover at an EEA-hub becomes relatively less attractive, as the second flight leg will be subject to the extended EU ETS scope. The other two travel options (direct and transfer at a non-EEA hub) are not affected by the EU ETS scope extension. To make a relevant comparison, the connection via the EEA-hub must be comparable in price or cheaper than the direct flight. Otherwise, the route via Europe is likely not to be chosen in the current situation and would only become less attractive. As a result of these requirements, it was rather difficult to select a proper case, since many options we initially had in mind had a cheaper direct flight or rather expensive EEA transfers. The chosen example is Toronto to Mumbai, which has a direct connection and options with transfers at Paris, Amsterdam, Dubai and Abu Dhabi.

Case 4: (non-)EEA destination choice

Destination at Mediterranean coast: The final case differs from the other cases, as it involves a destination choice and not a route choice. The case is representative for a holiday destination choice of European citizens, either within or outside the EEA. We zoom in to the Mediterranean coast, which includes destinations within the EU as well as just outside the EU[4]. For the Mediterranean coast destination, we compared both Greece and Turkey and Spain and Morocco. In the current EU ETS, destinations within the EU (Greece and Spain) have higher carbon costs, as they are part of the EU ETS. This implies that the current scope stimulates passengers to choose destinations outside the EEA, causing carbon leakage. Also, these destinations are further away leading to additional CO_2 emissions. The scope extension of the EU ETS to all departing flights from the EEA would reduce this form of carbon leakage, as all outbound flights would be subject to the EU ETS. However, the return flight from Turkey and Morocco would still be outside the EU ETS scope.

[4] We also considered a case in which a trip by non-European citizens to Europe is compared to for instance a trip to South-America. However, these destinations are much less comparable than those at the Mediterranean coast, and the choice for a visit to Berlin or Buenos Aires is often driven by other factors than the ticket prices (and thus the impact of the EU ETS scope extension), such as the destinations characteristics or traveller’s preferences.

Textbox 1 - Representativeness of selected cases

The cases are intended to illustrate the impact of an EU ETS scope extension and possible carbon leakage related to that. We are aware of the fact that it is difficult to generalise the findings on costs increases and carbon leakage for these cases due to price changes and route availability for different dates and periods in time. Most of our initial defined cases were found to be unrealistic or did not fully correspond with the intention of the case. A few encountered problems we faced in multiple cases and route selections were:

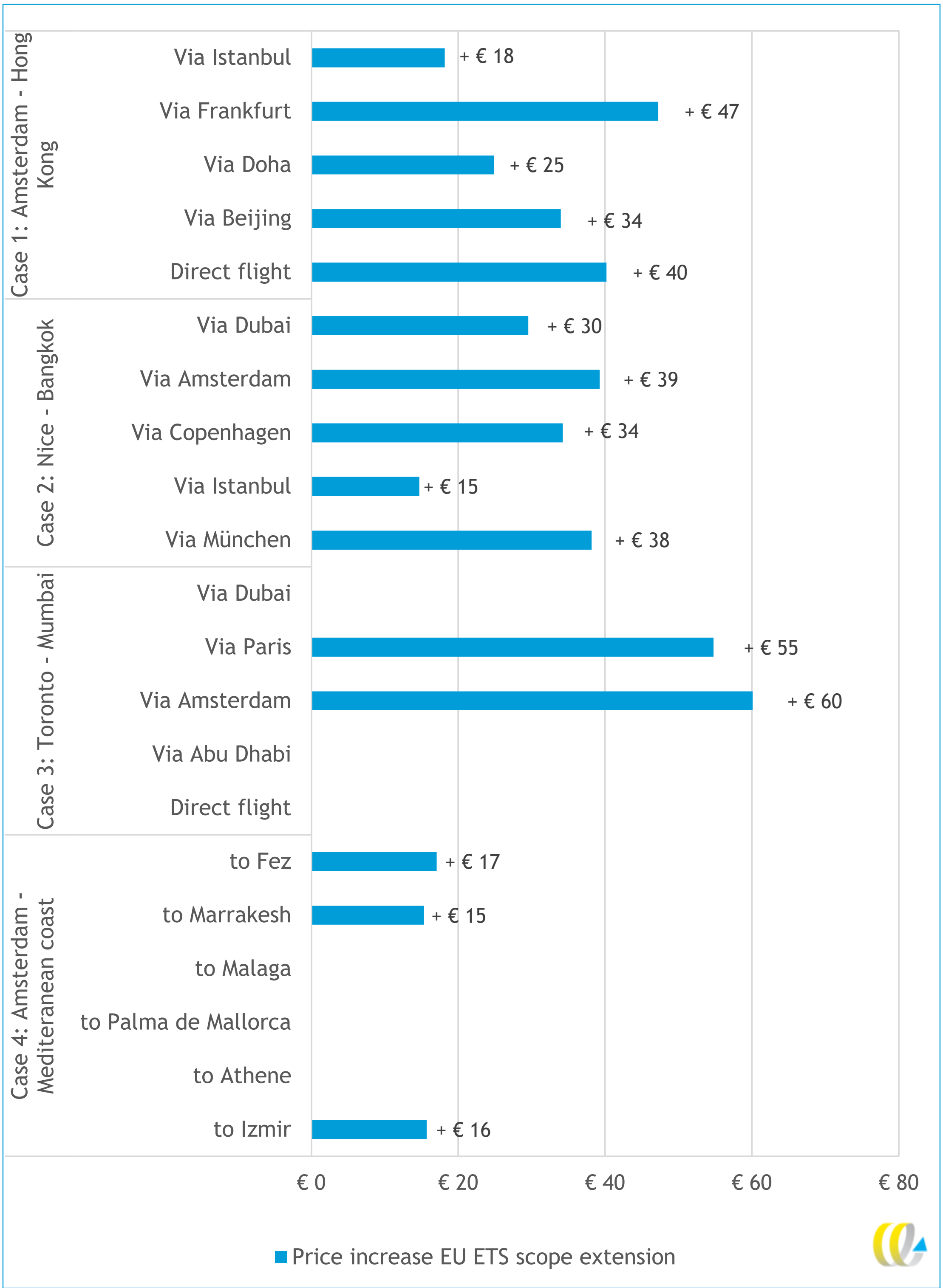
- no direct flight and/or transfer within an EU-hub available;
- the flight becoming relatively more attractive is already much cheaper compared to the alternative routes;
- dynamic ticket prices influence the above-mentioned points.

3.3 EU ETS induces ticket price increases

Carbon leakage is defined in this study, in line with IEA and IPCC definitions, as the increase in emissions outside a region as a direct result of the policy to cap emission in this region. For aviation and the EU ETS this implies a shift in aircraft movements, passengers and freight from routes via EEA airports to routes via non-EEA airports. A larger increase in EU ETS costs for routes via EEA airports compared to routes via non-EEA airports could lead to such a shift. Therefore, the cost increases by the extended EU ETS are discussed per case in this section.

The impact of an EU ETS scope extension to all departing flights on the ticket price for the four selected cases is shown in Figure 7. The methodology and assumptions used are discussed in Appendix C, along with a more detailed analysis of all cases. The blue bars in the figure, and values on the right of the bars, depict the ticket price increases due to the EU ETS scope extension assuming a 100% cost-pass through rate.

Figure 7 - Cost difference related to the EU ETS scope extension per economy class passenger in 2030



For Amsterdam to Hong Kong (Case 1) the ticket prices rise for all routes with an EU ETS scope extension. For the direct flight, we estimate a 40 euro increase. The route via Istanbul has the smallest increase of 19 euro. This implies that the Istanbul route gets a financial advantage of 22 euro due to the EU ETS scope extension compared to the direct flight. Transferring via an EU-hub (in this case Frankfurt) is most affected by the scope extension, with a ticket price increase of 48 euro, resulting in a financial disadvantage of 29 euro to Istanbul. The ticket price increase for a transfer in Frankfurt is also higher compared to the direct flight, since both routes fall completely under the EU ETS scope extension.
However, due to the extra landing and take-off and longer flight distance, the CO_2 emissions, and consequently the EU ETS costs, are higher for the transfer via Frankfurt.

In the case of Nice – Bangkok, no direct flight is available, so a transfer is required, either via an EEA hub or a non-EEA hub. For a route with a transfer via an EEA hub, the entire flight is subject to the EU ETS, while with a transfer outside the EU, only the first leg is subject to the EU ETS. A transfer via Istanbul is most attractive in terms of EU ETS costs (15 euro price increase). Transfers at more distant non-EEA hubs, such as Dubai incur higher EU ETS costs due to the increased emissions from the longer distance. The EU ETS costs for a transfer in Dubai are 15 euro more expensive than a transfer in Istanbul. Transfers at EEA hubs like Copenhagen, Munich, or Amsterdam are respectively 20, 23, and 25 euros more expensive than a transfer in Istanbul.

In the Toronto - Mumbai example (Case 3), only the routes via EEA hubs are affected by the EU ETS scope extension. Neither the direct flight nor the flights with transfers at Dubai or Abu Dhabi face additional costs. Ticket prices rise with 55 euro for the route via Paris and 60 euro via Amsterdam.

In the destination choice on the Mediterranean coast (Case 4), no price increase occurs for destination inside the EU, as these fall already under the current EU ETS. Mediterranean destinations outside the EEA become more expensive, a flight to Izmir, Turkey, increases by about 16 euro, while the ticket price for a flight to Athens, Greece, is not affected.

For all four cases we find that the scope extension of the EU ETS leads to different cost increases for EEA and non-EEA routes. In Cases 1, 2 and 3 the cost increase is the lowest for routes via non-EEA hubs close to the European border, potentially leading to a shift of passengers from routes via EEA hubs to routes via non-EEA hubs. For Case 4 the opposite happens, there is a cost increase for non-EEA destinations, partly compensating the cost advantage for non-EEA destinations due to the current EU ETS scope[5]. This potentially leads to a passenger shift from non-EEA destinations to EEA destinations.

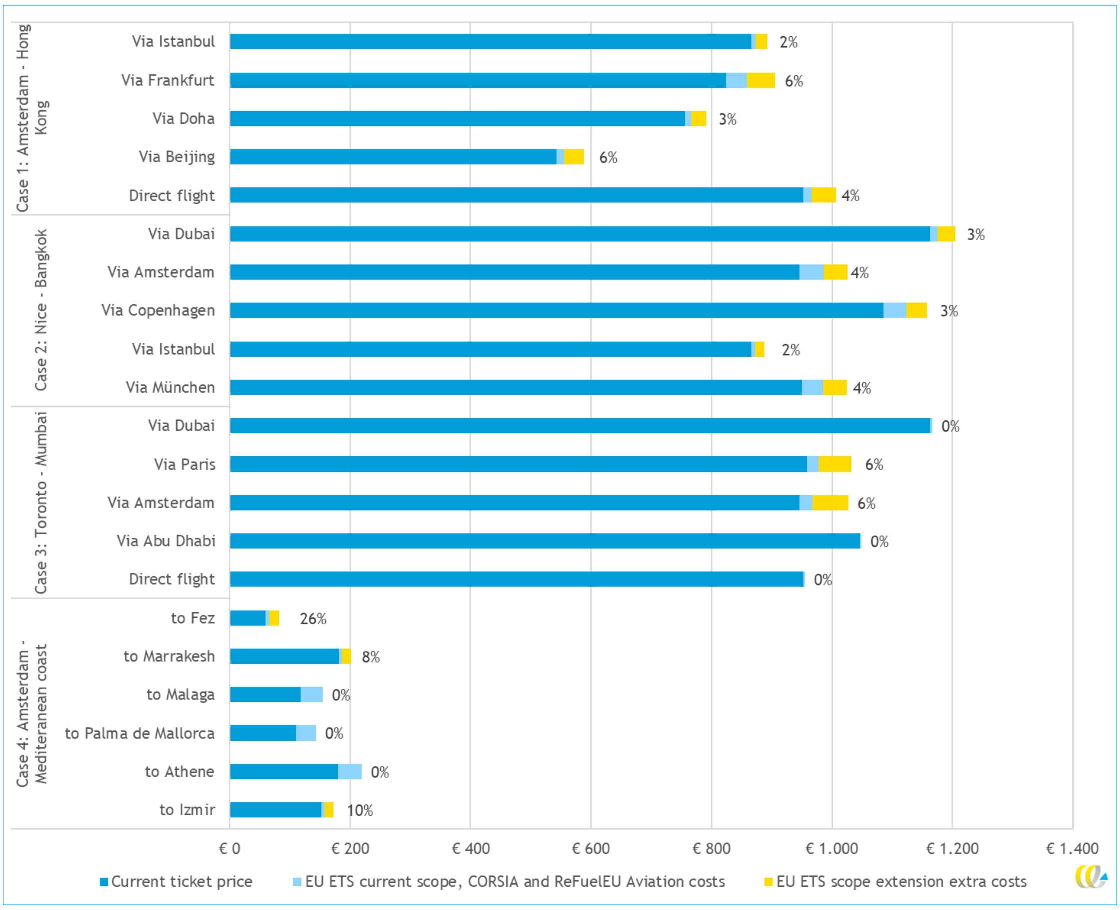
3.4 Ticket price increases in perspective

To put the EU ETS scope extension's cost increase into perspective, we applied the EU ETS, CORSIA and ReFuelEU Aviation costs to illustrative ticket prices, as shown in Figure 8.
The shown ticket prices are current offers found via Skyscanner, focusing on a specific

[5] As explained earlier, the current EU ETS system also has carbon leakage. In the current EU ETS, destinations within the EU (Greece and Spain) have higher carbon costs, as they are part of the EU ETS. This implies that the current scope stimulates to choose destinations outside the EEA, leading to carbon leakage, and also fly further which leads to more CO_2 emissions. The scope extension of the EU ETS to all departing flights from the EEA would reduce this form of carbon leakage, as all outbound flights would be subjected to the EU ETS. However, the return flight from Turkey and Morocco would still be outside the EU ETS scope.

period within each case to maximize consistency[6]. It is however important to note that these ticket prices are uncertain and fluctuate continuously. They depend on several factors such as the time in advance a ticket is booked, the day of the week, demand for specific routes, and other market conditions. The presented ticket prices should therefore only be viewed as indicative, intended to illustrate the magnitude of impact for passengers, rather than providing precise values.

Figure 8 - Illustrative impact of the EU ETS scope extension on ticket prices; the dark blue bar represents the current ticket price, the light blue bar illustrates the policy induced costs in 2030, the yellow bar represent the extra costs in case of an EU ETS scope



In the selection of the ticket prices, we focused on finding cheap available tickets. Consequently, it is likely that our indication of the relative ticket price increase represents an overestimation, as higher ticket prices would result in relatively smaller effects. This is because the aviation policy induced costs are constant, regardless of the basic ticket price.

Figure 8 gives an overview for the ticket prices and cost increases on all routes. The EU ETS scope extension to all European departing flights increases the ticket price between 2 and 6% depending on the chosen route, for the cases with a route choice (Case 1 to 3).

[6] Prices investigated in December 2024 for dates: 16 to 22 February 2025 for Case 1 and 3, 5 to 10 February 2025 for Case 2 and 16 to 23 March 2025 for Case 4.

For Case 4, the destination choice at the Mediterranean cost, higher price increases have been observed. The reason is that these routes are often operated by low-cost carriers, for which the average ticket prices are lower.

Transfer options via hubs just outside Europe (here Istanbul) in Case 1 and 2 has the smallest increase in ticket price as the distance over which ETS allowances must be surrendered is the smallest. These routes get a financial advantage compared to the alternatives. However, the cost difference between hubs within the EEA and outside the EEA is small with 1-2% for Case 2 and 2-4% for Case 1 compared to the total ticket price. Therefore, it is likely that these cost increases will only for a fraction of the passengers lead to route changes.

3.5 Comparing carbon leakage and CO_2 emissions between routes

The before mentioned sections illustrated the absolute and relative ticket price increase for each route. As found, the increased ticket prices on routes via EEA hubs would for a fraction of the passengers result in switching to routes via non-EEA hubs which are less affected by the EU ETS. For the fraction that does switch, carbon leakage will occur. To get a grasp on the amount of carbon leakage caused by these route changes, the CO_2-emissions of each route must be known.

Figure 9 presents the CO_2 emissions per passenger for all considered routes in the four cases for the outward journey. The dark blue bars depict CO_2 emissions that are part of the EU ETS scope (current and extended scope). The light blue bars show the emissions outside the EU ETS, which are the emissions from flights departing at non-EEA airports.

Carbon leakage is defined in this report, in line with IEA and IPCC definitions or ‘Option 2’ as discussed in Section 2.3, as the increase in emissions outside a region as a direct result of the policy to cap emission in this region. Therefore in this case, carbon leakage corresponds to an increase in emissions outside the EU ETS scope, which is represented by the light blue bar in the graph. Applying this concept of carbon leakage to a passenger in Case 1 who changes their flight from a direct flight to an indirect route with lower EU ETS costs, such as a transfer via Istanbul, results in carbon leakage of around 400 kg CO_2 per passenger (equal to the light blue bar for the Istanbul route). These represent the emissions that leak out of the EU ETS system. Table 1 present the carbon leakage figures for each case.

However, carbon leakage is not the same as additional global GHG emissions (discussed in Section 2.3 as ‘Option 3’). Table 3 also presents the additional global emissions per case (caused by for example longer flights paths). In all cases the effect on global emissions is (much) smaller than the carbon leakage. In Case 3 the direct flight alternative even leads to a decrease in global emissions because of a more efficient direct flight path (difference in the total bar between the indirect route and direct route in Figure 9). In Case 1 the effect on total global emissions for switching from a direct flight to an indirect flight via Istanbul leads to around 180 kg CO_2 additional emissions per passenger.

Figure 9 - CO_2 emissions per passenger (economy class) for all considered routes (outward journey only)

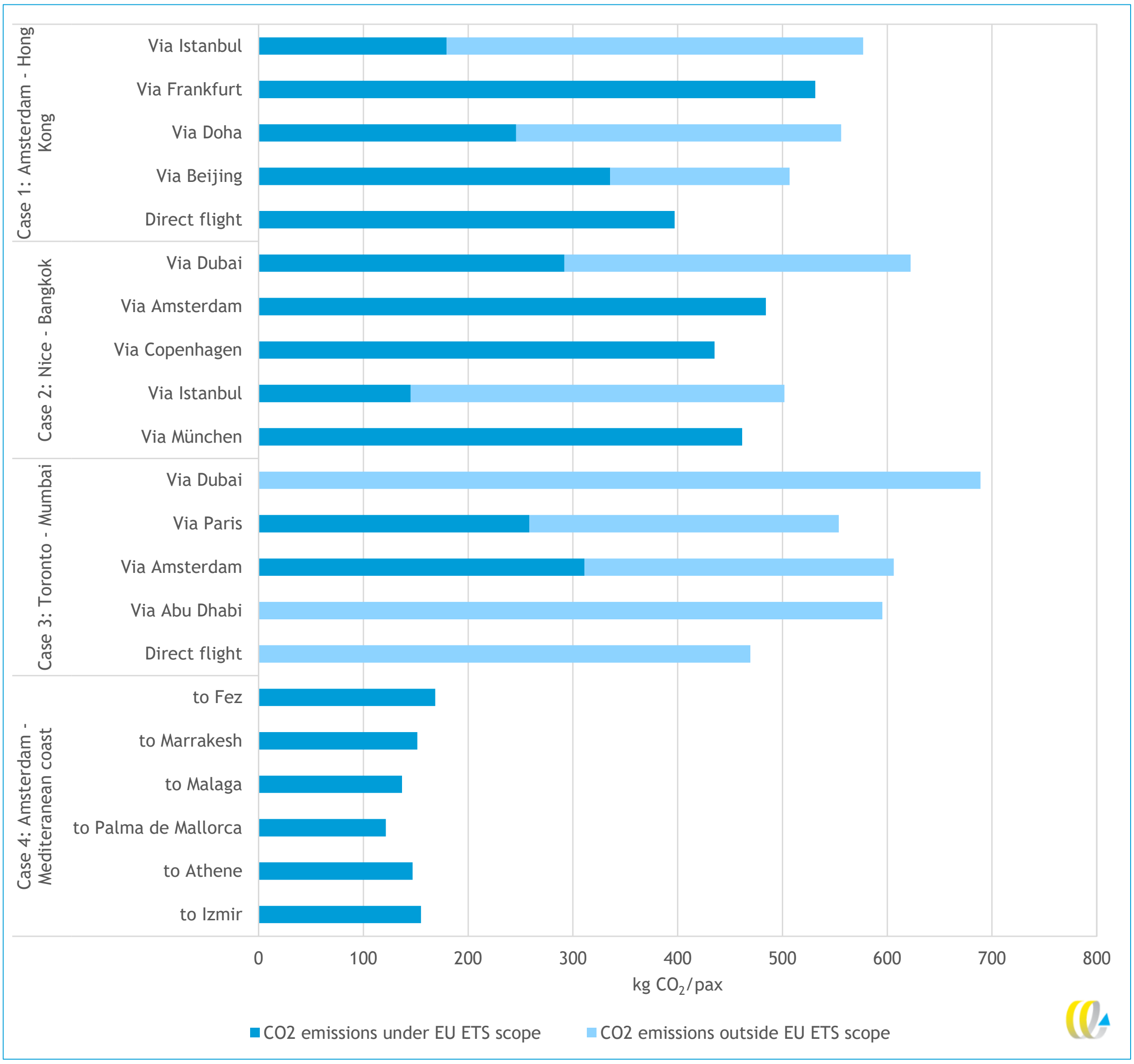


Table 3 - Carbon leakage and additional CO_2 emissions per passenger (economy class, outward journey only)

Case	Evasion airport	Carbon leakage ($kgCO_2$)	Additional emissions ($kgCO_2$)
Case 1: Amsterdam - Hong Kong *Direct flight*	Via Istanbul	397	180
	Via Doha	310	159
	Via Beijing	171	110
Case 2: Nice - Bangkok *Via München*	Via Dubai	330	161
	Via Istanbul	357	40
Case 3: Toronto - Mumbai *Via Amsterdam*	Via Dubai	394	83
	Via Abu Dhabi	300	42
	Direct flight	174	-137
Case 4: Amsterdam - Mediterranean coast *To Izmir*	to Malaga	-155	-18
	to Palma de Mallorca	-155	-34
	to Athene	-155	-8

3.6 Conclusions

Chapter 3 focussed on four specific cases representing the most likely types of carbon leakage. For the fourth case we actually find that there is currently a situation of carbon leakage due to the current EU ETS scope. Extending the EU ETS to all outbound flights would reduce this form of carbon leakage. For the other three cases, however, carbon leakage will potentially occur due to the EU ETS scope extension. This happens as follows. The cost increases caused by the EU ETS scope extension are larger for routes via EEA hubs than for routes via non-EEA hubs, especially routes via non-EEA hubs close to the European border. This cost difference is likely to cause a shift of passengers from routes via EEA-hubs to routes via non-EEA hubs. By comparing the cost increases to the ticket prices we however found that the additional costs are relatively small. Therefore, it is likely that only a fraction of the passengers would make the shift, causing carbon leakage. For a passenger that does switch in the Case 1 example Amsterdam – Hong Kong (from a direct flight to an indirect flight with a stop at Istanbul Airport) the carbon leakage is estimated to be around 400 kg CO_2.

As mentioned in the previous chapter, carbon leakage is not the same as additional global GHG emissions. For example, the effect on total global emissions in Case 1 for a route via Istanbul leads to around 180 kg CO_2 additional emissions per passenger, while the carbon leakage effect equals around 400 kg CO_2. To fully quantify the net carbon leakage for the selected cases, one has to consider all alternative routes using a full modelling approach. This falls outside the scope of this study. Some thoughts on carbon leakage for different passenger segments are covered in Textbox 2.

Textbox 2 - Carbon leakage for different passenger segments

Passengers typically have a strong preference for direct flights. The more price sensitive a passenger is, the more likely they opt for a connection flight via a hub if this option is cheaper. Leisure travellers are generally more price-sensitive compared to business travellers (InterVISTAS, 2007). Consequently, business travellers are generally expected to continue choosing direct flights, leading to minimal carbon leakage from this group of travellers.

Carbon leakage tends to be higher in cases where no direct flights are available, forcing all passengers to make a transfer. In such cases, passengers exhibit higher price elasticity, as passenger do not tend to have major preference for the transfer airport/hub decision. This increases the occurrence of carbon leakage. In contrast, when comparing direct flights to connection flights via a hub, carbon leakage is expected to be less significant, as passengers strong preference for direct flights makes them less likely to switch routes, even with a higher price increase on the direct route.

Carbon leakage is undesirable for multiple reasons. Mainly because the occurrence of carbon leakages results in a less effective policy instrument. In many cases, although in size often significantly smaller, it also leads to additional global emissions. Also, the associated shifts of passengers from EEA-hubs to non-EEA hubs lead to a reduction in the competitive position of the European aviation sector. To reduce the amount of carbon leakage, effective policy measures would have to be developed. In Chapter 4, various policy instruments that could reduce carbon leakage are introduced and discussed.

4 Potential instruments to prevent carbon leakage

4.1 Introduction

As discussed in the previous sections the total amount of carbon leakage would depend on multiple factors, including the specific scope of the EU ETS extension for aviation, cost differentials, strategic choices of airlines, and potential countermeasures. Carbon leakage would have a high heterogeneity, mainly occurring on routes with competition between options that are (partly) covered by the EU ETS scope extension and travel options that are (partly) out of scope.

In this chapter, various instruments that could prevent carbon leakage are introduced and discussed. But, before we look at the countermeasures individually in Section 4.3, we take a step back and have a general discussion on potential measures to reduce carbon leakage by using an example, the 'Istanbul challenge', in Section 4.2. Textbox 3 gives some general information about the EU ETS workings for aviation, which could help in better understanding the solutions discussed later on.

Textbox 3 - General information about the EU ETS workings for aviation

A basic principle of the EU ETS is that companies within the ETS sectors receive or purchase emissions allowances. Each allowance is granting the right to emit one ton of CO_2 (or its equivalent in other greenhouse gases). Airlines submit emissions reports to independent verifiers, and then declare emissions relating to burned fossil fuel on flights within the scope of the EU ETS. An equivalent number of EU allowances are then surrendered. SAF has a zero emission factor under the EU ETS if it fulfils the requirements of the Renewable Energy Directive (RED). Nowhere is there a requirement to submit information about passengers or freight on board. Since the EU ETS is a cap-and-trade system and not a tax, the price of the allowances is not fixed but changes over time at an equilibrium between supply and demand, similar to the kerosene price. The EU ETS with a scope extension to all departing flights from EEA airports would have the same geographical scope as the ReFuelEU Aviation blending obligation for SAF.

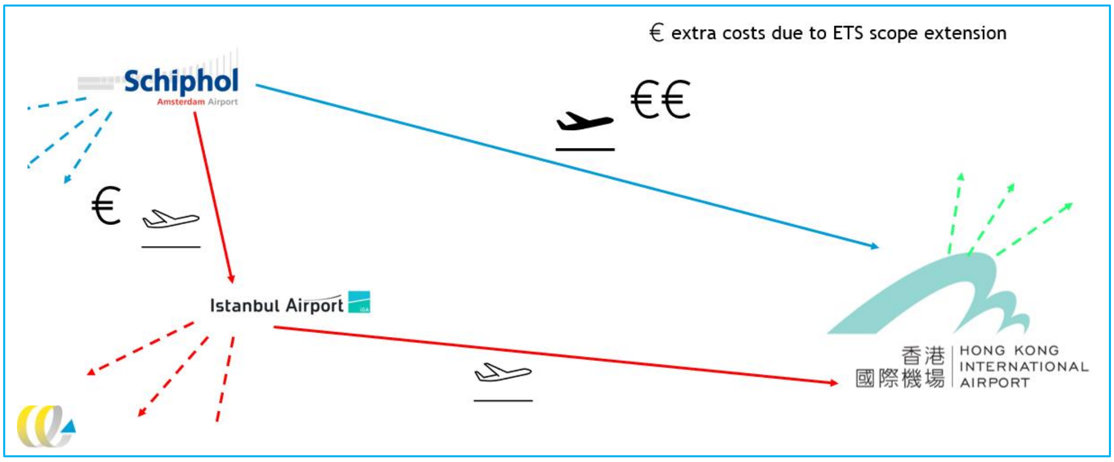
4.2 The 'Istanbul challenge'[7] and possible solutions

To show in what ways measures could address carbon leakage we use the 'Istanbul challenge' as an example, see Figure 10. This problem is based on Case 1 of the previous chapter. The problem is as follows: when flying to Hong Kong Airport from Schiphol Airport one could take either a direct flight or an indirect flight via for example Istanbul Airport. The direct flight will get more expensive with the EU ETS scope extension with aircraft emissions of the whole route taken into account. For the indirect flight only the first leg will count under the EU ETS, as this is a departure flight from an EEA airport, such that this route will become only slightly more expensive.

7 This name should not suggest that there is a problem with Istanbul airport. Due to its geographical location just outside the EEA and the fact that it is a major hub offering connections to multiple destinations globally, Istanbul is a good example to discuss the effects on the 'level playing field' between airlines operating from hubs inside the EEA and the competitors with hubs outside the EEA.

This EU ETS cost advantage for the indirect route is especially strong via non-EEA hubs close to the EEA border, such as Istanbul Airport. Passengers could shift from the direct flight to the indirect flight causing emissions outside the EU ETS (carbon leakage) and in this case also additional emissions due to the longer flight path.

Figure 10 - The Istanbul challenge; the EU ETS scope extension leads to lower cost increases on the route via Istanbul (€) than on the direct route (€€) from Amsterdam to Hong Kong leading to a potential shift in market shares to Istanbul



Note that in Section 3.2 for Case 1 we find a price increase for the direct flight of 40 euro (depicted here as €€), about twice as big as the cost increase for the indirect flight via Istanbul Airport of 19 euro (depicted as €).

In order to prevent carbon leakage, the induced price difference between the travel options caused by the EU ETS scope would have to be reduced. All theoretical options are shown in Figure 11, distinguishing a flight approach and a passenger approach. For background information see Textbox 4. Note that all countermeasures discussed in Section 4.3 can be linked to one of the options in Figure 11.

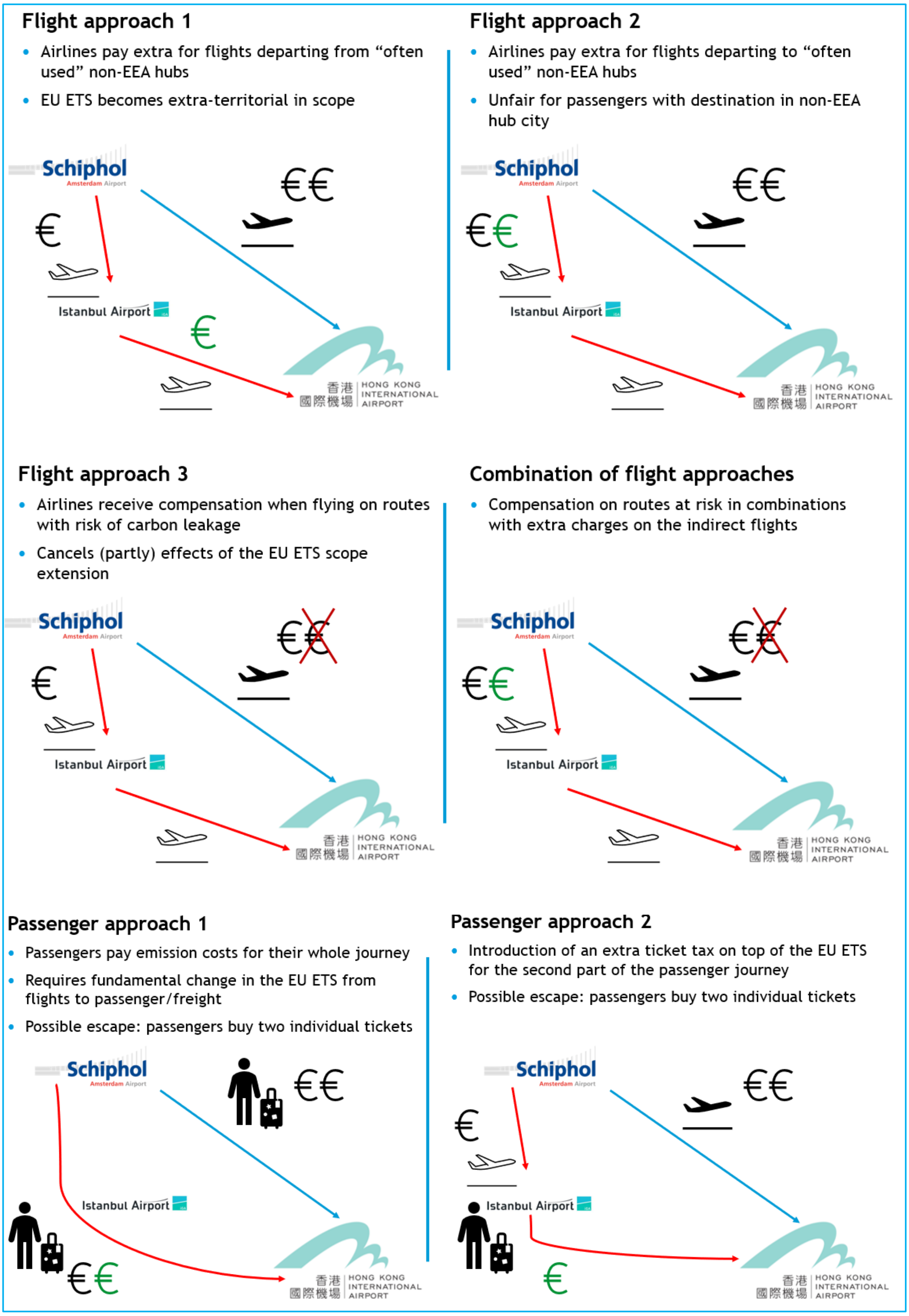
Textbox 4 - Description of direct connections and indirect connections via hubs

Airlines operate direct flights between individual airports. The business model of most low cost carriers is to provide point-to-point connections. Passengers buy tickets for individual flights, or return tickets consisting of two individual no-stop flights. Hence, a passenger journey overlaps 100% with a single flight of an aircraft.

Most major full-service passenger airlines use hub-and-spoke networks to operate their aircraft traffic. Aircraft from all kinds of destinations arrive at an international hub. For part of the passengers of each aircraft the hub is the final destination, whereas others change planes to continue their journey to the final destination (or another hub). In each departing aircraft from the hub the passenger mix consists of a blend of transfer passengers from multiple previously arrived aircraft and departing passengers starting their journey at the hub. This implies that passengers use one or multiple aircraft for a single trip from origin to the final destination. On each aircraft that is part of a hub-and-spoke network, passengers are combined with multiple origins and final destinations. Thus, a transfer passenger journey consists of several flights on different aircraft.

Direct transit passengers stay on the same plane, and the plane briefly stops en route to their final destination. These passengers don't usually disembark. Nowadays, direct transit has become less common due to the efficiency and flexibility of hub-and-spoke networks, where travellers more frequently change planes at major hub airports. Since the discussion about carbon leakage as a consequence of the EU ETS scope extensions is mainly about the competition with major hubs outside the EEA, the small transit segments can be neglected in further considerations.

Figure 11 - Theoretical approaches to reduce the cost difference between the direct route AMS to HKG (high EU ETS costs) and the indirect route via IST (low EU ETS costs)



Flight approaches

In order to reduce carbon leakage for the Istanbul example in a flight approach, either the cost for the direct flight AMS-HKG would need to be reduced, or the cost somewhere on the ANS-IST-HKG route would need to be increased. In the following section we will discuss the flight approaches, as shown in Figure 11, one by one:

1. Theoretically, the best option would be Flight approach 1 (target the IST-HKG flight) as this is the flight where the problem of the lower CORSIA carbon cost is introduced. However, this flight is out of scope of both the current and extended EU ETS. In this case, an EU measure would regulate flights between third countries, where neither the origin nor the destination is within an EEA country. The EU would probably face legal, diplomatic, and practical opposition due to the principles of international aviation law governed by the Chicago Convention and existing bilateral or multilateral agreement.

The other two of the three involved flights AMS-HKG and AMS-IST would be in-scope of an extended EU ETS. An adjustment of the costs here however would contradict the polluters pay principle in the EU ETS where each ton of CO_2 has the same price. Besides that:

2. Increasing the costs on the AMS-IST route, as in Flight approach 2, would also affect passengers that have Istanbul as the final destination. Countries may contest such a regulation that leads to a distortion of the level playing field and take countermeasures. A solution to this could be to only target flights that have a certain percentage of transfer passengers, therefore having little effect on direct passengers of the route AMS-IST. Also, for this approach to work, one needs to come up with a method for selecting flights to hubs that have a high risk of carbon leakage and come up with a reasonable extra charge. Textbox 5 discusses these challenges and poses possible solutions.
3. Flight approach 3, in this example decreasing the costs on the direct AMS-HKG flight, would require a method to determine what destinations have a high risk of carbon leakage. Based on research from (T&E, 2022) one could for example think of large airports/hubs in East and South-East Asia. Further research is needed to exactly determine which regions and corresponding airports should be selected.

Without carrying out a legal assessment, we conclude that of the flight approach options, Flight approach 3 seems the most feasible option. Flight approach 2 could also be possible, but has to overcome some challenges for which additional research is needed. A downside of both these approaches is that they will distort, for some routes, the polluters pay principle. Flight approach 1 seems not possible.

Textbox 5 - Initial ideas on how to make Flight approach 2 work

As mentioned before, the main challenges of Flight approach 2 are:

1. Finding a way to select hubs that have a high risk of carbon leakage.
2. Targeting flights with high shares of transfer passengers.
3. Coming up with a reasonable extra charge for these flights.

For solutions on the first two challenges, one could look for inspiration at the separate implementing regulation that is introduced for maritime shipping to reduce the risk of evasive port calls. This measure is explained in Section 4.3.1 more elaborately, showing that the principle cannot be copied to aviation directly as there are fundamental differences between shipping and aviation. However, by making some alterations one could use the solution of maritime shipping for inspiration to come up with a method to make Flight approach 2 work.

Selecting hubs with high risks of carbon leakage
Similar to maritime shipping one could introduce a buffer zone outside the European Union with certain criteria to identify hub airports with a high risk of carbon leakage. These criteria could for example be:

- Airports located outside the Union but less than X km from an airport under the jurisdiction of a Member State. Excluding airports located in a third country for which that third country effectively applies a carbon price similar to the EU ETS price.
- The airport's share of transfer passengers must exceed Y% of the total number of passengers of that airport during the most recent twelve-month period for which relevant data are available.

Targeting flights with high shares of transfer passengers
One could choose to introduce extra carbon costs for all flights from Union airports to hubs with high risk of carbon leakage. However, as mentioned, passengers flying directly to this hub will also be charged extra. Totally excluding passengers flying directly could (probably) never be fully realised, as most flights containing transfer passengers also contain passengers flying directly. Therefore, solutions could be found in minimising the targeted number of passengers flying directly. This could be done by targeting flights with for example at least Z% transfer passengers. However, at the moment of booking the flight the airline does not know to what extend it will be filled with OD- and transfer passengers. One could solve this by only selecting flights with certain criteria, for example:

- Flights for certain airport pairs, Union airport and the airport with high risk of carbon leakage, for which the share of transfer passengers exceed Z% of the total number of passengers during the most recent twelve-month period for which relevant data are available.

Extra charge
For the selected flights to the selected hubs with high risks of carbon leakage an extra charge needs to be formulated. As this flight will be filled with transfer passengers with different final destinations, this is not as simple as it may seem. This makes, that as it is not possible to distinguish between passengers since the EU ETS charges flights, that this flight containing all these different passengers would have to get one extra charge. This again, contradicts the polluters pay principle in the EU ETS where each ton of CO2 has the same price. Solutions could be to:

- Approximate the correct carbon price by charging the extra carbon costs for the weighted average next flight of the transfer passengers. The weighted average carbon of the next flight could be calculated for example once or yearly for each hub with high risk of carbon leakage, or with more detail per airport pair or airline; or
- Simply charging double the EU ETS costs. (This avoids all the complexity of the first solution and is the appropriate charge as found for the Istanbul challenge example of Figure 12, however this ratio will be different for other final destinations and other potential hubs with high risks of carbon leakage).

The solutions illustrated in this textbox are initial thoughts on how to make Flight approach 2 work. Further research is needed to make proper conclusions on whether this approach is feasible or not.

Passenger approaches

In a passenger approach, the final destination of passengers is known if they buy a ticket to the final destination, which is currently the case for most passengers that travel with full service carriers. National ticket taxes like the ones in Germany and the United Kingdom, have distance dependent rates and the tariff depends on the distance to the final destination. In an adjusted example of Figure 10 with a departure in Frankfurt, the German departure tax would have the same rate for both routes and hence not lead to carbon leakage.

We will discuss the passenger approaches, as shown in Figure 11, one by one:

1. Applying Passenger Approach 1 in the EU ETS, where passengers pay for the emissions costs of their whole journey, would require a complete redesign of the system. As mentioned before in Textbox 2, the EU ETS is a cap-and-trade system where a fixed and decreasing cap is set on total emissions, and airlines and companies must purchase or trade allowances for each ton of CO_2 they emit. The price of these allowances fluctuates based on supply and demand in the market. However, in a passenger approach the emissions of an aircraft would have to be allocated to tons of freight and individual passengers on board, the numbers of which are unknown at the moment when passengers purchase tickets. It would almost require changing the EU ETS into a tax, which would undermine the cap-and-trade principle. Such an adjustment could be seen as a disproportional change in order to prevent carbon leakage.
2. In Passenger Approach 2, the EU ETS would not be adjusted, but instead the cost for the emissions that are not covered by the EU ETS would be added to tickets for passengers departing in the EEA by a tax. The advantage of this approach compared to the flight approaches 2 and 3 is that the polluters pay principle is not contradicted, and the final destination of these passengers is known. However, implementing an EU wide tax is very difficult since this requires unanimity across member states. Therefore, implementing the tax nationally could be a solution. For the German ticket tax example the difference in EU ETS costs for both routes could be (partly) compensated in the German departure ticket tax, setting a higher rate for the route via Istanbul than the direct flight.

4.3 Overview of potential countermeasures

In this section, we describe and analyse potential countermeasures to prevent carbon leakage. For each measure we first give a brief description which is based on our understanding of the measures and afterwards elaborate whether the measure is potentially able to reduce carbon leakage and reflect on challenges in the implementation.
The considered measures are:

- shipping ETS carbon leakage instrument;
- CBAM certificates;
- free allocation of EU ETS allowances;
- SAF allowances;
- national levies or destination-based charges (within the EU ETS);
- other options.

4.3.1 Shipping EU ETS carbon leakage instrument

Table 4 - Summary of the shipping EU ETS as potential instrument to prevent carbon leakage

Main idea	Identifying airports at risk of causing carbon leakage and consider them as part of one route under the ETS instead of as stop-overs.
Currently applied for	Maritime shipping.
Description of existing instrument	For maritime shipping the EU ETS is applied with a 50% rate for all incoming and outgoing ships between EEA and non-EEA countries. To prevent carbon leakage, a buffer zone is created just outside of the EU border with ports in this buffer zone not being counted as stops in terms of the EU ETS costs.
Feasibility of applying to aviation	Not directly applicable since there are almost no stop-over flights in aviation. Aircraft operate between airports and passengers either take a direct flight or switch aircraft for an indirect route. However, with some adjustment the instrument might be feasible.

Principle

For maritime transport a separate implementing regulation (EC, 2023) is introduced to reduce the risk of evasive port calls by container ships to ports just outside of Europe. Ports meeting several criteria are excluded from the definition 'port of call', due to which the EU ETS applies for the whole journey to the final (or at least next) port call.
The criteria are as follows:
- The port's share of transhipment of containers must exceed 65% of the total container traffic of that port during the most recent twelve-month period for which relevant data are available;
- The port must be located outside the Union but less than 300 nautical miles from a port under the jurisdiction of a Member State. However, the implementing act is not to identify ports located in a third country for which that third country effectively applies measures equivalent to Directive 2003/87/EC.

Currently only two ports are identified as a neighbouring container transhipment port namely East Port Said in Egypt and Tanger Med in Marocco. Next to this a monitoring requirement is included in the implementing regulation: 'The Commission should monitor the implementation of the EU ETS in relation to maritime transport, in particular to detect evasive behaviour in order to address such behaviour at an early stage. The Commission should propose, where appropriate, measures to address evasive behaviour.'

Application to aviation

The main idea behind the implementing regulation for maritime transport is very similar to the aviation carbon leakage risk of Case 1 in this study: adding a stop just outside of the European border to reduce EU ETS costs to a short part of the journey. Therefore, an idea would be to define a similar buffer zone outside of Europe also for aviation and not count the stop-over at hubs inside this buffer zone.
Note, however, that shipping and aviation operate very differently. Ships usually make a multi-stop round trip with several port calls where they either unload or load cargo or passengers. In aviation there are almost no stop-over flights. Aircraft operate between airport pairs and passengers either take a direct flight or change aircraft for an indirect route (see Textbox 1). Since the EU ETS in aviation is applied to the emissions of flights, it is not possible to apply the same principle directly, as the aircraft does not make stop-overs, the passenger does. Therefore, this maritime transport principle cannot directly be copied to aviation.

Alternative applications

One could however, by making some alterations, use the solution of maritime shipping for inspiration to come up with a method to make 'Flight approach 2' from Figure 11 work. Similar to maritime shipping, a buffer zone could be introduced outside the European Union to identify hubs with a high risk of carbon leakage. Now flights, with a certain share of transfer passengers, to these high carbon leakage risk hubs would be charged extra.
This approach however still poses some challenges, which are explained in Textbox 3. Further research is needed to make proper conclusions on whether this approach is feasible or not.

Another solution here could be to apply the EU ETS in aviation not directly to the emissions of flights but to base it on the emissions of the whole journey of a passenger. This solution is based on 'Passenger approach 1' from Figure 11. But, as mentioned in Section 4.2, this approach would require a complete redesign of the system for aviation.

4.3.2 CBAM certificates

Table 5 - Summary of CBAM certificates as potential instrument to prevent carbon leakage

Main idea	Impose CBAM certificates for flights departing from non-EEA hubs that have a high risk of carbon leakage. This would mitigate the cost difference as non-EEA airlines now pay an equal carbon price compared to their EEA counterparts.
Currently applied for	Carbon-intensive (raw and basic processed) physical goods such as cement, iron and steel, aluminium, fertilizers, electricity and hydrogen.
Description of existing instrument	CBAM imposes a carbon price on imported goods at the EU border in cases where stricter carbon regulations within Europe lead to competitive disadvantages with producers in countries with less stringent climate policies.
Feasibility of applying to aviation	Air transport is a service on which passengers and goods are carried on a mobile asset, namely, an aircraft. Aviation has an interchangeability of flights which stands in contrast to fixed goods. CBAM applies to goods imported into the EU whereas this idea would be for flights departing from the EEA. However, the CBAM could be used as inspiration for alternative applications to aviation.

Principle

The Carbon Border Adjustment Mechanism (CBAM) is a key component of the EU's sustainability plans, designed to put a price on carbon-intensive imports. The legislation is designed to ensure that the carbon price paid for EU products is also applied to imported goods, creating a level playing field. The CBAM's primary goal is to prevent carbon leakage. This occurs when:

1. Non-EU products gain competitive advantages by not paying a carbon price and;
2. EU production decreases or relocates to countries without a carbon pricing scheme. To counter this, CBAM aims to equalize the price of carbon paid for EU products operating under the EU ETS, and for imported goods (Normative, 2024).

Application to aviation

Various parties in the airline industry suggest a CBAM for aviation as a countermeasure for carbon leakage, for example Lufthansa Group (2024b). However, the industry is unclear about how the implementation of a CBAM for aviation would look. An article by Buissing (2022) states: 'Under a CBAM for international aviation, third-country carriers benefiting from lower environmental standards outside the EU would be required to buy the CBAM certificates to mitigate the cost differences and thus pay an equal 'carbon price' for their flights compared to their EU counterparts.'

It is important to realise that the EU policy measures EU ETS and ReFuelEU Aviation do not distinguish between EU and non-EU carriers. All measures are applied based on the locations of departure and arrival airports. Therefore, EEA carriers and non-EEA carriers with flights departing from EEA airports are treated equally in the EU ETS. Buissing (2022) also mentions: 'To calculate the cost difference, CBAM certificates would need to consider the flight emissions of segments outside EU airspace, making the measure extra-territorial in scope.' The author seems to suggest that the CBAM allowances would have to be paid for flights that are outside of EU airspace. This would make the approach similar to 'Flight approach 1' in Figure 11. As mentioned in Section 4.2, this approach infers that an EU measure would regulate flights between third countries, where neither the origin nor the destination is within an EEA country. Such an approach would be extraterritorial and the EU would probably face significant legal, diplomatic, and practical challenges.

The main reason why CBAM, which is successfully implemented for physical products, is very challenging to apply to aviation is again the fact that the geographical scope of passengers and flights only partly overlaps (see discussion in Section 4.2). The emissions of aircraft departing to destinations outside the EEA would be in the extended EU ETS scope, but carbon leakage occurs if passengers can avoid EU ETS costs by choosing flights that are not covered by the measure. In addition, enforcement of CBAM for aviation would be complicated, since the CBAM authorities in Member States are those that control the flow of goods at the border, and are not equipped to regulate passengers or aircraft at the EU border.

Alternative application

An alternative application could be Flight Approach 2 in Figure 11, where airlines should pay for CBAM certificates on top of the EU ETS costs for flights to non-EEA hubs with high risk of carbon leakage. As mentioned in Section 4.2, this application comes with some challenges for which additional research is needed, but does seem more feasible.

Another alternative application could be Passenger Approach 2 from Figure 11. As explained in Section 4.2, costs for emissions that are not covered by the EU ETS would be added to tickets for passengers departing in the EEA. The principle seems similar to the CBAM principle: for the part of the passenger journey where no carbon costs are paid, CBAM certificates apply. Because in this application the CBAM costs are directed to passengers, emissions from the flight have to be translated to individual passengers on board, which are not known at the moment when passengers purchase tickets. Therefore, instead of using a CBAM price for flight's emissions, a fixed-tax rate per passenger seems more appropriate. As discussed in Section 4.2, a national tax seems more feasible than an EU wide tax.

4.3.3 Free allocation of EU ETS allowances

Table 6 – Summary of free allocation of EU ETS allowances as potential instrument to prevent carbon leakage

Main idea	**Provide free EU ETS allowances for flights on routes identified as having a significant carbon leakage risk.**
Currently applied for	Aviation and other sectors with high carbon leakage risk.
Description of existing instrument	The provision of free allowances limits costs for industries that are subject to the EU ETS. Sectors and sub-sectors facing competition from industries outside the EU that are not subject to comparable climate legislation receive more free allowances than those which are not at risk of carbon leakage.
Feasibility of applying to aviation	Free allowances are part of the EU ETS for aviation, but will be phased-out for the intra-EEA scope in 2026.

Principle

The EU provides free allowances within the EU ETS for industrial installations and aviation. The free allowances are distributed based on benchmarks that reward the most efficient installations. The proportion of free allocation decreases over time, focusing on sectors at high risk of carbon leakage. In addition, flexibility is introduced to align allocations with actual production levels and updated benchmarks reflect technological progress to ensure fairness and incentivize innovation (EC, Ongoing-a).

Application to aviation

Currently, airlines receive part of the EU ETS allowances for free. The share is decreasing over time and from 2026 onwards free allowances will be completely phased out.
The EU ETS scope extension does not interact with this agreement. Therefore, new free allowances could be introduced at the moment of a geographical scope extension of the EU ETS. An option would be to give part of the EU ETS allowances for free to airlines that operate flights between EEA and extra-EEA destinations. This would lead to a reduction of the price difference between travel options affected by the EU ETS and alternatives.
The downside of this approach is that it works like a general discount which would reduce costs and the incentive to decarbonize for all routes, independent of the fact whether they are at risk of carbon leakage or not. A solution could be to make the allocation of free allowances dependent on the risk of carbon leakage for certain final destinations. This would be an application of Flight Approach 3 from Figure 11. Such a method could have parallels with free allocations for industrial installations.

4.3.4 SAF allowances

Table 7 – Summary of SAF allowances as potential instrument to prevent carbon leakage

Main idea	**Discourage flights to non-EEA airports at risk of carbon leakage and/or encourage direct flights via financial SAF compensation.**
Currently applied for	Aviation ETS.
Description of existing instrument	SAF has a zero emission factor under the EU ETS if it fulfils the requirements of the Renewable Energy Directive (RED). Next to this, between 2024 and 2030 there will be 20 million EU ETS allowances set aside to further financially support the use of SAF. Aircraft Operators may request financial support in the form of these 'SAF allowances' up to varying percentages of the cost difference between fossil fuels and SAF.
Feasibility of applying to aviation	Requires slight alterations for current aviation measures EU ETS and ReFuelEU Aviation.

Principle

RefuelEU Aviation sets a SAF blending obligation for all departing flights from EEA airports (note that RefuelEU Aviation and the discussed EU ETS scope extension have the same scope of all departing flights from EEA airports). The RefuelEU policy defines a minimum SAF share that has to be blended and increases over time. Since SAF is currently much more expensive than fossil fuel, the SAF blending leads to additional costs for airlines.

To reduce the price difference between SAF and fossil fuel, the EU offers two forms of financial support:

1. SAF has a zero emission factor under the EU ETS if it fulfils the requirements of the Renewable Energy Directive (RED). This means no EU ETS allowances have to be paid for SAF use.
2. Between 2024 and 2030 there will be 20 million EU ETS allowances set aside to further financially support the use of SAF. Aircraft Operators may request this financial support in the form of 'SAF allowances'. The financial support amounts to varying percentages of the cost difference between fossil fuels and SAF:
   - 100% for small islands, small airports and the outermost regions;
   - 95% for renewable fuels of non-biological origin (RFNBOs);
   - 70% for green hydrogen and advanced biofuels; and
   - 50% for all other eligible SAFs.

Application for carbon leakage prevention

These two SAF financial support measures of the EU ETS could be used to prevent, or at least to decrease carbon leakage. One application would be to discourage flights to non-EEA airports at risk of carbon leakage, similar to Flight approach 2 in Figure 11. This could be done by declining the use of the zero emission factor for SAF for these flights, and therefore requiring the airline to also pay EU ETS allowances for the SAF use, and/or by declining the use of financial support in the form of 'SAF allowances' for these flights. But, as mentioned in Section 4.2, this Flight approach comes with some challenges for which additional research is needed.

Another application could be to encourage the direct flights, similar to Flight approach 3 in Figure 11. This could be done by allowing more financial compensation in the form of 'SAF allowances' for direct flights to destinations that have a high risk of carbon leakage (for example by supporting 100% of the cost difference between fossil fuels and SAF for these routes).

4.3.5 National levies or an EU SAF/Climate levy

Table 8 - Summary of national levies or an EU SAF/Climate levy as potential instrument to prevent carbon leakage

Main idea	**Compensate additional EU ETS costs in a levy based on travel destination, regardless of where the passenger changes planes. In addition, the raised money could be directed towards SAF.**
Currently applied for	National departure taxes for aviation passengers.
Description of existing instrument	The national departure taxes of several European counties distinguish in the rates based on the final destination of aviation passengers. However, making this a European tax would require unanimity between all member states.
Feasibility of applying to aviation	National departure taxes are passenger based and applied to the tickets, not taking into account the emissions of the aircraft. The EU ETS is flight based and costs are based on CO_2 emissions. Reimbursement of extra costs for SAF is not in line with the EU ETS basic principle of most cost-efficient decarbonization and a market between sectors.

Principle (in aviation)

In order to reduce carbon leakage the national departure taxes could have a discount for flights that are covered by the EU ETS. Passengers purchasing tickets to a final destination outside the EEA would pay different departure taxes for routes with different EU ETS coverage. In the example of Figure 10 the direct route with 100% EU ETS coverage would have a lower rate than the route via Istanbul, where only the flight to Istanbul is covered. Since the rates of national ticket taxes need to be known in advance, the discount can only be based on estimated EU ETS costs for passengers (see discussion in Section 4.3.2).

The aviation industry has alternatively proposed that national levies be entirely replaced by an EU SAF levy (Lufthansa Group, 2024a). This levy would be destination based, irrespective of where passengers transfer, and the raised funds used to support the market ramp-up of Sustainable Aviation Fuels. The major challenge this faces is that a tax at European level requires unanimity of EU member states and therefore is unlikely to be implemented.

4.3.6 Alternative options

The EU could explore ways to reduce the risk of carbon leakage by coordinating with the International Civil Aviation Organization (ICAO). Harmonisation between the EU ETS and the global CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation) would minimise carbon leakage but would most likely require fundamental adjustments of CORSIA. In case such an agreement on global scale is not possible, efforts could be put into bilateral or multilateral agreements. In case non-EU countries/airlines agree to apply the same carbon price as in the EU ETS on international aviation, no distortion of the level playing field would occur on these routes. Earmarking the revenues from aviation emission allowances for financial incentives to support the decarbonization of (long-haul) aviation could increase the willingness to collaborate. In case countries and airlines outside the EEA are not willing to cooperate, Europe could try to regulate the number of aircraft movements between European counties and hubs outside the EEA via capacity constraints at European airports or with unilateral surcharges. However, it is very likely that these measures would be legally challenged and countermeasures would be taken by affected countries.

4.4 Conclusions on the measures

All five assessed countermeasures to prevent carbon leakage have potential to work. However additional research (e.g. full work out of the instruments, legal analysis, effect analysis) is needed to definitely reject or approve countermeasures.

The instruments that were based on solutions for carbon leakage in other sectors, the Shipping EU ETS instrument and CBAM, are found to be not applicable in a direct way, but could with some alterations also potentially work for aviation. For both measures a solution would be to increase the costs on flights to non-EEA hubs with a high risk of carbon leakage. The challenge then is to define a ‘high carbon leakage risk non-EEA hub’. Inspiration could be found in the separate implementing regulation that is introduced for maritime shipping, which introduces a buffer zone outside the European Union using several criteria to reduce the risk of evasive port calls. A similar buffer zone could be introduced for aviation, using several criteria, to define ‘high carbon leakage risk non-EEA hubs’. Additional research would be needed, also to determine whether all flights to these hubs should be targeted or only a selection, and what the extra charge should be.

Another approach could be to decrease the costs of the extended EU ETS, by introducing free allowances for destinations with a high risk of carbon leakage. In this way also the incentive for carbon leakage is decreased, having parallels with free allocations for industrial installations.

Using 'SAF allowances' in decreasing carbon leakage could also work. Both the zero emission factor of SAF and the SAF allowances could help in discouraging flights to non-EEA airports at high risk of carbon leakage, and encouraging direct flights.

National levies or destination based charges could work, as these charges focus on passengers instead of flights, therefore allowing to charge a full passenger journey.
A challenge would be the harmonisation of national departure taxes in Europe. A tax at European level requires unanimity of EU member states and therefore is unlikely to be implemented.

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A Method EU ETS cost estimates

In this Annex the methodology and the assumptions used for the analysis in Chapter 3 is presented in more detail.

For each case the following steps are taken to estimate the amount of fuel per passenger in 2030 for all routes considered:
- Derive current CO_2 emissions per passenger from the ICAO carbon emission calculator for each flight leg separately (ICAO, ongoing).
- Convert CO_2 emissions to fuel use by applying a kerosene emission factor (TTW) of 3.15 kg CO_2per kg jet fuel. This is required to calculate the additional SAF costs mandated by ReFuelEU Aviation.
- Correct the fuel use for annual efficiency improvements of 1.05% (CE Delft, 2024) to obtain the total amount of fuel per passenger required in 2030.
- In 2030, ReFuelEU Aviation requires that 6% of the total fuel delivered to flights departing from EU airports must be SAF, of which 1.2% synthetic fuel and hence 4.8% biofuels. We apply these percentages to obtain the total amount of fuel required per passenger by type. We assume that flight not subjected to the ReFuelEU Aviation mandate do not blend SAF.

Based on the fuel use per type, the costs are calculated for the fossil part and the SAF part of the fuel, distinguishing outbound and inbound flights. This is done by multiplying the amount of fuel required by type with the expected fuel price in 2030. The assumed fuel prices are shown in Table 4. According to the ReFuelEU Aviation impact assessment, the price of the main SAF production route, HEFA, is lower than the kerosene price in both 2030 and 2035. As this would lead to the incentive to use as much SAF and possible, and is not expected in other researches and the industry, we assume the price of the Alcohol-to-Jet (AtJ) SAF production route from the ReFuelEU Aviation IA for the average bio-SAF.
For synthetic SAF we assumed the minimum selling price (MSP) from the IATA net-zero finance roadmap plus a market add-on price of approximately 0.9 €/kg. This equals the difference between the MSP of HEFA in the IATA research and the bio-SAF price we assume in Table 9. These add-ons can vary significantly. In 2024 the difference between production costs and market prices, thus the market premium, reached as high as around 1,000 US dollars per tonne, which equals about 0.95 EUR per kg. This illustrates that the market add-on price we assume is relatively high.

Table 9 - Fuel price in €/kg used in the analysis based on (EC, 2021) for kerosene and bio-SAF; E-SAF prices are based on (REF)[8]

Fuel type	2030	2035
Kerosene	1.05	1.12
Bio-SAF	2.09	2.13
Synthetic SAF (e-fuel)	4.62	3.90

8 Exchange rate for USD to EUR of 0.95 used (17/12/24).

It is very uncertain how the e-SAF market will develop to 2030 and 2035, including uncertainties around the market price. In the analysis, the e-SAF price has a minor impact as the blending obligation for e-fuel under ReFuelEU Aviation is rather low in 2030 and 2035. In 2050 the impact of the e-SAF price will increase as the blending obligation for e-SAF is 35%. However, 2050 is out of scope in this research. To illustrate the impact of higher e-SAF prices in 2030 and 2035, we conducted a quick sensitivity analysis to the route influences most by ReFuelEU Aviation, see Textbox 6 for this.

Textbox 6 - Sensitivity analysis e-SAF price Case 1: Amsterdam - Hong Kong via Frankfurt

Sensitivity analysis e-SAF price

To illustrate the impact of the used e-SAF price in the calculations, we applied an e-SAF price of 6.0 €/kg in both 2030 and 2035 to the route on which the ReFuelEU Aviation costs are highest. This is the route from Amsterdam to Hong Kong, with a transfer at Frankfurt (Case 1). Using the prices displayed in table 5, the total ReFuelEU Aviation costs (inbound + outbound flight) are € 18 in 2030 and € 54 in 2035. Using a price of 6.0 €/kg in both 2030 and 2035, results in total ReFuelEU Aviation costs of € 22 in 2030 and € 73 in 2035. The total policy induced costs increase with 4-10% in 2030 and 16-27% in 2035 depending on the current or extended EU ETS scope. A EU ETS scope extensions results in higher EU ETS costs and thus a smaller proportion of the ReFuelEU Aviation in the total policy induced costs.

The final step in the analysis is calculating the EU ETS and CORSIA costs, based on the following steps and assumptions:

- In line with the regulations in the EU ETS we assume that for all SAF a zero emission factor can be applied and no EU ETS allowances need to be surrendered. We reduced the amount of CO_2-emissions that are considered within the EU ETS by the share of SAF blending.
- Apply CORSIA to all flights not covered by EU ETS.
- CORSIA only applies to the emissions above the baseline, which is 85% of the 2019 emissions. Figure 2 shows the aviation emission that fall under the current and extended EU ETS scope. The 2030 emissions are almost equal to the 2019 emission, indicating only 15% of the 2030 emissions must be offset by CORSIA international credits. Therefore, we reduced the CORSIA costs with 85%.
- The expected EU ETS allowance and CORSIA international credit prices are shown in Table 10, which are multiplied with the CO_2 emissions.

Table 10 - EU ETS and CORSIA price in €/ton CO_2 used in the analysis

Policy framework	2030	2035
EU ETS	€ 100	€ 125
CORSIA	€ 15	€ 22

Source: TAKS (2022).

B Detailed case analysis

In this Annex, we present a more detailed analysis of the effect of the EU ETS scope extension for the year 2030 and 2035. To make a fair comparison, we include other aviation policy induced costs as CORSIA and ReFuelEU Aviation and fuel efficiency improvements. The results for Case 1 are presented here, the detailed analysis of Case 2, 3 and 4 is presented in Annex B.1. The methodology and assumptions are discussed in Annex A.

Table 11 gives an overview of the travel options considered in the analysis of Case 1, including the additional CO_2 emissions that would become subject to the EU ETS in case of the scope extension. For the route via Istanbul extra EU ETS allowances would be required for 2,200 kilometres of the journey. For the direct flight this would be for 9,300 km to the final destination. This indicates that the route via Istanbul becomes relatively more attractive as the least extra kilometres are subject to the extended EU ETS scope.

Table 11 - Routes considered under Case 1, including the effect of the EU ETS scope extension

Route	EU ETS scope: intra-EEA	EU ETS scope: departing flights	Extra ton CO_2 emissions under EU ETS scope extension (one-way)
Direct flight	-	Amsterdam to Hong Kong	218
Via Beijing	-	Amsterdam to Beijing	183
Via Doha	-	Amsterdam to Doha	146
Via Frankfurt	Amsterdam to Frankfurt	Amsterdam to Frankfurt and Frankfurt to Hong Kong	268
Via Istanbul	-	Amsterdam to Istanbul	55

Figure 12 displays the cost impacts of the EU ETS, ReFuelEU Aviation and CORSIA for 2030, split for the outbound and inbound flight to show the impact of the different scopes of the policies. As a result of the EU ETS scope extension, ticket prices increase for all routes, although the extent of the increase varies across the routes. The ticket prices to Istanbul experience the lowest increase due to the EU ETS scope extension. After the scope extension, total costs for all considered policies are € 25. In comparison, policy induced costs for the route via Frankfurt would be € 77. The direct flight, a stopover at Beijing and a stopover at Dubai have price increases of respectively € 52, € 45 and € 34. The difference in costs between a direct flight and a transfer via Beijing is relatively small (€11).
This shows that the biggest competitive advantage is for hubs just outside the EEA, with Istanbul at the perfect geographic position for connections to Asia.

The analysis also shows that CORISA only has a small effect on the ticket prices. Furthermore, when comparing ReFuelEU Aviation and EU ETS costs in the extended scope, it is evident that ReFuelEU Aviation costs are smaller than EU ETS costs, accounting for 21-22% of total aviation induced policy costs.

Figure 12 - Impact of EU ETS, CORSIA and ReFuel EU Aviation on ticket prices for economy class passengers in 2030 on the routes from Amsterdam to Hong Kong

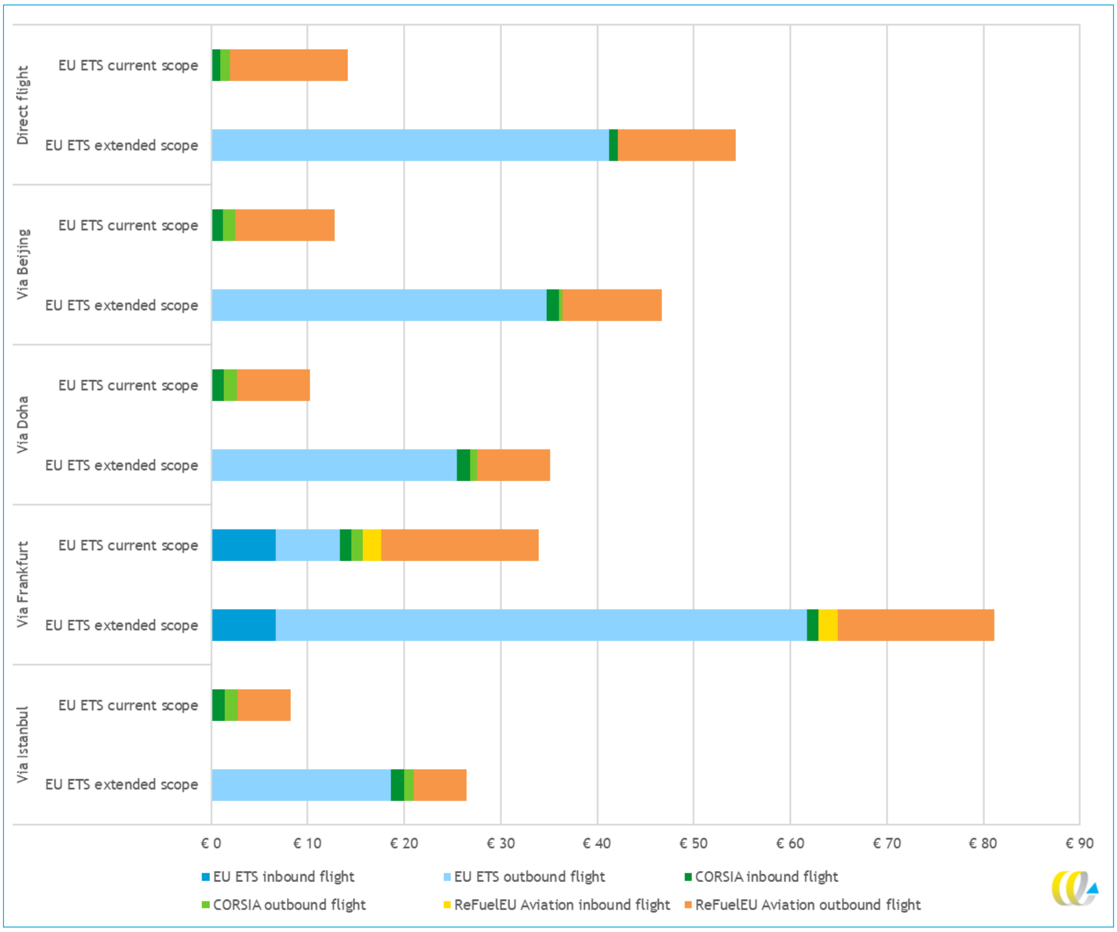
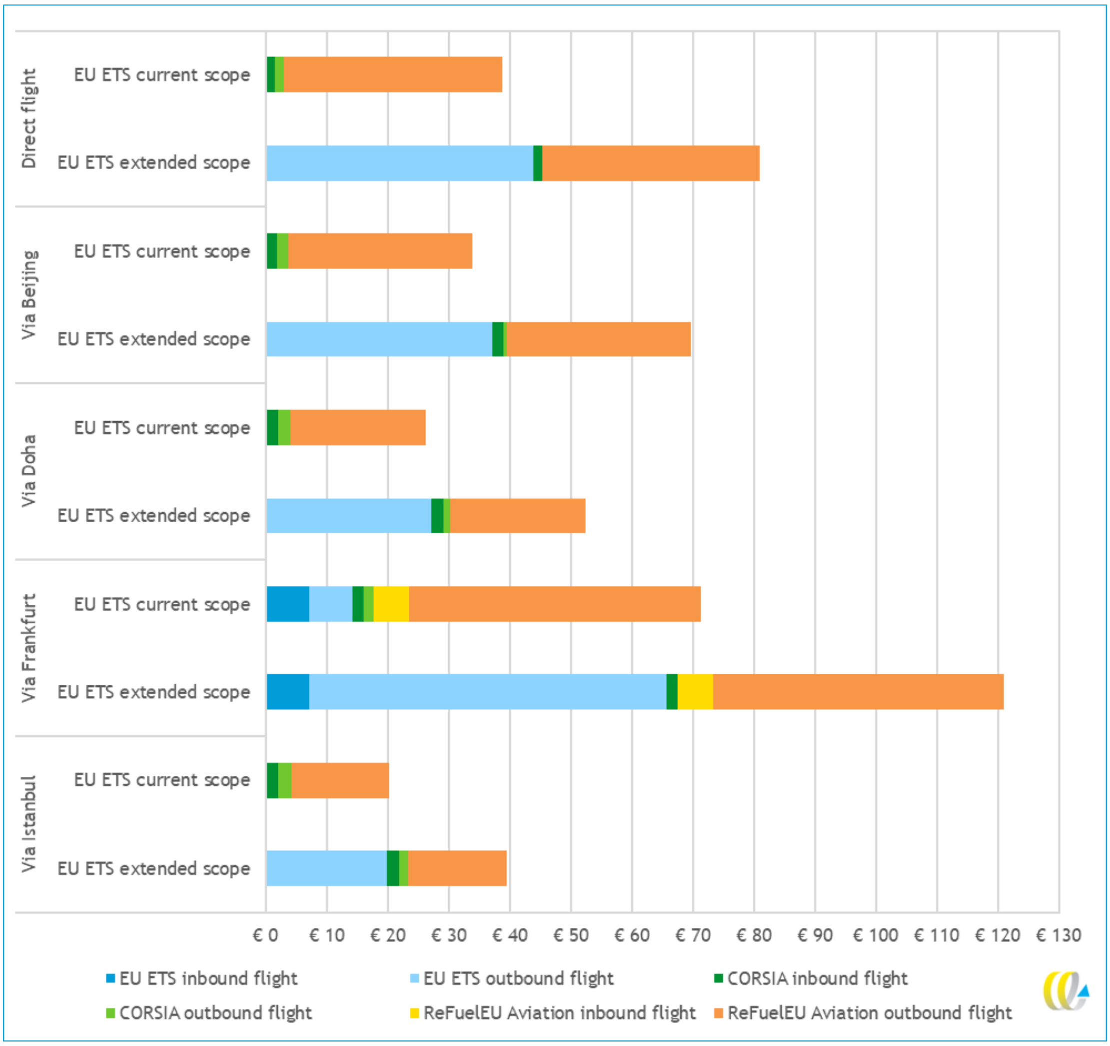


Figure 13 shows the same impacts as Figure 12, but for 2035. In 2035, the EU ETS allowance price is expected to rise by 25%, from 100 to 125 euro per ton CO_2 (see Figure 3). However, a part of this price increase is compensated by fuel efficiency improvements and more SAF blending. The difference between the current and extended EU ETS scope is at most € 3 higher in 2035 compared to 2030. The main difference between 2035 and 2030 are the higher costs for ReFuel EU Aviation, as a consequence of the increasing SAF mandate.
In 2030, ReFuel EU Aviation accounted for 21–22% of total aviation policy induced costs, in 2035 this rises to 41-44%, still less than EU ETS costs in the extended scope.

Figure 13 - Impact of EU ETS, CORSIA and ReFuel EU Aviation on ticket prices for economy class passengers in 2035 on the routes from Amsterdam to Hong Kong



B.1 Results detailed case analysis Cases 2, 3 and 4

The following figures are depicted in this appendix:

- **Nice - Bangkok (Case 2)**
  - Figure 14- Impact of EU ETS scope extension for different routes from Nice to Bangkok in 2030 for economy class passengers. Including EU ETS, CORSIA and ReFuelEU Aviation costs per passenger.
  - Figure 15- Impact of EU ETS scope extension for different routes from Nice to Bangkok in 2035 for economy class passengers. Including EU ETS, CORSIA and ReFuelEU Aviation costs per passenger.

- **Toronto - Mumbai (Case 3)**
  - Figure 16- Impact of EU ETS scope extension for different routes from Toronto to Mumbai in 2030 for economy class passengers. Including EU ETS, CORSIA and ReFuelEU Aviation costs per passenger.
  - Figure 17- Impact of EU ETS scope extension for different routes from Toronto to Mumbai in 2035 for economy class passengers. Including EU ETS, CORSIA and ReFuelEU Aviation costs per passenger.
- **Amsterdam - Mediterranean coast (Case 4)**
  - Figure 18- Impact of EU ETS scope extension for different routes from Amsterdam to Mediterranean coast in 2030 for economy class passengers. Including EU ETS, CORSIA and ReFuelEU Aviation costs per passenger.
  - Figure 19- Impact of EU ETS scope extension for different routes from Amsterdam to Mediterranean coast in 2035 for economy class passengers. Including EU ETS, CORSIA and ReFuelEU Aviation costs per passenger.

EU ETS scope extensions effect on the routes considered

Table 12 - Routes considered under Case 2, including the effect of the EU ETS scope extension

Route	EU ETS scope: intra-EEA	EU ETS scope: departing flights	Extra ton CO_2 emissions under EU ETS scope extension (one-way)
Via Munich	Nice to Munich	Nice to Munich and Munich to Bangkok	253
Via Istanbul	-	Nice to Istanbul	29
Via Copenhagen	Nice to Copenhagen	Nice to Copenhagen and Copenhagen to Bangkok	249
Via Amsterdam	Nice to Amsterdam	Nice to Amsterdam and Amsterdam to Bangkok	272
Via Dubai	-	Nice to Dubai	251

Table 13 - Routes considered under Case 3, including the effect of the EU ETS scope extension

Route	EU ETS scope: intra-EEA	EU ETS scope: departing flights	Extra ton CO_2 emissions under EU ETS scope extension (one-way)
Direct flight	-	-	-
Via Zayed (Abu Dhabi)	-	-	-
Via Amsterdam	-	Amsterdam to Mumbai	187
Via Paris	-	Paris to Mumbai	157
Via Dubai	-	-	-

Table 14 - Routes considered under Case 4, including the effect of the EU ETS scope extension

Route	EU ETS scope: intra-EEA	EU ETS scope: departing flights	Extra ton CO_2 emissions under EU ETS scope extension (one-way)
To Izmir	-	Amsterdam to Izmir	28
To Athene	Amsterdam to Athene	Amsterdam to Athene	-
To Palma de Mallorca	Amsterdam to Palma de Mallorca	Amsterdam to Palma de Mallorca	-
To Malaga	Amsterdam to Malaga	Amsterdam to Malaga	-
To Marrakesh	-	Amsterdam to Marrakesh	30
To Fez	-	Amsterdam to Fez	29

Graphical representation of aviation policy induced costs for 2030 and 2035

Figure 14 - Impact of EU ETS scope extension for different routes from Nice to Bangkok in 2030 for economy class passengers; including EU ETS, CORSIA and ReFuelEU Aviation costs per passenger

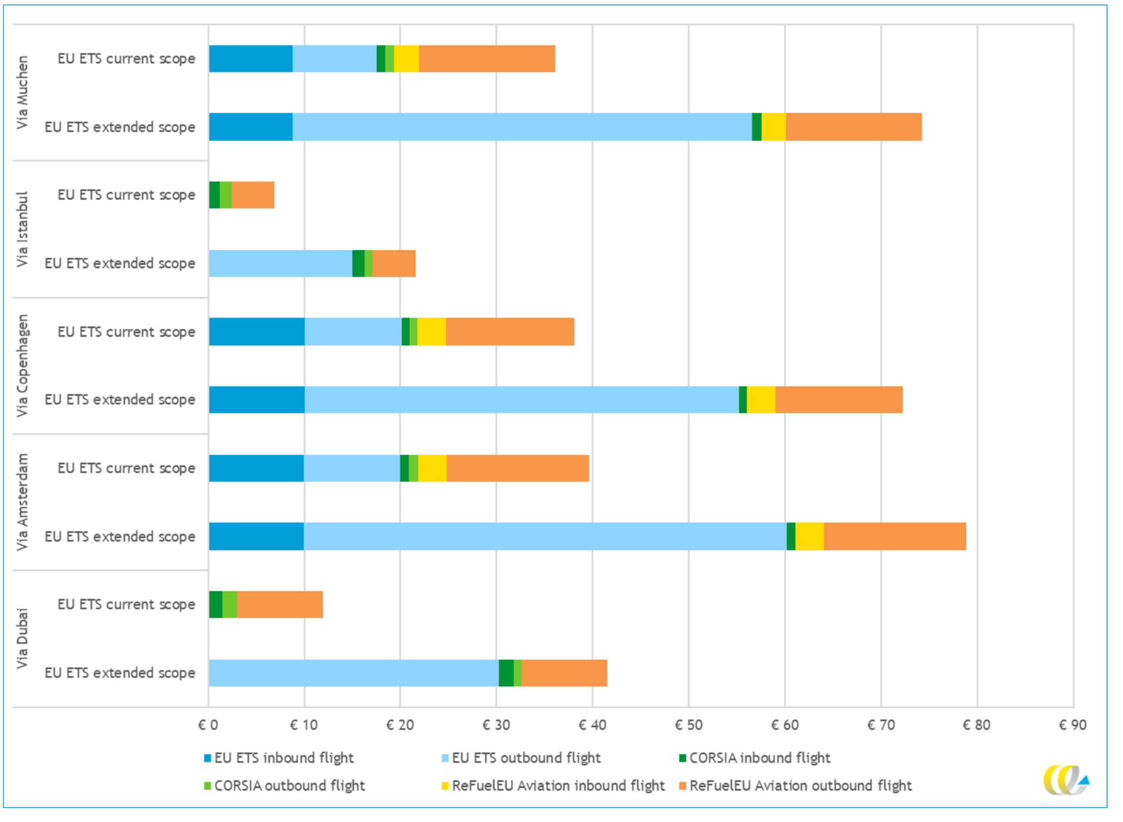


Figure 15 - Impact of EU ETS scope extension for different routes from Nice to Bangkok in 2035 for economy class passengers; including EU ETS, CORSIA and ReFuelEU Aviation costs per passenger

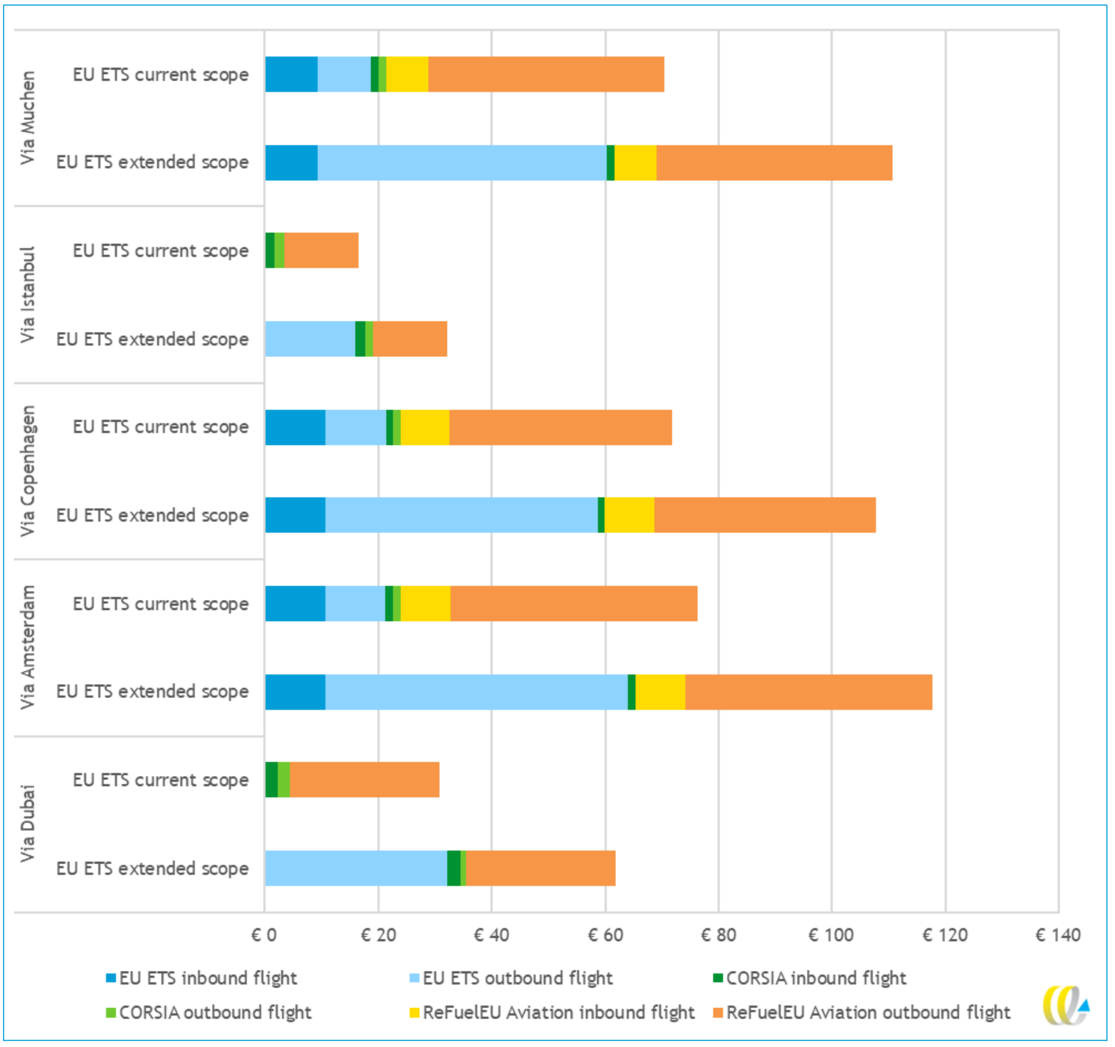


Figure 16 - Impact of EU ETS scope extension for different routes from Toronto to Mumbai in 2030 for economy class passengers; including EU ETS, CORSIA and ReFuelEU Aviation costs per passenger

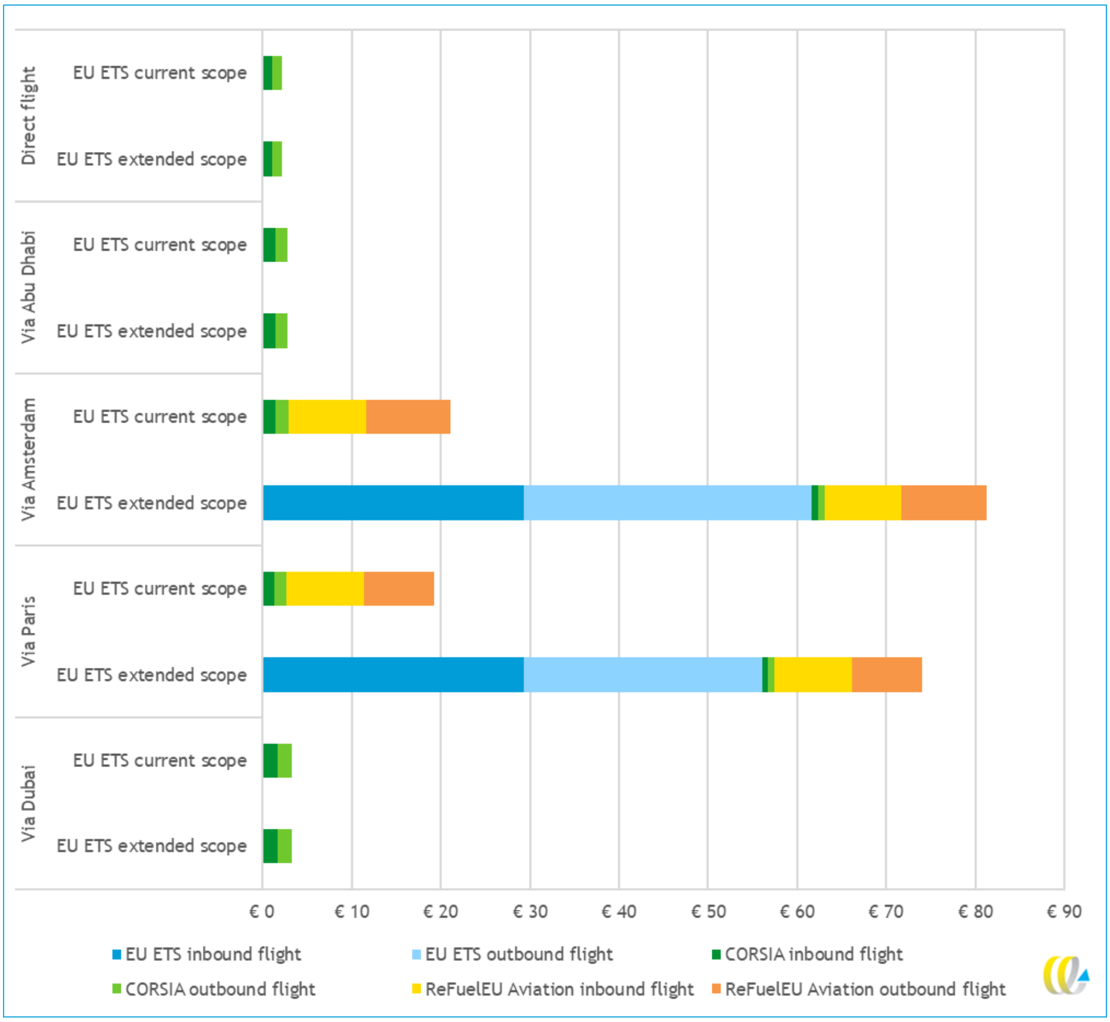


Figure 17 - Impact of EU ETS scope extension for different routes from Toronto to Mumbai in 2035 for economy class passengers; including EU ETS, CORSIA and ReFuelEU Aviation costs per passenger

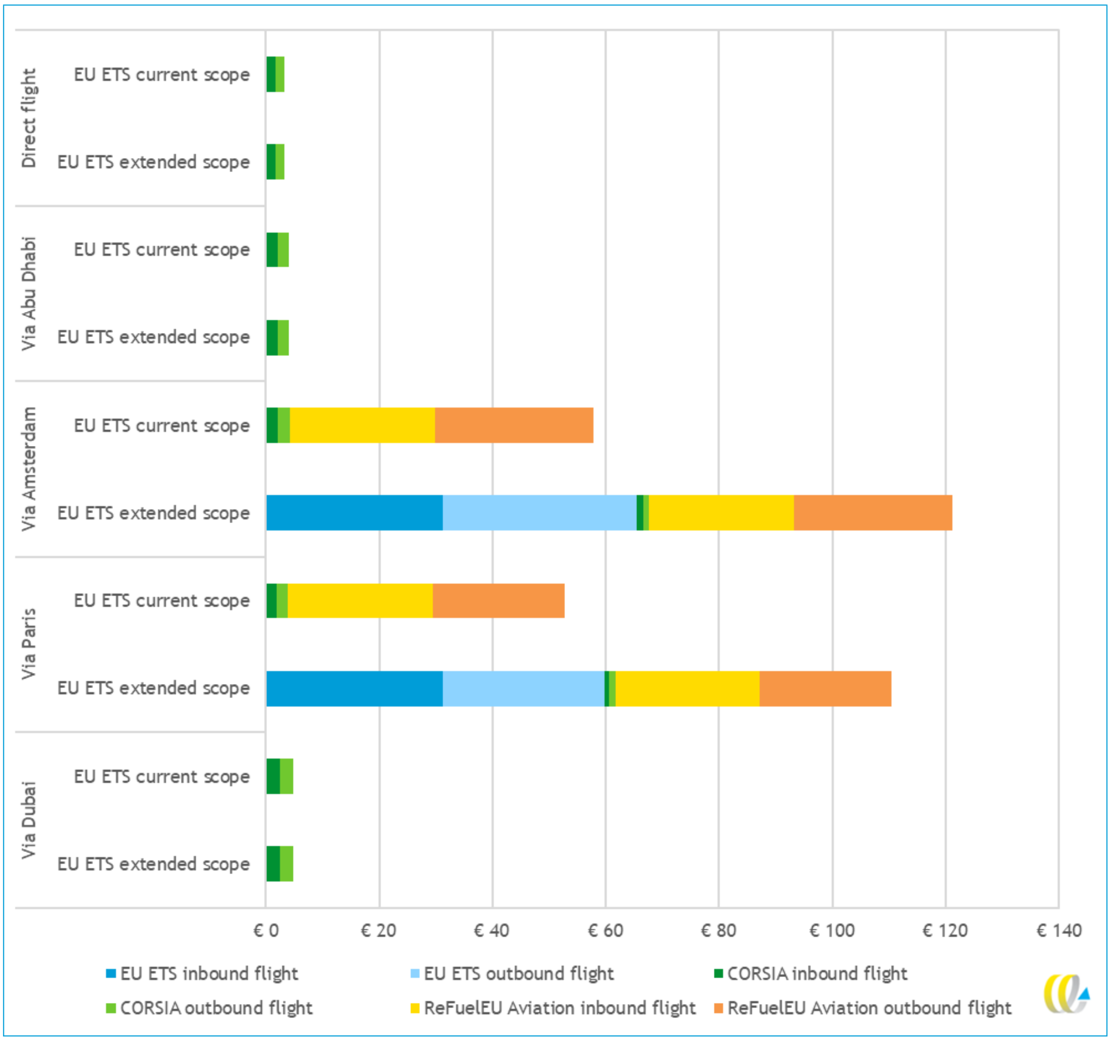


Figure 18 - Impact of EU ETS scope extension for different routes from Amsterdam to Mediterranean coast in 2030 for economy class passengers; including EU ETS, CORSIA and ReFuelEU Aviation costs per passenger

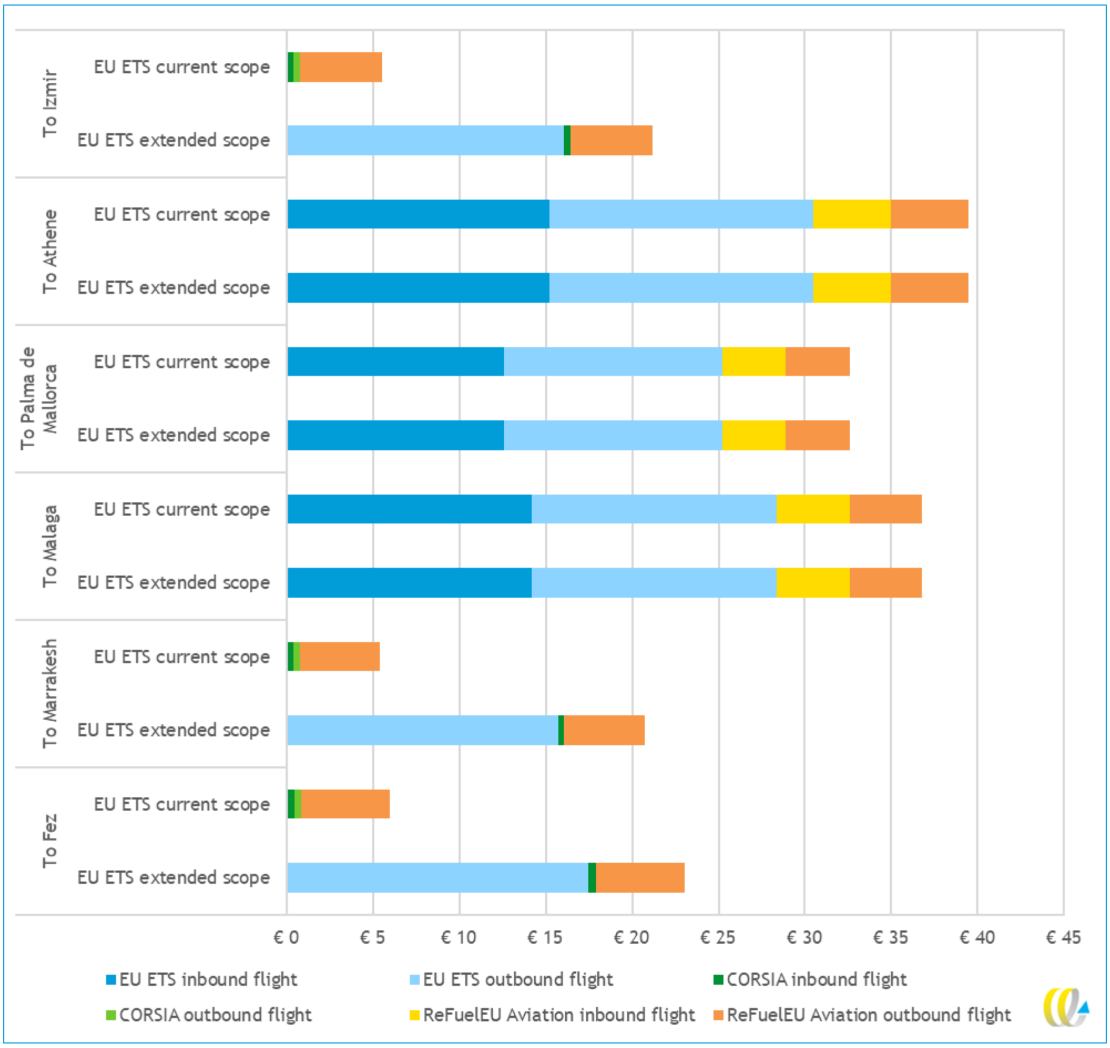
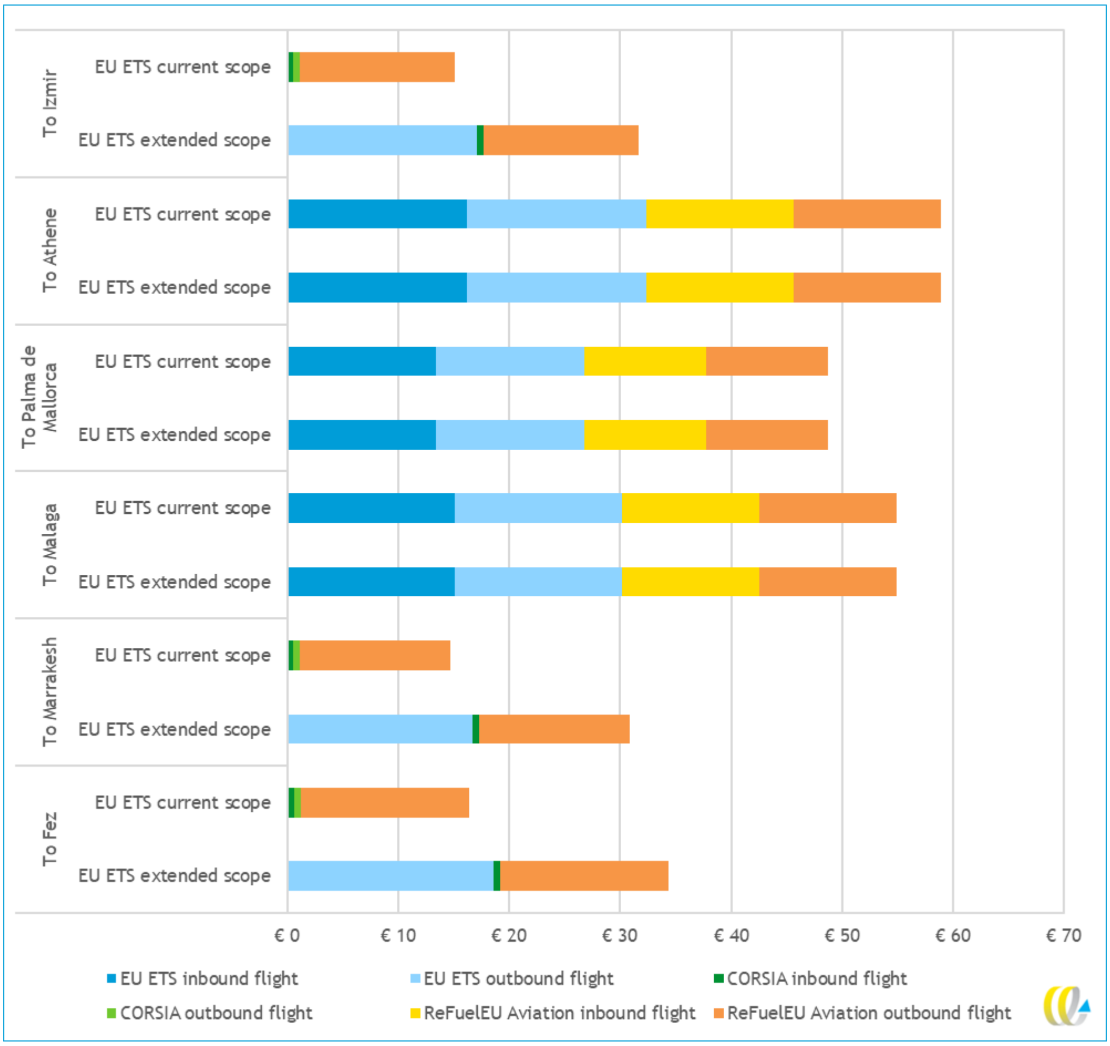


Figure 19 - Impact of EU ETS scope extension for different routes from Amsterdam to Mediterranean coast in 2035 for economy class passengers; including EU ETS, CORSIA and ReFuelEU Aviation costs per passenger



C Case analysis for business class

The analysis presented in Chapter 3 concerns economy class passengers. In this Annex, we apply the same method to business class passengers. The only difference between those two passenger types we consider are the CO_2 emissions per passenger. We decide to remove Case 4 from this analysis, as business class is not available for all destinations.

Business class is also not available for several flights departing in Nice (Case 2), for example for flights between Nice and Copenhagen. For this example the ICAO emissions calculator tool displays the same emission value for economy and business class. For consistency reasons, we applied the average factor between the CO_2-emissions of an economy and of a business class passenger of the other routes to these flights.

The following figures are presented here:
- Figure 20- Cost difference EU ETS scope extension per business class passenger in 2030. The amount next to the blue bar is the price difference between that route and the cheapest route for that case.
- Figure 21- Impact of EU ETS scope extension for different routes from Amsterdam to Hong Kong in 2030 for business class passenger. Including EU ETS, CORSIA and ReFuelEU Aviation costs per passenger.
- Figure 22- Impact of EU ETS scope extension for different routes from Nice to Bangkok in 2030 for business class passengers. Including EU ETS, CORSIA and ReFuelEU Aviation costs per passenger.
- Figure 23- Impact of EU ETS scope extension for different routes from Toronto to Mumbai in 2030 for business class passengers. Including EU ETS, CORSIA and ReFuelEU Aviation costs per passenger.

Figure 20 - Cost difference EU ETS scope extension per business class passenger in 2030; the amount next to the blue bar is the price difference between that route and the cheapest route for that case

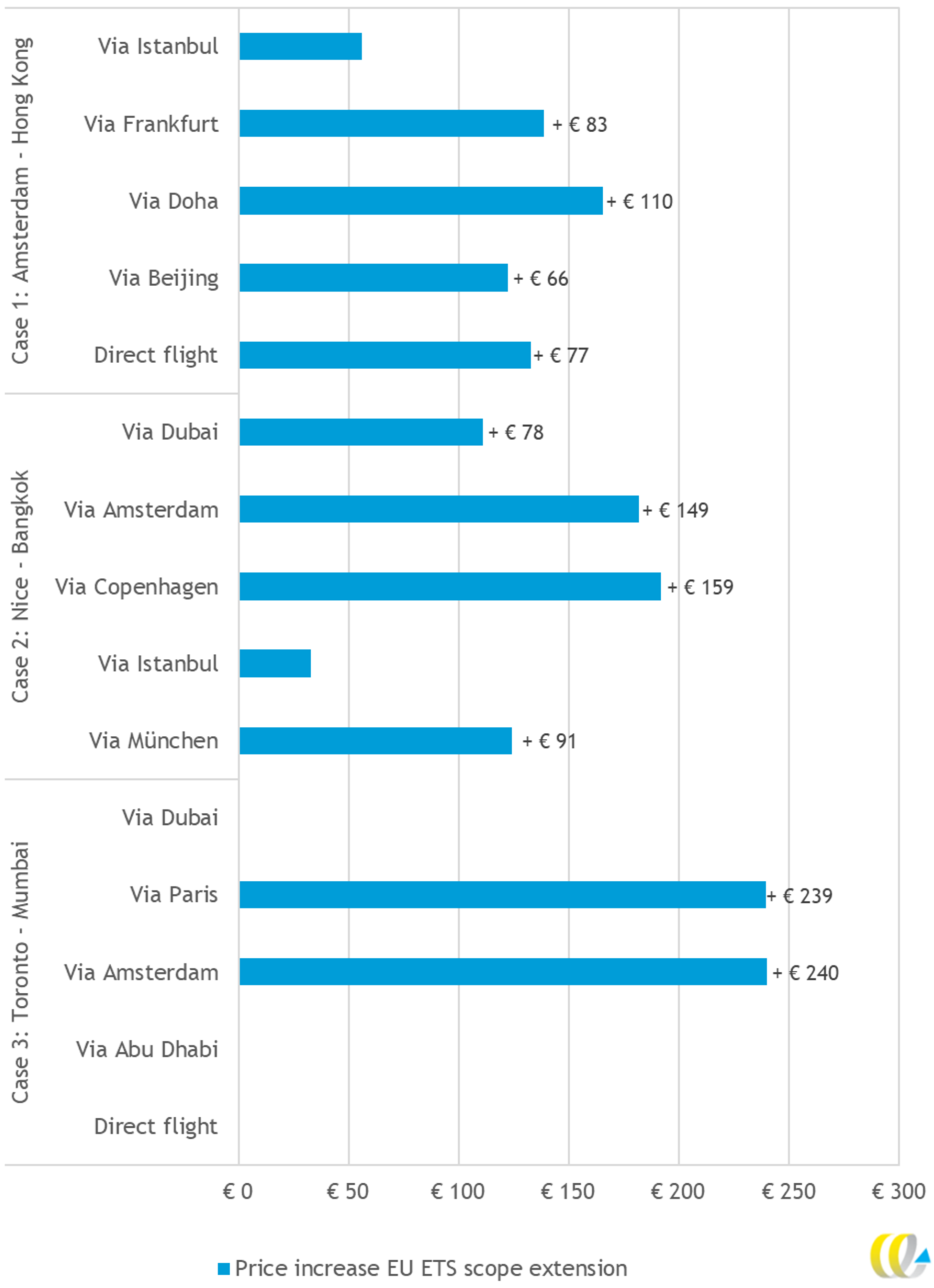


Figure 21 - Impact of EU ETS scope extension for different routes from Amsterdam to Hong Kong in 2030 for business class passenger; including EU ETS, CORSIA and ReFuelEU Aviation costs per passenger

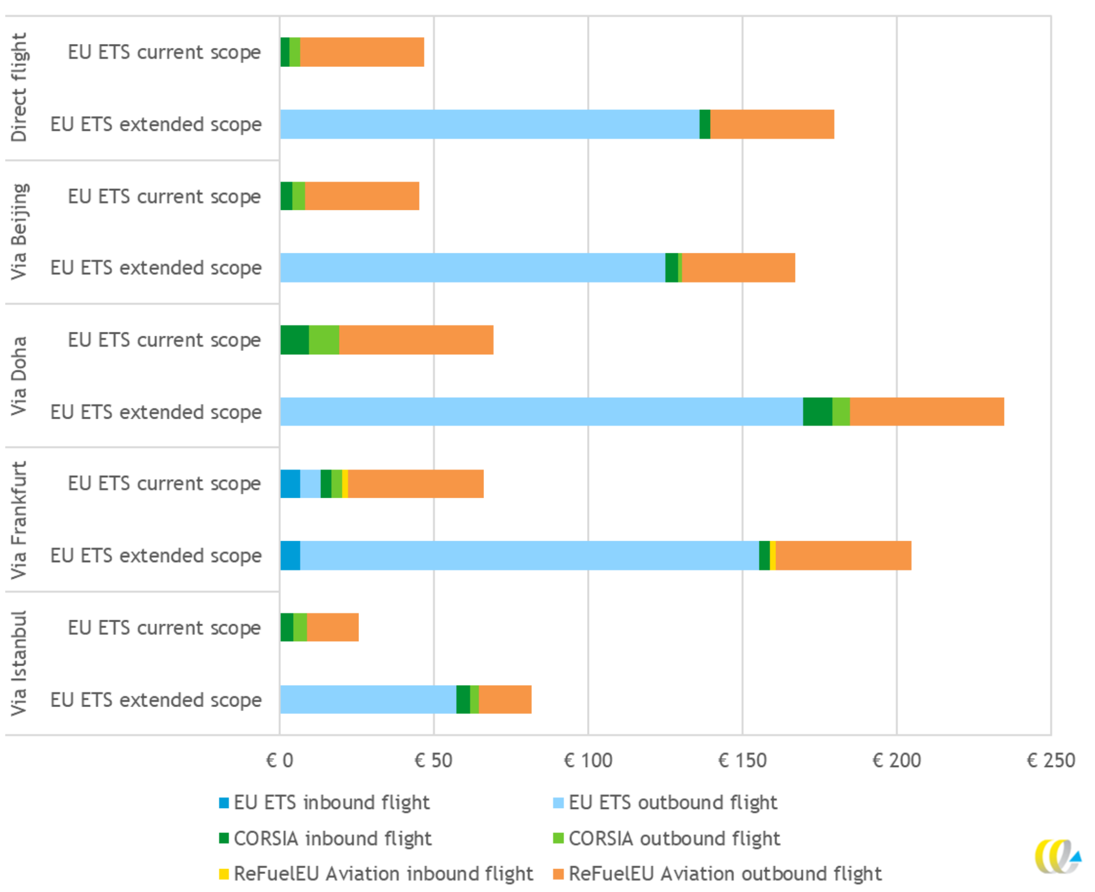


Figure 22 - Impact of EU ETS scope extension for different routes from Nice to Bangkok in 2030 for business class passengers; including EU ETS, CORSIA and ReFuelEU Aviation costs per passenger

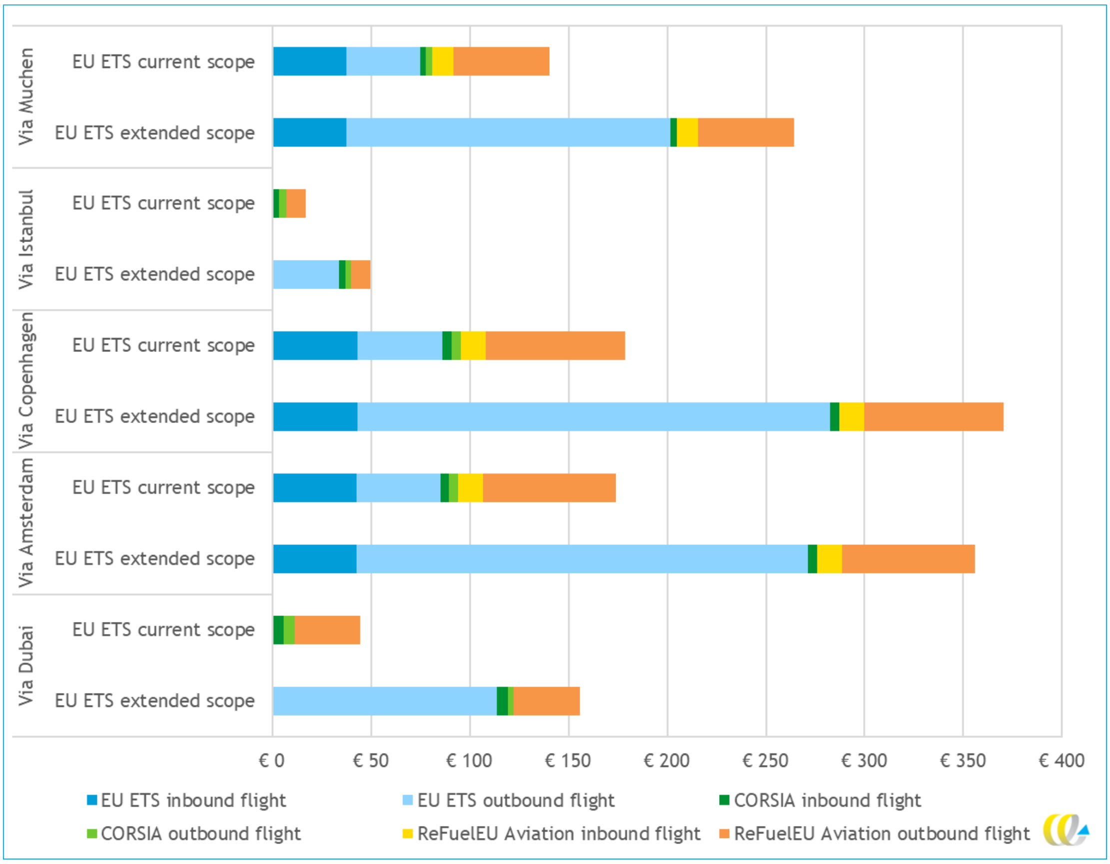


Figure 23 - Impact of EU ETS scope extension for different routes from Toronto to Mumbai in 2030 for business class passengers; including EU ETS, CORSIA and ReFuelEU Aviation costs per passenger