AVIATION FIT FOR 55

TICKET PRICES, DEMAND AND CARBON LEAKAGE

RESEARCH REPORT

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Executive Summary: Aviation Fit For 55

The costs associated with Fit for 55 policies make European air travel more expensive. Higher costs reduce the demand for air travel to, from and within the European Economic Area (EEA) and cause a shift in demand to competing non-EEA hub airports and routes. Fit for 55 policies reduce aviation CO_2 emissions, but carbon leakage due to the demand shift reduces these emission savings.

In this study, SEO Amsterdam Economics (SEO) and Royal Netherlands Aerospace Centre (NLR) estimate Fit for 55 impacts on ticket prices, demand, CO_2 emissions and carbon leakage, based on a global passenger choice model.[1,2]

The report focuses on air travel to, from and within the EEA. This approximates the EU scope of the Fit for 55 policies:
- **EU-ETS** (EU Emissions Trading System), and **CORSIA** (Carbon Offsetting & Reduction Scheme for International Aviation)
- **ETD** (Energy Taxation Directive, i.e., kerosene tax)
- **ReFuelEU** Aviation (Sustainable Aviation Fuel blending mandate)

The **costs** of air travel increase due to these policies. Within the EEA, Fit for 55 increases the cost of a return flight of 3000 km within the EEA by about €45 per passenger in 2030 and €65 per passenger in 2035 compared to a no-policy scenario in those years. For flights to non-EEA destinations, costs increase for a return flight of 19,000 km (e.g. Frankfurt-Tokyo) around €50 per passenger in 2030 and by €105 in 2035.[3] While costs are an almost linear function of flight distance, both within and outside the EEA, there is variation because the average additional cost per airport may differ. Since longer distances within the EEA imply higher costs, airports closer to EEA borders (e.g. Helsinki, Madrid, Cyprus) have a relative cost disadvantage in comparison to airports located more towards the centre of Europe. Airports just outside the EEA area have a competitive cost advantage as an onward hub for indirect flights from the EEA. Depending on the pass-through rate to the consumers, ticket prices are expected to increase.[4]

The **demand** for air travel decreases due to the additional cost and resulting ticket price increases from Fit for 55 policies. In case the complete cost increase would be passed on to consumers in its entirety, overall passenger volumes in 2030 decrease by 8.4 percent compared to the no-policy scenario of the same year. This implies a decrease of around 75 million passengers (summary Table S.1). In 2035, the overall passenger volumes decrease by 11.6 percent compared the reference scenario, adding up to a total reduction of 119 million passengers. The number of passengers traveling to a non-EEA destination, either directly or via an EEA hub, decreases by 6 percent in

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[1] This independent assessment is commissioned by Air France-KLM Group, Groupe ADP, Lufthansa Group and Royal Schiphol Group.

[2] This model was also used in *'Destination 2050: A Route To Net Zero European Aviation'* by NLR and SEO (2021).

[3] Due to the remaining uncertainty around sustainable aviation fuel prices, price forecasts are conservative and therefore could be an underestimate. Larger SAF price forecasts used in industry estimates suggest even higher cost increases. Similarly, there are uncertainties related to other policies, such as RefuelEU applicability and carbon abatement cost.

[4] The assumed pass through rate is 100%. This is a strong assumption usually only applicable to markets with perfect competition. A 100% pass-through rate results in an upper bound on demand impacts, CO_2 savings and carbon leakage. Actual pass through will vary according to competition on the route, airport congestion and airline operating profits. The demand and carbon leakage impacts scale linearly with the pass-through, so that a 50 percent pass through would yield half the demand impact and carbon leakage shown here.

2035 (minus 10 million passengers). On the other hand, the number of intercontinental passengers travelling through non-EEA hubs increases by 2 percent (plus 1.4 million passengers).

Table S.1 Overview of impacts on demand and CO_2 emissions

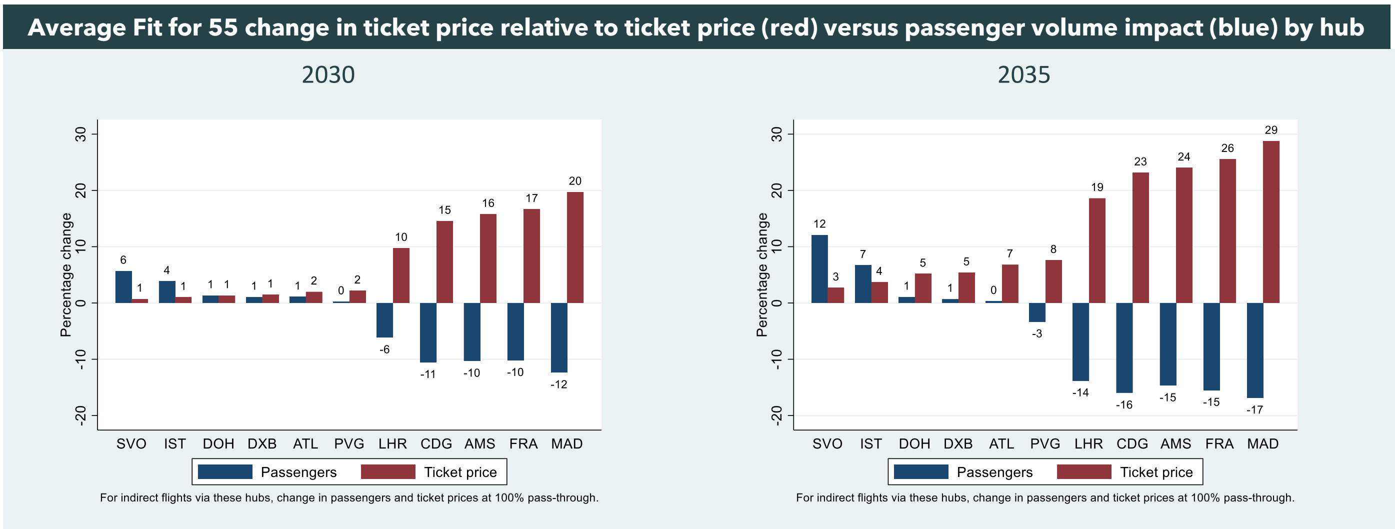
	Intra-EEA			**EEA → non-EEA**						
	2018	2030	2035	2018	2030			2035		
	Total	**Total**	**Total**	**Total**	EEA hubs or direct	non-EEA hubs	**Total**	EEA hubs or direct	non-EEA hubs	**Total**
Passenger demand [a]										
Baseline traffic (x mln pax) (without FF55 measures)	578	702	792	152	141	53	194	167	63	230
Absolute change (x mln pax) (due to FF55 measures)		-72	-110		-3.8	1.0	-2.8	-10.0	1.4	-8.6
Relative change (%)		-10%	-14%		-2.7%	1.9%	-1.4%	-6.0%	2.2%	-3.8%
CO_2 emissions [b]										
Baseline emissions (x Mton)	60	64	71	93	62	39	101	71	46	118
Absolute change (x Mton)		-9.1	-19.3		-4.6	-0.2	-4.8	-15.7	-3.3	-19.1
Relative change (%)		-14%	-27%		-7.4%	-0.5%	-4.7%	-22%	-7%	-16%
Carbon leakage (x Mton) [c]		0.0	0.1				0.7			1.1

Notes: [a]: Total number of departing Origin & Destination (O&D) passengers from EEA airports.
[b]: Total estimated CO_2 emissions of all departing O&D passengers from EEA airports. Baseline emissions are without Ff55 measures, but include reduced CO_2 emissions as a result of technological and operational improvements, based on developments according to Destination 2050.
[c]: Sum of all additional emissions due to a shift of demand to non-EEA hubs.
Source: SEO & NLR (2022)

The figures on the next page show the relative impact of Fit for 55 fare increases on average passenger volumes for a selection of EEA and non-EEA hubs, compared to a reference scenario in the same year with no Fit for 55 policies. Competitiveness of European airlines and hubs is expected to diminish in comparison to non-European airlines and hubs. Hubs close to the EEA such as Istanbul (IST) and Moscow Sheremetyevo (SVO) respectively gain 7 and 12 percent of traffic from EEA hubs in 2035 (0.8 and 0.5 million passengers per year). High volume EEA hubs have more to both gain or lose. Since airports at EEA border have a cost disadvantage from Fit for 55, the negative demand impacts are slightly larger (minus 17 percent for Madrid) than for airports located at the centre of Europe, such as Amsterdam or Frankfurt (minus 15 percent, equal to 1.2 and 1.7 million passengers, respectively).

For the purpose of this study, it is assumed that ETD does not apply for the UK, whereas all other measures are in full alignment with the EEA. As a result of the combined impacts, ticket prices for flights via London Heathrow are expected to increase by 19 percent, leading to a 14 percent demand decrease in travel via Heathrow (minus 1.1 million passengers).

Figure S. 1 Ticket price and demand impacts of the Fit for 55 measures



For indirect flights via these hubs, change in passengers and ticket prices at 100% pass-through.

For indirect flights via these hubs, change in passengers and ticket prices at 100% pass-through.

Source: SEO & NLR (2022)

A reduction of demand and a relative loss in competitiveness of EU airlines and hubs – in particular on long-haul routes – could jeopardize the further development of EU air connectivity. Although a causal relationship can run both ways, various studies acknowledge that there is a positive relationship between air connectivity and economic growth. From that perspective, a reduction of demand reduces economic growth and aviation employment in the EU compared to the no-policy reference scenario.

The **CO_2 savings and carbon leakage** depend directly on the demand impacts of Fit for 55. The higher cost per ticket reduces demand for air travel and the SAF uptake with lower CO_2 emissions, in combination result in substantial CO_2 savings. For travel from the EEA to a destination outside the EEA, Fit for 55 costs are lower, and demand for air travel via non-EEA hubs increases, thereby reducing overall CO_2 savings, i.e., causing carbon leakage.

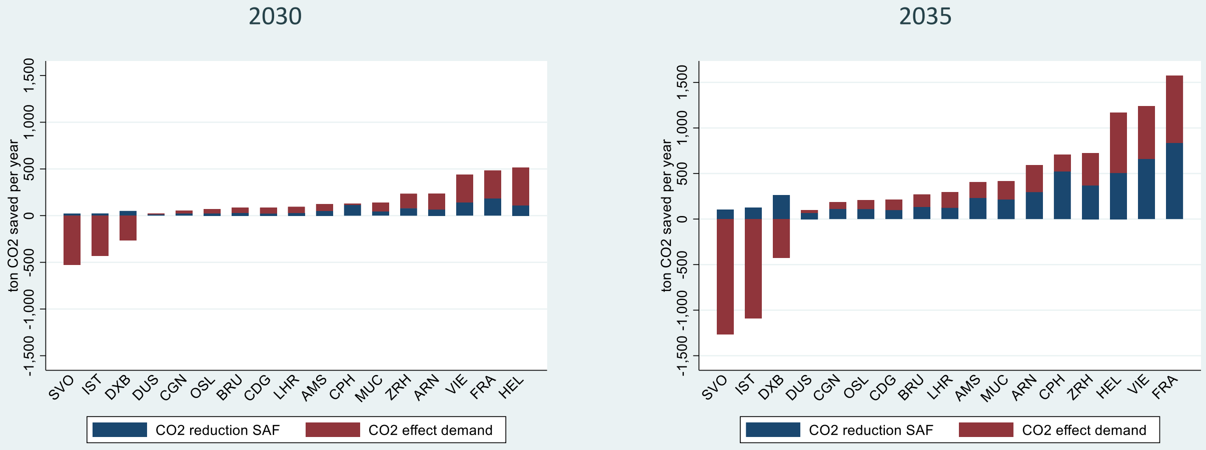
Carbon leakage, the increase of emissions in one country due to the reduction efforts in another, mainly occurs on non-EEA routes. In 2035, the Fit for 55 policy leads to a net CO_2 reduction of 19 megatons per year (roughly the emissions of all passenger flights departing from France in one year), whilst carbon leakage leads to an increase of 1.1 megatons of CO_2 (equivalent to about 7,000 flights between Frankfurt and New York JFK). Carbon leakage mainly occurs on long-haul markets, particularly on routes with high competition from non-EEA hubs and airlines. On such routes, carbon leakage can be substantially higher, for example on routes towards Asia (e.g. 46 percent on the route Nice to Seoul and 35 percent for Hamburg to Bangkok. Conversely, there are routes with little or no carbon leakage. Taking into account all non-EEA routes, carbon leakage is estimated to be at least 6 percent of total CO_2 savings associated with the Fit for 55 policy. Competitive distortion and the resulting carbon leakage are unintended consequences of the Fit for 55 policy.

For intra-EEA routes, there is a limited risk of CO_2 leakage. Two sources for carbon leakage within the EEA are that indirect flights within the EEA use a non-EEA hub or that travellers substitute for non-EEA destinations. The former occurs for 0.2 percent of all within EEA travel in 2035. The latter requires analysing travellers' destination choices, which was beyond the scope of the current research.

Case study: Impact in 2035 on a selected route (Hamburg – Bangkok)

On the Hamburg – Bangkok route, CO_2 savings occur for EEA hubs such as Frankfurt, Paris and Amsterdam, but CO_2 leakage takes place for routes through non-EEA hubs such as Dubai and Istanbul. The figure below shows the total CO_2 savings per hub airport for this particular route. Total CO_2 savings via Frankfurt are highest, as this alternative has the highest passenger volume. Demand reductions from EU-ETS and Energy Taxation Directive add to the CO_2 savings from ReFuelEU, the Sustainable Aviation Fuel blending mandate. An increase in demand at non-EEA hubs due to lower prices add carbon emissions and therefore reduces the overall CO_2 savings. The net (overall) CO_2 savings for this example are positive in comparison with a no policy reference case.

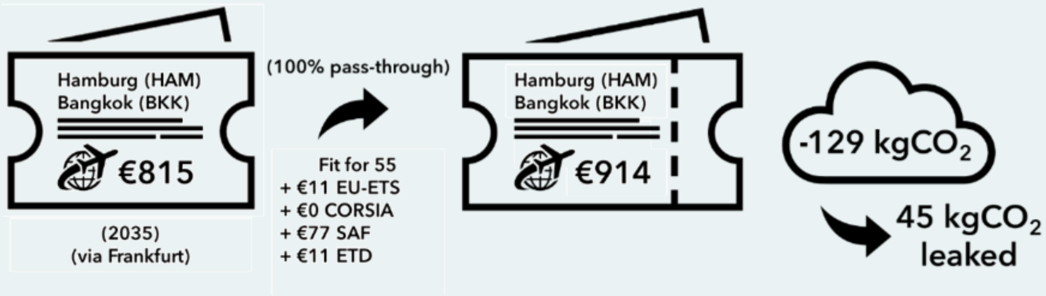
Breakdown of CO_2 savings by SAF uptake and demand reduction, by hub
Hamburg (HAM) ↔ Bangkok (BKK) (assuming 100 percent pass-through rate)



2030

2035

The price, demand and CO_2 emission changes can be compared for the two-way travel from Hamburg (HAM) to Bangkok (BKK) via Frankfurt (FRA) and back. In 2035, Fit for 55 policies add € 99 to the return ticket price. This price increase reduces passengers via Frankfurt by 17 percent (approximately 970 passengers annually) in comparison to the reference case of no Fit for 55 cost. Non-EEA hubs gain a competitive advantage over EEA hubs: demand via non-EEA increases by 24 percent whereas traffic via EEA hubs decreases by 15 percent. The SAF mandate and the demand reduction lead to an annual net saving of around 6430 tCO_2 for all air travel between Hamburg and Bangkok, which translates to 129 kg per remaining passenger. The amount of CO_2 reduction achieved is reduced because some passengers reroute through non-EEA hubs. Without leakage of passengers and emission to non-EEA airports, the CO_2 savings could have been 45 kg higher per passenger traveling under the assumed price conditions, implying carbon leakage of 35 percent.



Source: SEO & NLR (2022)

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1. Introduction

The European Commission's Fit for 55 package proposes legislative measures that aim to reduce carbon emissions. The additional costs incurred from these measures may be passed on to consumers, which may then impact passenger volumes, competitiveness, and policy effectiveness.

In July 2021, the European Commission (EC) proposed the Fit for 55 package,[5] which aims to reduce greenhouse gas emissions in the EU by 55 percent by 2030. A number of proposals aim to support the European aviation industry to become more sustainable and to reduce emissions. These components concern the EU Emissions Trading System (EU-ETS), the implementation of ICAO's Carbon Offsetting and Reducing Scheme for International Aviation (CORSIA) in the EU, a revision of the Energy Tax Directive (ETD) including the introduction of a European kerosene tax, and the ReFuelEU Aviation proposal which introduces an EU sustainable aviation fuel (SAF) blending mandate.[6] Since some – if not all – of the additional costs incurred are passed on to consumers, ticket prices are likely to increase. Since the aviation sector is a highly global competitive environment, changes in prices will translate to changes in volumes, network composition and competitiveness.

In this research report, SEO Amsterdam Economics (SEO) and the Royal Netherlands Aerospace Centre (NLR) forecast these changes. To do so, we use the highly detailed market model NetCost, also used in the recent study '*Destination 2050: A Route To Net Zero European Aviation*' by NLR and SEO (2021). In this way, we are able to generate the expected fares for a set of typical routes, including a breakdown highlighting the contribution of each of the aforementioned Fit for 55 measures on ticket prices. Application of the NetCost model allows us to highlight the implications of implementing the Fit for 55 plans as proposed in the aviation industry.

This research also identifies the implications of foreseen EU measures in terms of tons of CO_2 saved. Due to the aviation sector's global nature, there is the risk of carbon leakage to non-EU countries. Such leakages reduce the effectiveness of the policy in terms of international CO_2 reduction. Most policies included in Fit for 55 risk CO_2 leakage. By modelling these within the NetCost model, we can determine when and where these leakages are likely to occur, what measures contribute to them, and what part of the aviation industry is most affected. Furthermore, we identify which EU regions or airports are most affected and which non-EU airports are most likely to benefit from any potential leakage (i.e., benefit from a shift of air traffic from more expensive EU airports as a result of the Ff55 measures). This study does not take into account the likely capacity expansion of some hubs outside of Europe. Also, the results do not anticipate the possibility of other countries outside of Europe introducing measures which may be similar to the Fit for 55 proposal, such as a regional or global sustainable aviation fuel blending mandate.

The next chapter details the various EC proposals in the Fit for 55 package that impact the aviation industry in Europe, the applicability and the assumptions used in the model. Chapter 3 explains our approach and the workings and outcomes of the model. Chapter 4 presents the results including the cost and demand impact of the Fit for 55 package and also the potential carbon leakage sources. Chapter 5 provides the outlook for 2050 and chapter 6 concludes. The appendix further details the NetCost passenger choice model.

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[5] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/delivering-european-green deal_en#documents

[6] The anti-tankering clause of ReFuelEU is not modeled and AFID/AFIR and RED III are not in the scope of this report.

2. Fit for 55 regulation

The EC's Fit for 55 legislative package includes a number of proposed measures that aim to make the aviation sector more sustainable and reduce aviation emissions. The proposals affect CO_2 pricing through EU-ETS and CORSIA and includes a European kerosene tax and a sustainable aviation fuel blending mandate. Most proposals are aimed at domestic and intra-EU flights, some affect intercontinental travel as well.

2.1 Components

This study considers four legislative proposals from the Fit for 55 package, which are applicable to the aviation industry, that is:

1. **EU-ETS** (EU Emissions Trading System), and **CORSIA** (Carbon Offsetting & Reduction Scheme for International Aviation)
2. **ETD** (Energy Taxation Directive, including an EU kerosene tax)
3. **ReFuelEU Aviation** (including a Sustainable Aviation Fuel blending mandate)

2.1.1 EU-ETS and CORSIA

The EU-ETS is a cap and trade scheme, which reduces EU emissions in selected sectors by 4.2 percent annually (as of Jan 2022 proposed). Current free allowances are progressively phased out by 25 percent per year until a complete phase-out from 2027 onwards. From then on, airlines have to buy EU-ETS allowances to cover their full CO_2 emissions. EU-ETS is applicable to (domestic) intra-EU flights, including flights to and from Norway, Iceland and Lichtenstein (from now on referred to as the European Economic Area, or EEA). The United Kingdom uses the similarly organised UK ETS and Switzerland (CH) uses the CH ETS, which is linked to the EU scheme. Flights from the EEA to the UK or Switzerland are subject to the EU-ETS scheme, whilst flights from the UK or Switzerland to the EEA are subject to the UK ETS or CH ETS, respectively (DEHSt, 2021; FOEN, 2020; BEIS, 2020). Flights to and from the outermost regions (OMR, e.g., Réunion, Madeira, Canary Islands) of EU member states are also exempt except for domestic flights within these regions (Nea, n.d.).

Figure 2.1 Global CORSIA coverage

Source: EC (2020, Figure 6)

CORSIA is a global offsetting scheme applicable to international flights to and from participating countries shown in Figure 2.1. The scheme has been in place since 2021 and has been initiated by the ICAO. An offsetting scheme means that there is no cap on the total amount of CO_2 emitted into the atmosphere. Rather, the scheme requires participants (airlines) to offset the amount of CO_2 they emit on top of a predetermined baseline value. Offsetting regularly takes the form of planting trees (such that an equivalent amount of CO_2 is captured and stored in biomass) or financing CO_2 reductions in other industries. Among the participating states are almost all countries in Europe, North America and Oceania and from 2027 onwards, also Russia, China, India and Brazil. Exempted are least developed countries, small island states, landlocked developing countries, small operators and aircraft, and flights with a public purpose. Intra-EU flights are exempt from CORSIA due to coverage of the EU-ETS scheme, relevant here.

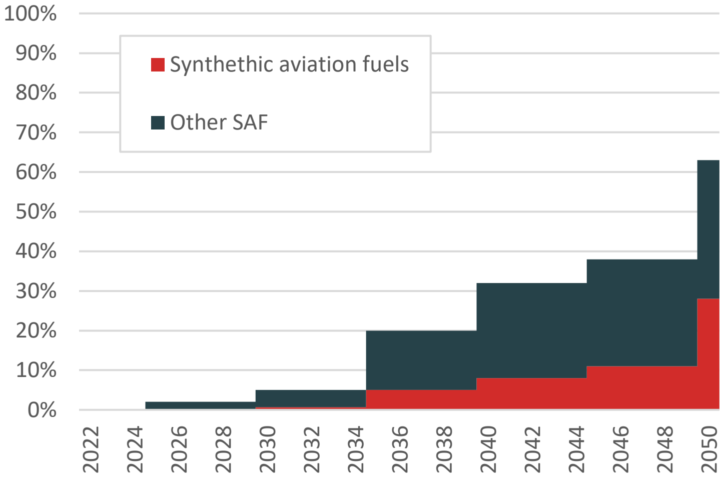
2.1.2 ETD

The proposal to introduce a kerosene tax for intra-EU flights is part of the overall Energy Tax Directive (ETD) revision and aims at a final rate of € 10.75 per Gigajoule in 2033. This is reached by gradually increasing the tax over a 10-year period from 2023 (a rate of zero) to 2033 (full rate). The coverage of the tax is similar to EU-ETS and only applies to domestic and intra-EU flights. Cargo-only flights are exempted and also sustainable aviation fuel do not face any minimum EU taxes during that 10-year period. In this study, the ETD has been modelled to remain 0 for advanced SAF (bio-fuels produced from feedstock listed in Part A of Annex IX of the recast Renewal Energy Directive or synthetic fuels), whereas a 50% rate is modelled for 'regular' SAF (i.e., bio-fuels produced from Part B feedstock)[7].

2.1.3 ReFuelEU Aviation

The proposal for an EU sustainable aviation fuel (SAF) blending mandate is part of the ReFuelEU initiative. It aims at increasing the share of SAF, which bring up to 85 percent less CO_2 emissions than regular kerosene, being used in aviation (currently less than 0.1 percent). The EU blending mandate is increased from 2 percent in 2025 to 5 percent in 2030, 20 percent in 2035 and eventually up to 63 percent in 2050 as shown in Figure 2.2. Part of the SAF mandate is an obligation to mix in synthetic aviation fuels (so called e-fuels) and also, there is a maximum to the share of biofuels being used. Advanced SAF (including synthetic fuel) does not face the EU kerosene tax up to 2033. Contrary to the EU-ETS and the ETD, the SAF mandate also covers all flights departing from EU airports, including those flying to a non-EU airport.

Figure 2.2 SAF mandate per year



Source: SEO & NLR (2022)

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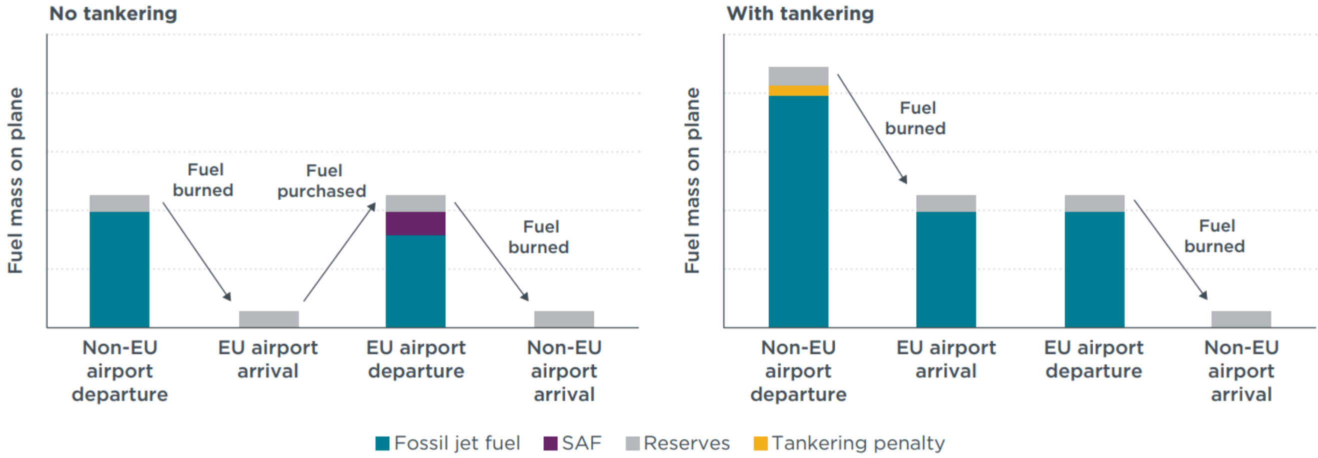
[7] In the proposal EC (2021b, July), article 2, paragraph 4 defines "biofuels" and "advanced biofuels" per Directive (EU) 2018/2001, the recast Renewable Energy Directive. This (article 2, paragraphs 33 and 34) defines biofuels and "liquid fuels for transport produced from biomass" and advanced biofuels as "biofuels that are produced from the feedstock listed in Part A of Annex IX". A later sentence in article 2, paragraph 4, of the ETD proposal ("Biofuels, biogas and bioliquids produced from the feedstock listed in part B of Annex IX to that Directive shall be considered equivalent to advanced products."), is contradictory. For Part B-derived bio-SAF, the assumptions used in the modelling lead to a more pronounced effect (larger shift in demand and associated carbon leakage), as they assign a higher taxation rate (5.38€/GJ) than would be applicable to Part A-derived bio-SAF or synthetic SAF (0.15€/GJ). For Part A-derived bio-SAF and synthetic SAF, the current modelling (using a rate of 0 rather than 0.15€/GJ) yields a slight underestimation of effects. Taken together, the current modelling is conservative.

2.2 Fit for 55 overview

Table 2.1 below shows an overview of the proposed rules per year and the applicability per region and the type of flight for each of the four Fit for 55 policies. The EU-ETS scheme applies to domestic flights in the EEA and the EU's OMR as well as to intra-EEA flights and flights departing to the UK or Switzerland. Flights departing from the UK or Switzerland are subject to a local ETS scheme for the respective countries. CORSIA applies to international flights between applicable countries, which are non-exempt from participation from 2027 onwards. The maximum kerosene tax rate is reached in 2033 where it equals € 10.75 per Gigajoule and since it is increased linearly over a 10-year period. This implies a cost of € 7.53 per Gigajoule in 2030. We assume here that non-advanced SAF face no kerosene tax up to 2033, after which a € 5.38 per Gigajoule tax rate is implemented. Advanced SAF face no kerosene tax. The tax only applies to domestic flights in the EU and intra-EU flights. In contrast to the kerosene tax, the mandate also applies to flights departing from an EU airport and destined for any non-EU country, but not to a second leg of that intercontinental flight. Moreover, the mandate does not apply for flights arriving from non-EU countries.

Box 2.1 Fuel tankering and ReFuelEU's refuelling obligation

One risk of a policy that puts an additional monetary burden on fuel is 'fuel tankering'. This is the practice of carrying excessive volumes of fuels or changing the refuelling strategies in order to avoid using these costs. Examples of such costs may be the SAF mandate or the kerosene tax depending on the exact scope and applicability. Figure 2.3 illustrates how it works. With fuel tankering, the airlines avoid having to refuel with the more expensive SAF (in purple) at the EU transfer hub and instead increase the fuel uptake on the plane at the initial departure at a non-EU hub. This leads to a higher amount of fuel burned (in yellow) and thus higher emissions, a form of carbon leakage. At the EU transfer, the airplane does not have to refuel anymore and continues its flight using the remaining fuel mass on the plane. Tankering practices are limited by the maximum amount a tank can carry and by the additional costs of burning the additional fuel used.



Source: ICCT (2021, Figure 1)

To combat such practices, the EC (2021a, Article 5) has initiated an additional refuelling obligation for aircraft operators. This entails that the annual quantity of aviation fuel uplifted by a given airline at a given EU airport must be at least 90 percent of the annual aviation fuel required. This therefore vastly limits the fuel tankering potential ensuring that a substantial amount of SAF is taken up even for flights transferring in the EU. In our modelling we assume that no fuel tankering takes place.

Table 2.1 Fit for 55 components split out over different years, regions and flights

	Ruling per year			Applicability to region or flights					
Policy	2030	2035	2050	Domestic (EU)	Domestic (non-EU)	Intra-EU	EU → non-EU	non-EU → EU	non-EU ↔ non-EU (intl.)
EU-ETS [a]	From 2027, free allowances phased out			*EEA & OMR* yes	no	*EEA* yes	*Only to UK & CH*	no	no
CORSIA [a]	From 2027, mandatory for non-exempt countries			no	no	no	*For applicable countries* yes	yes	yes
ETD [b]	*Fossil kerosene*			yes	no	yes	no	no	no
	€ 7.53/GJ	From 2033, € 10.75/GJ							
	Non-advanced SAF (Part B)								
	0	From 2033, € 5.38/GJ							
	Advanced SAF (Part A + synthetic)								
	0	0							
ReFuelEU [c]	*Min. SAF*			yes	no	yes	yes	no	no
	5%	20%	63%						
	Min. synthetic fuels								
	0.7%	5%	28%						
	Max. Part A + Part B biofuels								
	4.3%	15%	35%						

Source: SEO & NLR (2022)

[a]: All EU countries and Norway, Iceland and Lichtenstein (together the EEA) should be seen as 'EU' countries in the rows for the EU-ETS and CORSIA schemes. The UK uses the similarly organized UK-ETS and Switzerland (CH) uses the CH-ETS, which is linked to the EU scheme. Only flights from the EEA to the UK or Switzerland are subject to the EU-ETS scheme (DEHSt, 2021). Flights from Switzerland to the EEA are subject to CH-ETS, whilst flights from the UK to the EEA are subject to the UK-ETS (FOEN, 2020; BEIS, 2020). Flights to and from the outermost regions (OMR) of EU member states are exempt except for domestic flights within these regions (Nea, n.d.).

[b]: EC (2021b, Annex I, Table A). See footnote 7. Cargo-only flights are exempted from the kerosene tax (EC, 2021b, p. 41). A linear phase-in between 2023 (rate of zero) and 2032 (full rate), so the 2030 value is 70 percent of the final rate. Non-advanced SAF faces a "minimum rate of zero […] over that transitional period of ten years" (EC, 2021b, p. 40). It is still unclear if and to what extent other European countries will also adopt a kerosene tax.

[c]: EC (2021a, Annex I). A SAF blending mandate is considered in various non-EU countries, such as the UK, but the details are uncertain.

3. Model and assumptions

The NetCost passenger choice model allows us to study the cost and demand impact broken down by each Fit for 55 measure. By applying a set of assumptions, such as the cost pass-through rate and forecasts of carbon and SAF price developments, we are able to assess the effectivity of the Fit for 55 proposal. This includes competitiveness, CO_2 savings, carbon leakages, and the efficiency of the measures in terms of CO_2 savings.

3.1 The NetCost passenger choice model

To forecast the changes in volumes, network composition and competitiveness, we use the highly detailed market model called the NetCost passenger choice model. This model was also used in the recent study *'Destination 2050: A Route To Net Zero European Aviation'* by NLR and SEO (2021). In this way, we are able to generate the expected fares for a set of typical routes, including a breakdown highlighting the contribution of each Fit for 55 measure on ticket prices. Application of the NetCost model allows us to highlight the implications of implementing the Fit for 55 plans in the aviation industry and compare those with the stated goals of European and national level policies of a competitive aviation sector. Box 3.1 details the workings of the NetCost passenger choice model. Appendix A provides more detailed technical details of the model.

Box 3.1 The NetCost passenger choice model

SEO's NetCost model is a detailed passenger choice model that can be applied to estimate the impact of cost increases for passengers, thus impacting passenger demand and the number of aircraft movements in 2030, 2035 and 2050. The NetCost model determines the total generalised travel costs for each travel alternative, including the cost of the air fare and travel time. Higher costs, that are passed-through to consumers, increase the cost of air travel and therefore reduce demand, and in turn lead to a reduction in the number of flights and therefore connectivity. The NetCost model estimates the impact of such cost increases on an airport level.

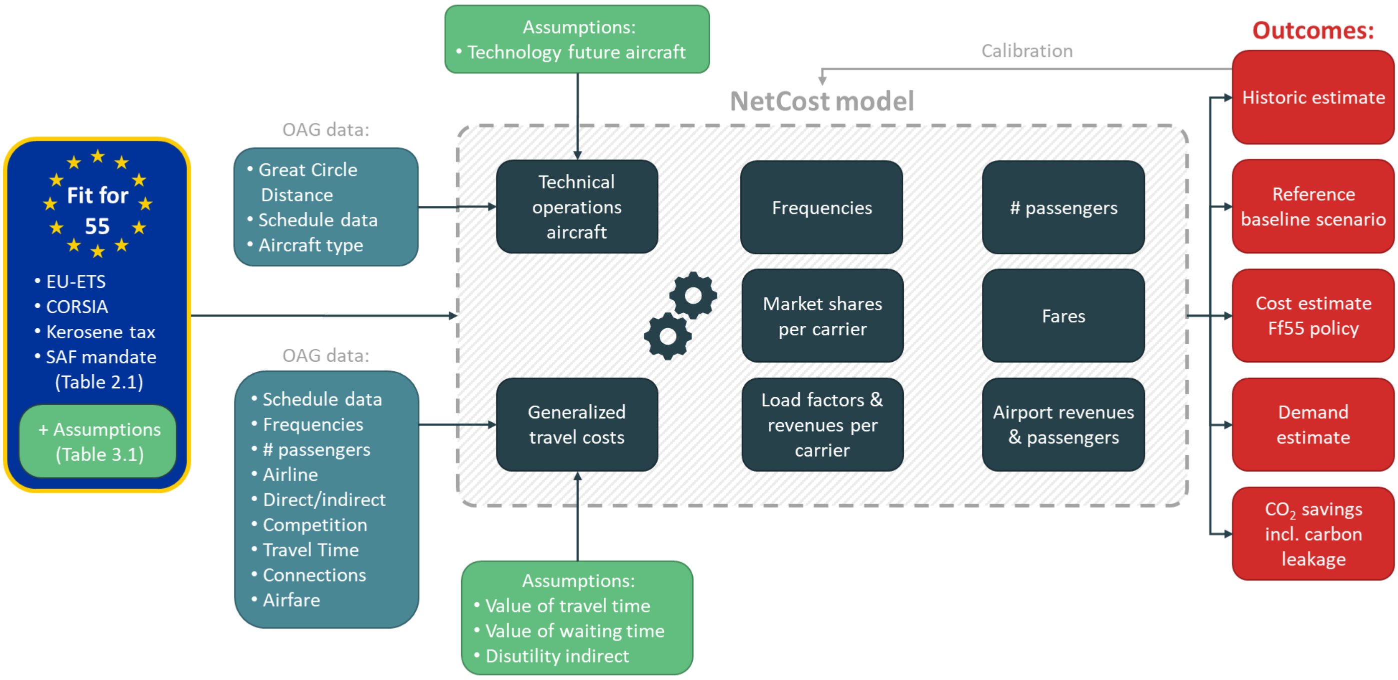
The model distinguishes between direct and indirect flights, as cost increases may differ between direct and indirect flights serving the same market. The model estimates the distribution of passengers over different route options, including indirect route options via individual (European or non-European) hubs. As European policy measures do not apply to non-European hubs, the model can identify a shift of traffic from European hubs to non-European hubs. As such, the model is well applicable to identify potential carbon leakage impacts. In the Destination 2050 study the NetCost passenger choice model has been used to assess the impacts of higher fuel prices and costs of economic measures on demand and supply. The NetCost model has been used in many different studies for IATA, ACI EUROPE, the Civil Aviation Authority of Singapore (CAAS) and the Dutch government. In addition, it has been used in several scientific publications.

The NetCost passenger choice model provides several monetary, passenger volume and environmental outcomes. These include the following:

- Fit for 55 cost, broken down by individual elements, flight and route level;
- Impacts on ticket prices under different assumptions on cost pass-through rates;
- Impacts on passenger demand;
- Impacts on competitiveness of EU hubs versus non-EU hubs;
- Impacts on CO_2 savings; and
- Efficiency of the measures (that is, CO_2 savings per € invested).

Figure 3.1 shows an overview of the workings of the NetCost model. Inputs include the components of the Fit for 55 proposal including several assumptions (as detailed in Section 3.2), airline schedule data from Official Airlines Guide (OAG), and additional assumptions on, for example, future aircraft technology and the value of travel and waiting time. Within the model, the technical aircraft operations and the generalized travel costs are calculated based on all inputs. The model is calibrated based on historical passenger booking data.

Figure 3.1 The NetCost model



Source: SEO (2022)

Application of the model

The legislative proposals included in the Fit for 55 package will increase the costs (see section 3.2) faced by airlines operating flights within and departing from Europe. In case of the kerosene taxation (ETD), this is a direct cost increase. In case of the SAF mandate (ReFuelEU) and strengthened market-based measures (EU-ETS and its interaction with CORSIA), this happens indirectly, as SAF is more expensive than fossil kerosene and CO_2 costs will rise. Modelling these cost increases, which depend on flights characteristics, is the first step of our approach.

Airlines are likely to (partially) pass-through cost increases to passengers, by increasing ticket prices. This study assumes that all costs are passed-through (see section 3.2.1), implying that ticket prices increases are equal to the cost increases due to the combined Fit for 55 measures.

The impacts on demand and emissions are estimated by comparing a scenario with the Fit for 55 measures to a reference scenario without these measures in the same year. For a fair estimation of the impacts, both scenarios are identical in assumptions besides the application of the Fit for 55 measures.

As a consequence of increased ticket prices, some travellers might choose not to travel at all, switch to another transportation mode or use an alternative flight option, which might be cheaper because it is not subject to the Fit for 55 package or similar proposals. This causes a reduction in demand for air travel from and via European airports, compared to the reference scenario. The extent to which demand is reduced, depends on demand elasticities and the level of competition.

The impacts on CO_2 emissions and carbon leakage are assessed by comparting the total CO_2 emissions in the scenario with the Fit for 55 measures to the reference scenario. Carbon leakage may occur as cost impacts differ over various hub and route alternatives, which depend on the model assumptions.

For all elements, the 2030 and 2035 outcomes are detailed in the results sections in chapter 4 and a cost outlook for 2050 is presented separately in chapter 5.

3.2 Model assumptions

In order to study the impact of the Fit for 55 package using the NetCost model, we need to make a number of assumptions on the rate of pass-through, carbon price developments, and SAF price developments.

3.2.1 Pass-through

The first assumption is that additional costs that airlines face are passed on to consumers at a 100 percent rate. This assumption gives the upper bound in terms of fare cost and demand impact. Whilst acknowledging that a 100 percent pass-through rate could overestimate the demand impacts, there are multiple reasons to maintain this assumption: A 100 percent pass-through rate helps to assess the potential maximum impact if the full cost increase comes at the expense of the consumer. Cost absorption of airlines may have other effects on airline's ability to invest and could as a result impact airline networks and connectivity. These dynamics cannot be captured in our model, for which lower pass-through rates only presents the demand-side part of the impacts. Moreover, the extent to which airlines can absorb the costs is potentially limited, given the relatively low industry profit margins (EC, 2021c). Each airline will make their own business decisions, and airlines can also cross-subsidise cost absorption on one (highly competitive) route by increasing fares on routes with less competition.

As a sensitivity check, we also analyse the impact of the Fit for 55 regulation using a cost pass-through rate of 50 percent (see Appendix C). An EC study on cost pass-through found that pass-through rates may vary between 45 and 95 percent, depending on the level of competition and the level of congestion at the airport (EC 2020). Moreover, pass-through rates tend to be higher for short and medium distance flights than for long haul flights. Based on this study, the 50 percent pass-through rate in the sensitivity analysis could be considered as a lower bound, see also Footnote 4.

3.2.2 Cost assumptions

Table 3.1 gives an overview of the additional model assumptions being used per Fit for 55 component per year. To see the exact ruling per year and the applicability per region or flight, please, see Table 2.1.[8]

EU-ETS price developments are based on recent forecasts. Morgan Stanley (2022) estimates EU-ETS prices of € 130 per ton by 2030. This is in line with other recent forecasts by BofA (2021) of € 100 per ton by 2025) and Pietzcker et al. (2021) at €129 per ton. For the forecast until 2050 we align with the estimates as used in Destination 2050 (NLR & SEO, 2021). Hence, it is assumed that the price per EU-ETS allowance increases from € 130 per ton of CO_2 in 2030 to € 175 in 2035 and € 315 in 2050. Flights to and from the EEA, the UK and Switzerland are assumed to be part of the EU-ETS scheme.[9] Since CORSIA carbon credits are not limited, the prices per ton of CO_2 are expected to increase more rapidly for ETS allowances, which is capped and gradually more limited in volume. This results in CORSIA carbon credits expected to be only € 20 per ton of CO_2 in 2030. Afterwards, it increases to € 55 in 2035 and € 160 per ton of CO_2 in 2050. We assume that flights covered by EU-ETS, such as intra-EEA flights, are not subject to additional CORSIA regulations.

The final kerosene tax of € 10.75 per Gigajoule, reached in 2033, equals € 462.25 per ton of fossil kerosene fuel. Non-advanced SAF face a € 231.13 per ton of fuel tax rate from 2033 onwards. Advanced forms of sustainable aviation fuel, such as Part A feedstock and synthetic fuels, are exempt from the kerosene tax.

The price of SAF is expected to decrease over time due to the increased uptake. In 2030, synthetic SAF is expected to cost € 2,900 per ton of fuel which decreases to € 2,566 and € 1,557 in 2035 and 2050 respectively. Biofuels listed as part A decrease from € 2,765 in 2030 to € 1,790 in 2050. Meanwhile, the emission reductions which can be achieved by using SAF instead of fossil fuel kerosene are assumed to increase over time. For example, the emission reduction from using synthetic SAF increases from 85 percent in 2030 to 100 percent in 2050. For 2050, we assume that all biofuels used are Part A feedstock, which explains why we have no 2050 assumption detailed for Part B biofuels. The SAF prices and emissions reductions are from Destination 2050 (NLR & SEO 2021). Recent developments indicate that these assumptions are still realistic. Norway, Iceland and Liechtenstein (together with the EU the EEA) and also the UK and Switzerland are assumed to align with the SAF blending mandate as detailed in the Fit for 55 proposal.[10] Meanwhile, we also assume that there is no fuel tankering occurring due to the refuelling obligation.

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[8] It should be noted that other national measures to reduce CO_2 emissions (e.g. passenger taxes, higher national blending mandates) that are not stated in the assumptions have not been taken into account.

[9] This assumption is based on the similarities between the EU-ETS and the UK ETS (set up after Brexit) and the CH ETS (linked to the EU scheme).

[10] As for the UK, the UK's Department for Transport indicated that "[The UK Government] would like to introduce a SAF mandate that is world leading and as ambitious as possible." (UK Department for Transport 2021).

Table 3.1 Overview of the assumptions being used per Fit for 55 component per year

Policy	Component	Assumptions per year			Measure
		2030	2035	2050	
EU-ETS	Applicability	EU-ETS for complete EEA, UK & CH region			
	Allowance price	130 [a]	175 [b]	315 [c]	€/tCO2
CORSIA	Applicability	No CORSIA for flights covered by EU-ETS			
	Carbon credit price	20	55 [b]	160 [c]	€/tCO2
ETD [d]	Applicability	Only EU countries			
	Fossil kerosene tax	323.58	462.25	462.25	€/ton fuel
	Non-advanced SAF tax (Part B)	0	231.13	231.13	€/ton fuel
	Advanced SAF tax (Part A + synthetic)	0	0	0	€/ton fuel
ReFuelEU [e]	Applicability	EEA, UK & CH align with blending mandate			
	Refuelling obligation	No fuel tankering			
	Biofuel, Part A	2,765 [f]	2,521 [b]	1,790 [g]	€/ton fuel
	Biofuel, Part B	1,170 [f]	1,170 [b]	- [h]	€/ton fuel
	Synthetic	2,900 [f]	2,566 [b]	1,557 [g]	€/ton fuel
	Biofuel, Part A	65% [f]	70% [b]	95% [g]	emission reduction
	Biofuel, Part B	65% [f]	65% [b]	- [h]	emission reduction
	Synthetic	85% [f]	85% [b]	100% [g]	emission reduction

Source: SEO & NLR (2022), based on:

[a]: Predictions by Morgan Stanley (2022), BofA (2021), and Pietzcker et al. (2021)

[b]: Assumed/interpolated between 2030 and 2050

[c]: NLR & SEO (2021; Destination 2050, Table 43, p. 143)

[d]: EC (2021b, Annex I, Table A). See footnote 7. Cargo-only flights are exempted from the kerosene tax (EC, 2021b, p. 41). A linear phase-in between 2023 (rate of zero) and 2032 (full rate), so the 2030 value is 70 percent of the final rate. Non-advanced SAF faces a "minimum rate of zero […] over that transitional period of ten years" (EC, 2021b, p. 40). It is still unclear if and to what extent other European countries will also adopt a kerosene tax. The energy density for jet fuel, such as kerosene, is 43 MJ/kg.

[e]: SAF counts as 100 percent CO_2 neutral in EU-ETS, but not in CORSIA, see ICAO (2018; Chapter 3.3). Norway, Iceland and Lichtenstein (together with the EU the EEA) and also the UK and Switzerland are assumed to align with the Fit for 55 SAF blending mandate.

[f]: NLR & SEO (2021; Destination 2050, Table 30, p. 98). Due to the remaining uncertainty around sustainable aviation fuel prices, price forecasts are conservative. Appendix D provides more detail on the SAF price premium.

[g]: NLR & SEO (2021; Destination 2050, Table 32, p. 103)

[h]: For 2050, we assume that all biofuels used are listed as Part A feedstock

3.3 Hub and route selection

Based on the methodology outlined in this chapter, the next chapter presents the results in terms of costs, demand and CO_2 emissions. For each of the elements, we assess the results at three levels. Firstly, overall results are presented, broken down by intra-EEA and non-EEA flights.

Secondly, the impacts are shown for a selection of relevant EEA and non-EEA hub airports and at a route level. The selected includes four large EEA hubs: Amsterdam Schiphol (AMS), Paris Charles de Gaulle (CDG), Frankfurt (FRA), and Madrid Barajas (MAD); and seven non-EEA hubs: Moscow Sheremetyevo (SVO), Istanbul (IST), Dubai (DXB), Doha (DOH), Atlanta (ATL), Shanghai Pudong (PVG) and London Heathrow (LHR). This selection allows to show the implications for the largest European hubs, and the competitive impacts with respect to a selection of important competitor hubs outside the EEA in various world regions.

Thirdly, we present detailed results on ten specific flight routes., as detailed in Table 3.2 below. Six flights go from an EEA departure airport to a non-EEA airport in either Asia or Africa. The other three flights are ultra-long haul and fly from USA to two non-EEA airports. These flights are used to illustrate the potential impact of Fit for 55 on the competitiveness of EEA hub airports vis-à-vis non-EEA hubs. There is one direct intra-EEA route for comparison.

Table 3.2 Flight routes analysed

	Location A				Location B		
Flight	Airport	Country and region			Airport	Country and region	
1.	Amsterdam (AMS)	NL	EEA	↔	Budapest (BUD)	Hungary	EEA
2.	Nice (NCE)	France	EEA	↔	Seoul (ICN)	South Korea	non-EEA
3.	Copenhagen (CPH)	Denmark	EEA	↔	Johannesburg (JNB)	South Africa	non-EEA
4.	Madrid (MAD)	Spain	EEA	↔	Shanghai (PVG)	China	non-EEA
5.	Barcelona (BCN)	Spain	EEA	↔	Osaka (KIX)	Japan	non-EEA
6.	Frankfurt (FRA)	Germany	EEA	↔	Tokyo (HND)	Japan	non-EEA
7.	Hamburg (HAM)	Germany	EEA	↔	Bangkok (BKK)	Thailand	non-EEA
8.	Atlanta (ATL)	USA	non-EEA	↔	Mumbai (BOM)	India	non-EEA
9.	Atlanta (ATL)	USA	non-EEA	↔	Hong Kong (HKG)	Hong Kong	non-EEA
10.	New York (JFK)	USA	non-EEA	↔	Johannesburg (JNB)	South Africa	non-EEA

Source: SEO & NLR (2022)

4. Impact of Fit for 55

The Fit for 55 package increases costs for EEA aviation and – as these costs are passed on to passengers – inflates ticket prices, which results in a demand drop for European aviation. While the net CO_2 emissions are reduced due to the policy proposals, flights from or connecting through EEA hubs become more expensive, which reduces competitiveness for EEA hubs and causes carbon leakage.

This section present the results of the costs of the Fit for 55 proposal, the associated demand implications on an EEA and non-EEA level, and the thereby resulting carbon savings and leakage potential. While the costs of Fit for 55 depend purely on the previously explained proposals, the demand impacts are dependent on airline pass through rates. Further, the sensitivity of the model with respect to the model components is briefly touched upon, reassuringly suggesting robustness of the results across various Fit for 55 cost assumptions. Examples that highlight the cost, demand and CO_2 effects on specific routes are presented along the general findings.

Routes and airports with higher associated costs lose travellers with respect to the baseline scenario (that is, without Fit for 55 regulations). For flights with destinations outside the EEA, a non-negligible share of passengers switches to routes via non-EU hubs, that incur lower costs. While passenger losses in EU hubs depend on current passenger volumes and route compositions, EU hubs that are located closer to the EU borders are more affected than centrally located airports. This results from the higher costs incurred on the relatively longer intra-EU connections where Fit for 55 costs apply. Meanwhile, centrally located EU hubs have shorter connecting legs and thus face lower costs.

Compared to a scenario without any Fit for 55 regulations, by 2035, EU hubs lose 3.8 percent of their traffic (-8.6 million passengers) on routes between Europe and the rest of the world, while non-EU hubs gain 2.2 percent of traffic (+1.4 million passengers), with some specific hubs close to the EU borders such as Istanbul and Moscow gaining up to 12 percent of traffic. Hence, market shares of airlines and aviation hubs in Europe decrease by 6 percentage points with respect to a scenario with no Fit for 55 regulations (10 million passengers).

4.1 Cost impact

The cost impact of the Fit for 55 regulations follow the policy assumptions detailed before (see Table 2.1 and Table 3.1). Some costs are specific to both direct or indirect travel within the EU. With regards to the UK, it is assumed that Fit for 55 regulations apply as if it were an EEA country, except for the ETD (kerosene tax).

4.1.1 Cost impact per passenger kilometre

Table 4.1 below details the average ticket price increase for 2030, 2035 and 2050 divided over the Fit for 55 policies, compared to the baseline scenario with no Fit for 55 regulations. We find that in 2030 the EU-ETS allowances and the ETD revision impose the higher cost burden for intra-EEA flights with 0.8 and 0.53 additional eurocents per passenger kilometre ('per pax km'). Even though these regulations do not apply for flights from the EEA to non-EEA airports, the ticket prices increase on average by 0.08 eurocents per pax km due to the ETS allowances and 0.06 cents due to the ETD kerosene tax. These cost increases are driven by indirect flights for which the first flight leg is an intra-EEA flights. The ReFuelEU SAF mandate increases prices per pax km by 0.18 eurocents for intra-EEA flights and 0.10 eurocents for flights going between EEA and non-EEA airports. The lower costs for non-EEA flights result from the fact that the SAF mandate only applies for the outbound flight, but not for the inbound flight, while the cost increases are estimated for the average return flight. In 2035, all cost components increase compared to 2030. For intra-EEA flights, the EU-ETS is the most important additional cost factor with 0.87 eurocents per pax km, whilst ReFuelEU is the most important for flights between EEA and non-EEA airports with 0.34 eurocents per pax km in 2035. The CORSIA price increase is still limited with an average increase of 0.05 eurocents per pax km. Indirect travel from the EEA to a non-EEA country via an EEA hub, face intra-EEA price for the first leg of the travel.

In 2050, the average price increase due to EU-ETS and the revised ETD are 0.16 and 0.28 eurocents respectively for flights within the EEA. For flights between EEA and non-EEA countries, these price increases have dropped to 0.02 and 0.03 eurocents per passengers kilometre, respectively. The ticket price increase due ReFuelEU has meanwhile increased to 1.27 and 0.52 eurocents per pax km for intra-EEA flights and flights between EEA and non-EEA airports, respectively. The decrease in EU-ETS and ETD costs follow from a higher level of in-sector CO_2 emissions reduction in 2050, as a result of the increased uptake of SAF as well as technological and operational improvements.

Table 4.1 Overview of average price increases from Fit for 55 in eurocents per passenger kilometre

	Price increase (eurocents per passenger km for return flights)					
	2030		2035		2050	
	Domestic or intra-EEA	EEA ↔ non-EEA	Domestic or intra-EEA	EEA ↔ non-EEA	Domestic or intra-EEA	EEA ↔ non-EEA
EU-ETS	0.80	0.08	0.87	0.09	0.16	0.02
CORSIA	0	0.00	0	0.05	0	0.23
ETD	0.53	0.06	0.62	0.07	0.28	0.03
ReFuelEU	0.18	0.10	0.60	0.34	1.27	0.52
Total	**1.51**	**0.24**	**2.09**	**0.55**	**1.71**	**0.80**

Source: SEO & NLR (2022)

4.1.2 Ticket price impact per country

Based on the NetCost model, Figure 4.1 details the average ticket price increase for flights from EEA countries internally and to non-EEA countries. In 2030, we find that for intra-EEA flights, prices increase the least for Norway with on average € 29 per ticket and the most for Cyprus with € 61 per ticket. [11] One striking result is that in particular peripheral countries – such as Cyprus, Iceland and Estonia – are impacted the most. This is largely driven by the relatively long flight distance – and therefore higher fuel usage – within the EEA. For direct flights between EEA and non-EEA destinations, price increases are determined by the SAF mandate which covers the one leg departing from an EEA airport to a non-EEA destination. The lowest increase is observed for Cyprus, with approximately € 2 and the most for the Portugal with almost € 12 per ticket. This is largely driven by the average flight distance from these countries, which determines the required amount of SAF based on the ReFuelEU proposal. Indirect flights leaving the EEA have cost somewhere in between the aforementioned. All costs are higher in 2035 due to the assumptions in Table 3.1.

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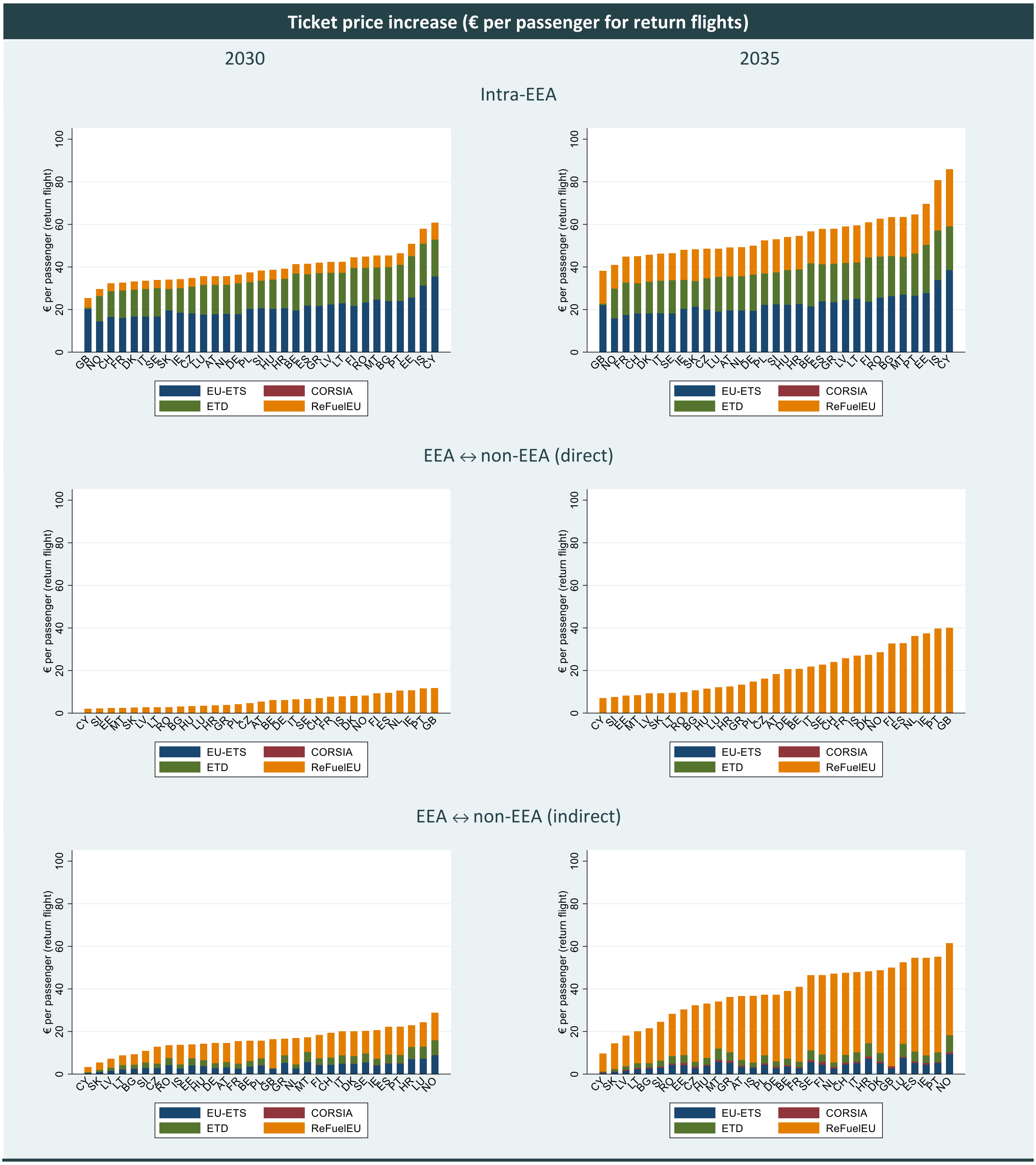
[11] Although not part of the EEA, the figure also includes data for the United Kingdom. The ticket price increase from the UK is lower than from the EEA countries because the kerosene tax does not apply in the UK. In this study, it is assumed that the UK does fully align with the other regulations proposed under Fit for 55.

Figure 4.1 Expected ticket price increase per passenger per European country



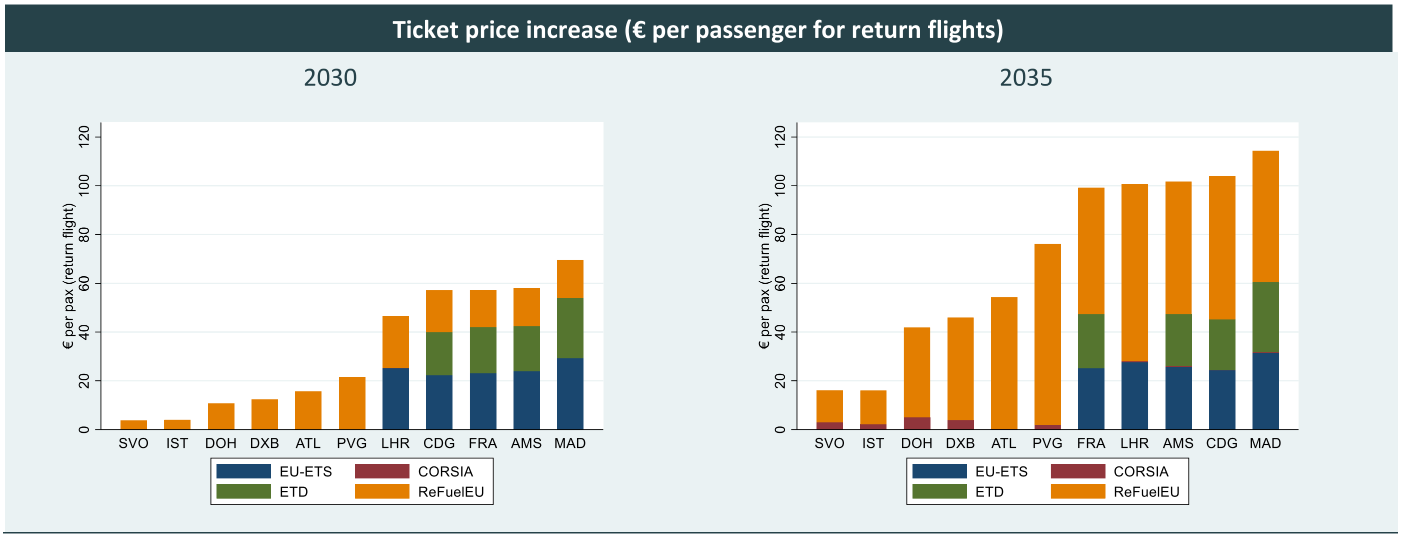
Source: SEO & NLR (2022)

4.1.3 Ticket price impact per airport

The average cost impact of Fit for 55 policies on ticket price per country varies according to the flight composition per airport. Airports that have a higher share of shorter flights and flights leaving the EEA, will incur lower cost from Fit for 55 than airports with longer distance flights. For intra-EEA flights, we find that the average price increase is not uniformly distributed between airports. For 2030, some incur an average increase of below € 5 whilst others incur an increase of around € 40. The outliers which face up to € 60 or even € 70 ticket price increases are islands in the EU, such as the Canary Islands. For flights to and from non-EEA countries, average price increases are lower, but still significant and again not uniformly distributed. For these flights, the SAF mandate constitutes a larger share in the total ticket price increase. The additional ticket charges due to CORSIA are nil in this case.

Figure 4.2 details the average price increase on flights via selected EEA and non-EEA hubs.[12] Averages are indicative of price increases of average flight distances and OD flight mix. For all airports, ticket prices in 2030 and 2035 increase. The price increase is largest for Madrid (MAD) with more than € 65 in 2030 and more than € 114 in 2035. Spain is an example of a country, which is peripheral and therefore faces higher cost increases due to the larger amount of kilometres flown within the EEA. From the selection of hubs, flights passing through Moscow's' Sheremetyevo International Airport (SVO) are impacted the least with less than € 4 per ticket in 2030 and € 16 in 2035. Even though London (LHR) faces no kerosene tax, its prices increase by more than € 46 for an average flight. The range of cost increases per flight is large, e.g., from a minimum of € 13 and a maximum of € 175 for a hub such as Frankfurt. In 2035, costs are higher for all airports. Cost for EEA hubs increase by about € 100 per return flight where non-EEA hub alternatives see price increases between € 16 and € 76. Further away hubs such as Atlanta (ATL) and Shanghai (PVG) have larger associated cost due to the ReFuelEU mandate.

Figure 4.2 Ticket price increase per passenger by selected EEA and non-EEA hubs



Source: SEO & NLR (2022)

4.1.4 Ticket price increase for Hamburg – Bangkok

Ticket prices on specific routes can help clarify the respective cost increases. Figure 4.3 below details the ticket price increase per transfer hub for all indirect flights between Hamburg and Bangkok. We find that EEA hubs as well as

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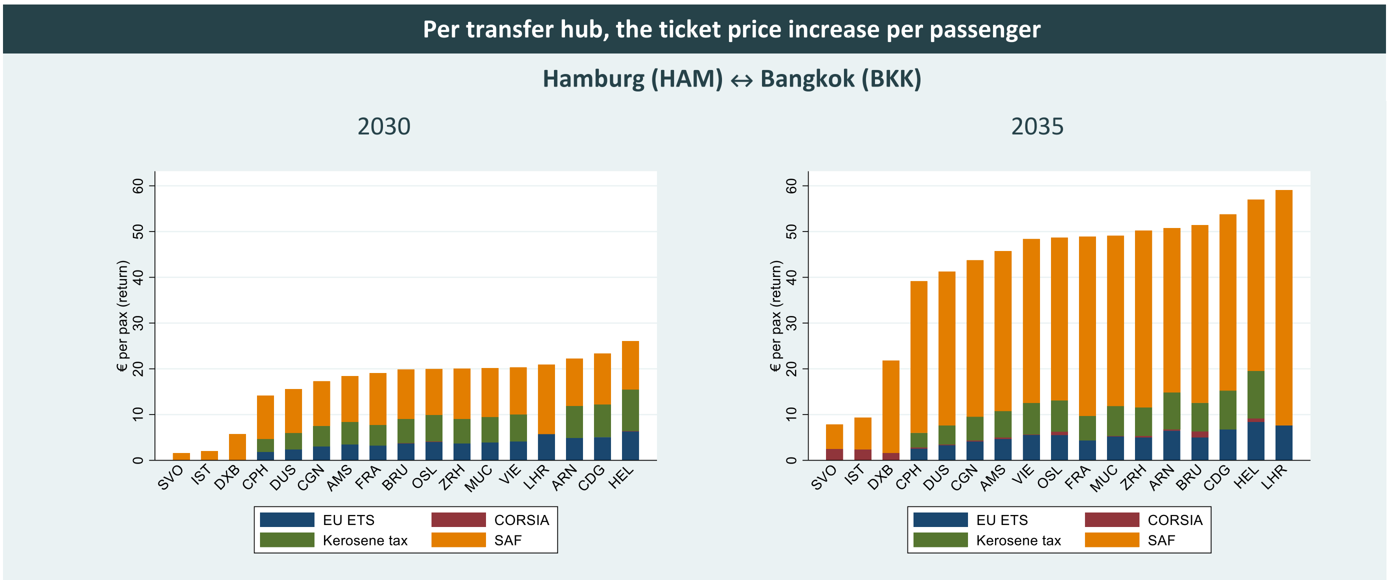
[12] This is the average cost increase of flights from a European airport, transferring at the selected hubs, to a destination within or outside the EEA.

London (LHR) have much higher prices increases compared to hubs such as Moscow (SVO), Istanbul (IST) or Doha (DXB). For EEA airports, prices increase with € 40 to € 59 per return ticket in 2030, while increasing by less than € 12 per ticket for the non-EEA alternatives. In 2035, the price difference increases further, as ticket price increases accrue to € 78 to € 120 for flights via EEA hub airports, mainly as a result of the higher SAF costs. At the non-EEA hub airports, Istanbul and Moscow Sheremetyevo in particular, price increases remain below € 19 per flight. The alternative via Dubai becomes more expensive, because ReFuelEU also applies to the flight between Hamburg and Dubai.

Figure 4.3 Ticket prices increases for the Hamburg – Bangkok route



Source: SEO & NLR (2022)

4.2 Demand impact

The Fit for 55 impact on passenger demand depends on the pass through by the airline. At the full 100 percent pass-through, on intra-EU routes, demand for aviation is reduced by 10 percent in 2030 (72 million passengers) in comparison with the reference case of a no Fit for 55 policies. On non-EEA routes passenger numbers decrease by 1.4 percent (2.8 million passengers). The lower relative reduction in passenger demand on non-EEA destinations is partly driven by the fact that passengers can reroute via non-EEA hubs, to mitigate some of the Fit for 55 compliance costs.

By the year 2035, the number of passengers on intra-EEA flights decreases by 14 percent compared to a scenario without any of the Fit for 55 measures (110 million passengers). On flights to non-EEA destinations the Fit for 55 measures lead to a total demand reduction of 3.8 percent (8.6 million passengers) (see Table 4.2).

It should be noted that these are overall demand impacts. Especially for non-EEA destinations, a shift in traffic from EEA hubs to non-EEA hubs is observed, resulting from the higher cost increases faced by EEA airlines.

Table 4.2 Overview of demand impacts

	Intra-EEA			EEA → non-EEA						
	2018	2030	2035	2018	2030			2035		
	Total	**Total**	**Total**	**Total**	EEA hubs or direct	non-EEA hubs	**Total**	EEA hubs or direct	non-EEA hubs	**Total**
Passenger demand [a)]										
Baseline traffic (x mln pax) (without FF55 measures)	578	702	792	152	141	53	194	167	63	230
Absolute change (x mln pax) (due to FF55 measures)		-72	-110		-3.8	1.0	-2.8	-10.0	1.4	-8.6
Relative change (%)		-10%	-14%		-2.7%	1.9%	-1.4%	-6.0%	2.2%	-3.8%

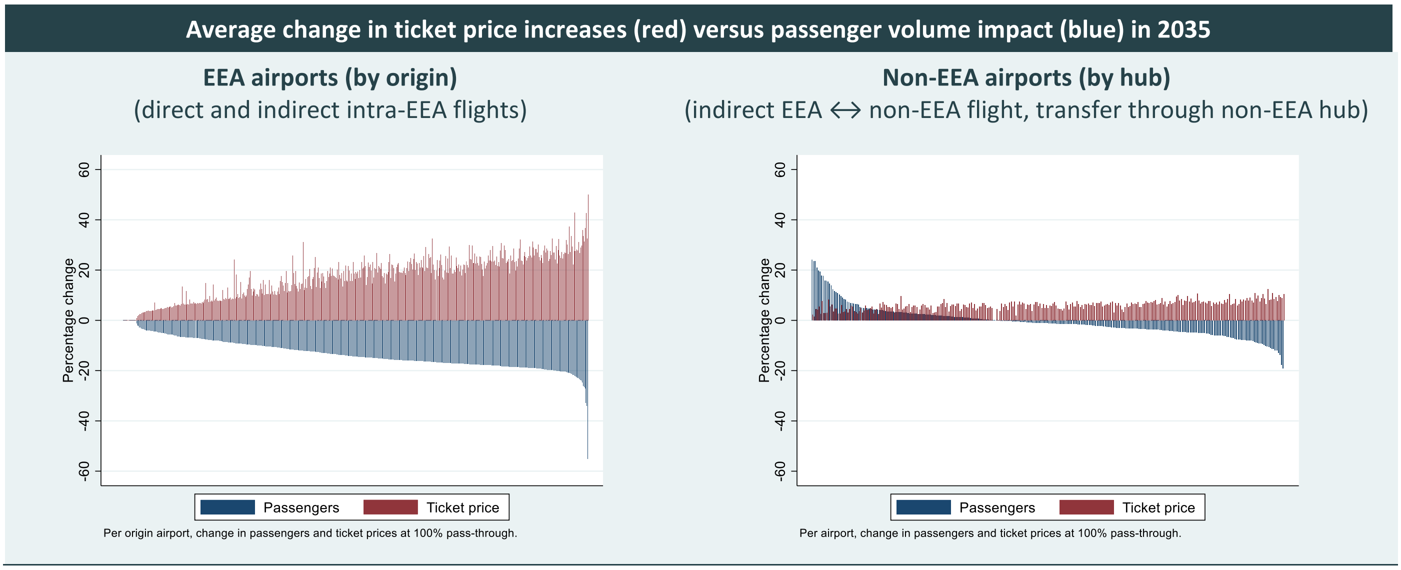
Notes: [a)]: Total number of departing Origin & Destination (O&D) passengers from EEA airports.
Source: SEO & NLR (2022)

4.2.1 Demand impact per airport

Figure 4.4 details the relationship between the ticket price increases and demand impact per airport. The graph on the left-hand side presents the cost and demand impacts for all intra-EEA flights by origin airport. In other words, for each origin airport there are two corresponding bars, one for the average change in ticket and another one for the prices average change in passengers, sorted in decreasing order over the latter. The figure shows that that ticket prices increase up to 50 percent, while passenger demand decreases varying from a few percentage points up to around 25 percent for most other EEA airports.

The figure on the right-hand side considers cost and demand impacts via non-EEA hubs. For these alternatives, costs still increase but to a much lesser extent than for EEA hubs (as seen in the previous section). Price increases vary between 1 and 15 percent at non-EEA hubs, while EEA hubs observe price increases up to over 20 percent. As the non-EEA hubs gain a competitive advantage over EEA hubs, passenger volumes through these hubs increase by up to 20 percent compared to the baseline scenario. On the other hand, there are also non-EEA hubs that lose traffic as a result of the Fit for 55 cost increases. The relationship between ticket cost increase and demand depends on the pass-through rate, which is here set to 100%. At lower pass through rates, costs are the same, but not fully passed on to consumers via ticket prices, and hence demand reactions are smaller, see Appendix C for 50% pass-through rates.

Figure 4.4 Relationship between the ticket price increase and the demand impact


Average change in ticket price increases (red) versus passenger volume impact (blue) in 2035

EEA airports (by origin)
(direct and indirect intra-EEA flights)

Non-EEA airports (by hub)
(indirect EEA ↔ non-EEA flight, transfer through non-EEA hub)

Per origin airport, change in passengers and ticket prices at 100% pass-through.

Per airport, change in passengers and ticket prices at 100% pass-through.

Source: SEO & NLR (2022)

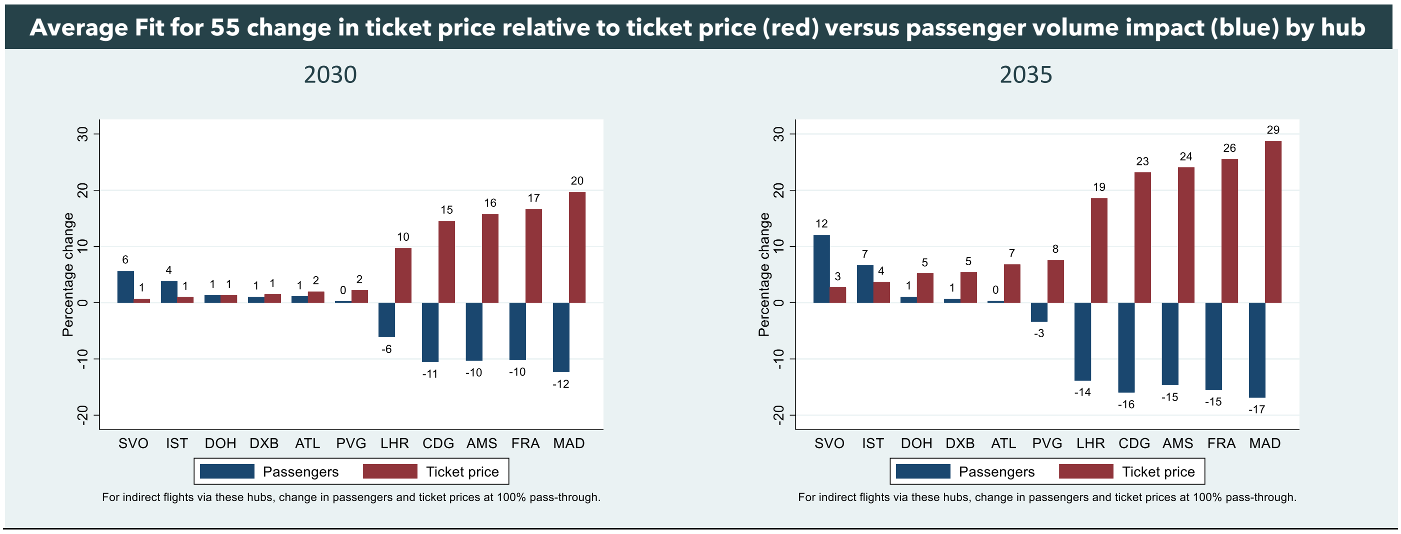
If we zoom in on selected EEA and non-EEA hubs, as detailed in Figure 4.5, we find that EEA airports lose significant passenger volumes in comparison to the reference scenario without a Fit for 55 policy. Meanwhile, non-EEA airports – such as Istanbul (IST) and Moscow (SVO) – win up to 12 percent in passenger demand while still facing some additional costs, as they gain a competitive advantage over EEA hubs.

For all indirect passengers travelling to a non-EEA destination, EEA hubs lose 13.6 percent of their traffic – roughly 6.9 million passengers in 2035. Meanwhile the traffic via non-EEA hubs increases by 2.2 percent. 1.4 million passengers "leak" from the EEA to non-EEA hubs.

A reduction of demand and a relative loss in competitiveness of EU airlines and hubs could jeopardize the further development of European air connectivity. Although the causal relationship can run both ways, various studies acknowledge that there is a link between air connectivity and economic growth (Zhang & Graham, 2020; Pot & Koster, 2022). Henceforth, the overall demand impacts could reduce aviation employment and GDP growth in the EU. Reduced growth of the aviation sector means that future employment growth that could occur in the EU aviation sector partially occurs outside the EU, and partially not at all. We can provide rough estimates of foregone employment impacts related to overall demand impacts based on multipliers from the literature. A meta-analysis of different publications (ATAG, 2020; SEO, 2017, 2018; InterVISTAS, 2015) suggest a relationship of 1 million air travellers with 600-1200 direct jobs, and 500-1000 additional indirect jobs associated the with air transport sector.

We find that we find that unrealized growth in the aviation sector could accrue to 119 million passengers by 2035, in comparison to no Fit for 55 policy. Using the multipliers above, this would sum to 130-260 thousand foregone jobs within the EU aviation sector, roughly the direct and indirect employment associated with two large international airports. It should be noted that potential employment reductions are not employment losses in the traditional sense, but indicates the foregone employment growth in the aviation sector. Moreover, these rough estimates indicate potential gross employment impacts: most people that cannot find employment in the aviation sector will be employed in other sectors – therefore net employment impacts will be substantially smaller. Wider economic ramifications of Fit for 55 on the labour market and GDP deserve more rigorous analysis and are as such not within the scope of this study.

Figure 4.5 Relationship between the average ticket price increase and the demand impact by selected hubs



Note: Changes in passengers weighted by passenger volume per route.
Source: SEO & NLR (2022).

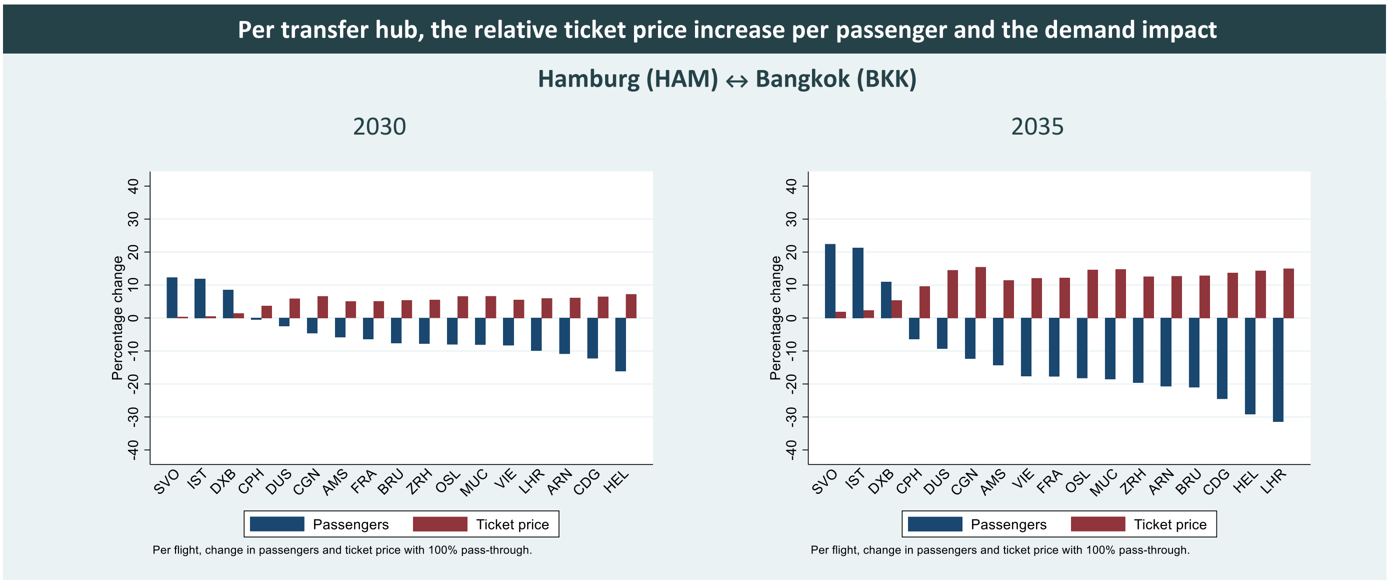
4.2.2 Demand impact for Hamburg – Bangkok

We determine the demand impact of Fit for 55 for a select group of intercontinental routes that have high degree of competition on the origin destination pair. Such routes serve the illustrative purpose of highlighting the extent and place of carbon leakage. We continue to show the results for Hamburg-Bangkok in Figure 4.6. Fact sheets in the Appendix B present the demand impacts on the other routes. Due to their similar properties, the overall qualitative conclusions are comparable and in line with the drivers of Fit for 55.

For the Hamburg-Bangkok example, we find that passenger demand via EEA hubs decreases as a result of the Fit for 55 cost increases. For example, by 2030, passenger numbers via Frankfurt decrease by 6 percent. Helsinki observes twice the reduction in passengers, around 13 percent. The respective reductions in passengers are related to the size of the cost increases, but not perfectly linear as a result of other factors such as frequency of flights and travel time differences. Routes through non-EEA hubs such as Moscow (SVO), Istanbul (IST) and Dubai (DXB) see their passenger numbers on this route increase by between 8 percent and 12 percent due to comparatively lower price increases from Fit for 55. By 2035, demand shifts become more exaggerated as a result of the higher cost increases: traffic via London Heathrow and Helsinki reduce by circa 30 percent, whereas traffic via Moscow Sheremetyevo and Istanbul increases by over 20 percent.

The size of absolute changes is dependent on the current demand of air travel through those hubs, with EEA hubs that have large demand having higher absolute losses. Hubs on the borders of the EU have larger relative cost increases from Fit for 55 and therefore higher demand losses than hubs closer to the core of the EEA. This is due to the higher fuel consumption within the EEA. For example, for flight going from Nice to Seoul, an airport like Helsinki loses the most in terms of passenger volume, whilst Rome, London or Munich are relatively less impacted (see Table B.2 in the Appendix). And when flying from Copenhagen to Johannesburg, passengers are a lot less likely to fly through Madrid, while Amsterdam and London lose fewer passengers.

Figure 4.6 Relative ticket price and demand impact for 2030 and 2035 for different intercontinental flights with a transfer hub


Per transfer hub, the relative ticket price increase per passenger and the demand impact

Hamburg (HAM) ↔ Bangkok (BKK)

Per flight, change in passengers and ticket price with 100% pass-through.

Per flight, change in passengers and ticket price with 100% pass-through.

Source: SEO & NLR (2022)

4.3 CO_2 impact and carbon leakage

As the Fit for 55 proposal aims at reducing aviation emissions, calculating the amount of CO_2 saved by implementing these measures is an important step. Due to the cost increases and associated shift in demand, there is however a potential for carbon leakage. The three possible forms of carbon leakage are: diverting to more distant airports, diverting to airports without a sustainability mandate, and fuel tankering.

First, passengers may divert to more distant (transfer) airports where they face less additional costs. Flying longer distances eventually leads to more fuel burned and thus higher emissions, all other factors being equal. The second example is also about diverting to airports without a sustainability mandate, but not necessarily further away. If a flight is not covered by EU-ETS or CORSIA, it means that there are more net emissions globally since they do not contribute to the EU's CO_2 cap nor are they offset using CORSIA credits. Similarly, if flights divert to any routes that are not subject to any SAF blending mandate, the flight itself will also cause higher CO_2 emissions. With regards to the kerosene tax, diverting to an airport without the kerosene tax does not lead to additional carbon leakage impacts, as the revenues are not earmarked for carbon capture or other CO_2 prevention goals. The potential for fuel tankering, the third potential source of carbon leakage, is limited by the anti-tankering provision in the ReFuelEU Aviation proposal. Potential impacts of tankering are not modelled in this study.[13]

4.3.1 Overall CO_2 impacts

The Fit for 55 proposals lead to CO_2 savings via reduced emissions from using SAF and from reducing demand for air travel. Together, we find that the policy leads to global net CO_2 emission savings in the aviation sector of 13.9

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[13] In addition to the three aforementioned sources of carbon leakage, substitution between destinations could also form a source of carbon leakage. Especially leisure passengers may choose to travel to a 'cheaper' destination outside of the EEA, where fewer regulations apply (e.g. travel to Turkey instead of Spain). Such carbon leakage is based on choices considering overall trip characteristics, and therefore outside the scope of this research.

million tCO$_2$ in 2030 and 38.3 million t CO$_2$ in 2035 (see Table 4.3).[14] By 2035, 19.3 million t CO$_2$ is reduced on intra-EEA flights, and the remaining 19.1 million tons on flights to non-EEA destinations. This implies a respective 27 and 16 percent decrease compared to the baseline. The relative savings are higher for intra-EEA flights as a result of a higher relative cost increase. On these flights, about half of the emissions savings is a result of demand decrease, whereas on intercontinental flights around 80 percent of the CO$_2$ reduction results from increased SAF use.

For all flights, by 2035, direct CO$_2$ savings from SAF accrue to 25.0 million t CO$_2$, and the remaining 13.3 million tons arise from demand-induced effects. Additional CO$_2$ savings from CORSIA offsets and EU-ETS credits are not considered in these figures, as they depend on the effectiveness in terms of CO$_2$ reduction of the measures on which the receipts are spent.

Table 4.3 Overview of total CO$_2$ impacts and carbon leakage

	Intra-EEA			EEA → non-EEA						
	2018	2030	2035	2018	2030			2035		
	Total	**Total**	**Total**	**Total**	EEA hubs or direct	non-EEA hubs	**Total**	EEA hubs or direct	non-EEA hubs	**Total**
CO$_2$ emissions a)										
Baseline emissions (x Mton)	60	64	71	93	62	39	101	71	46	118
Absolute change (x Mton)		-9.1	-19.3		-4.6	-0.2	-4.8	-15.7	-3.3	-19.1
Relative change (%)		-14%	-27%		-7.4%	-0.5%	-4.7%	-22%	-7%	-16%
Carbon leakage (x Mton) b)		0.0	0.1				0.7			1.1

Notes: a): Total estimated CO2 emissions of all departing O&D passengers from EEA airports. Baseline emissions are without Fit for 55 measures, but include reduced CO2 emissions as a result of technological and operational improvements, based on developments according to Destination 2050.
b): Sum of all additional emissions due to a shift of demand to non-EEA hubs.
Source: SEO & NLR (2022)

4.3.2 Carbon leakage

Figure 4.7 presents the distribution of total CO$_2$ emissions savings per route option along the full itinerary, i.e. origin-hub-destination, for flights to non-EEA destinations. The figure indicates that the Fit for 55 measures leads to net savings on the majority of routes. Intra-EEA emissions (which are not shown in the figure) have only positive CO$_2$ savings, i.e. no carbon leakage. But there are routes leaving the EEA where the CO$_2$ savings are negative. Carbon leakage occurs as due to the higher costs on particularly intra-EEA routes, a part of the traffic deviates to alternative non-EEA routes. Looking at the overall picture, considering all the routes, one can observe that despite the carbon leakage effect the Fit for 55 policy yields CO$_2$ savings on routes via non-EU hubs, mainly resulting from the SAF mandate on the first flight leg.

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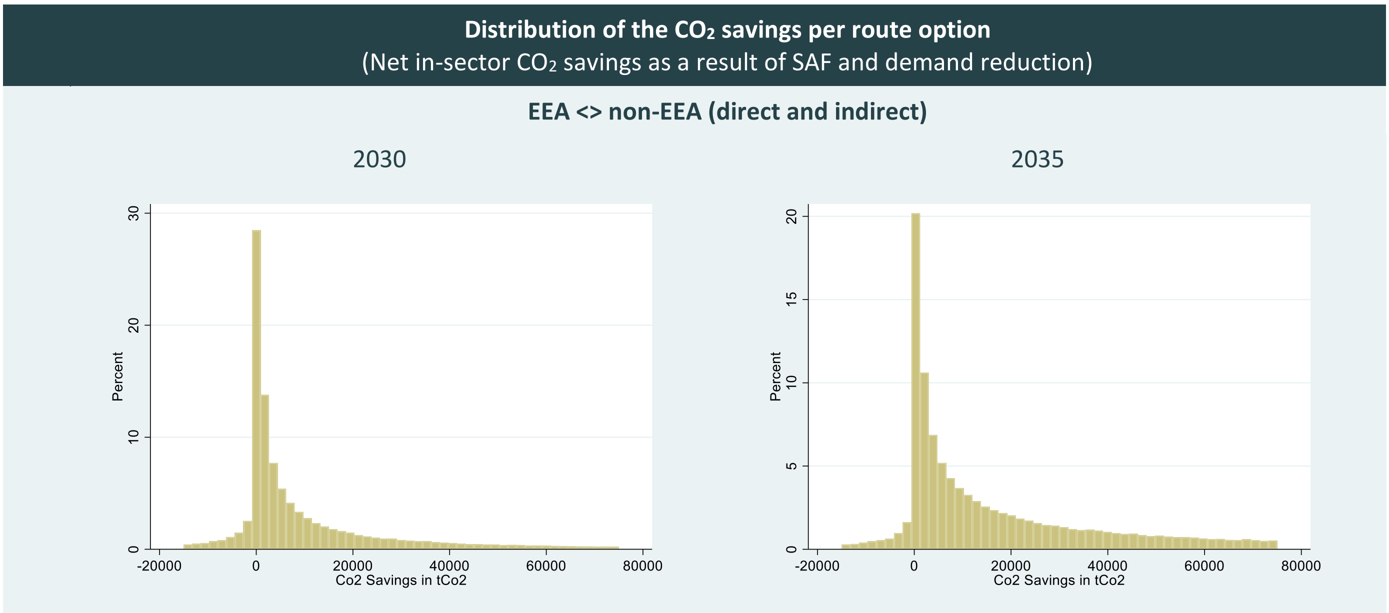
[14] These are the in-sector CO$_2$ savings on all OD-traffic departing from EU airports. It includes estimated global emissions on all flight legs, hence also emissions that are not officially counted as EU aviation emissions (e.g. the emissions of passengers travelling via Dubai, of which the second flight leg are non-EU emissions). Potential CO$_2$ savings associated with EU-ETS allowances or CORSIA offsets are not included here. In-sector CO$_2$ savings arise from increased SAF uptake and from reduced aviation demand.

Figure 4.7 Distribution of the CO2 savings per route option



Source: SEO & NLR (2022)

To further explain why CO_2 emissions increase on certain routes, whilst they decrease on others, we break down the CO_2 savings impacts by direct emissions reductions through the use of SAF, and the reductions as a result of demand implications. Figure 4.8 presents this breakdown for a selection of hubs. On some route options via the non-EU hubs a net decrease in CO_2 emissions is observed. The increased emissions due to the demand increase on these route alternatives – carbon leakage – in most cases do not outweigh the CO_2 savings arising from the same mandate that applies to the outbound flight from the EU airport to the non-EU hub. In 2035, when the SAF mandate is 20 percent, one can observe sizeable CO_2 savings from the SAF mandate, especially for flights via Doha and Dubai. As these hubs are relatively far away from the EU border, the SAF mandate applies for a relatively long flight. For Dubai, the total amount of CO_2 savings is particularly high because of the deployment of the less fuel-efficient Airbus A380 on a large number of routes.

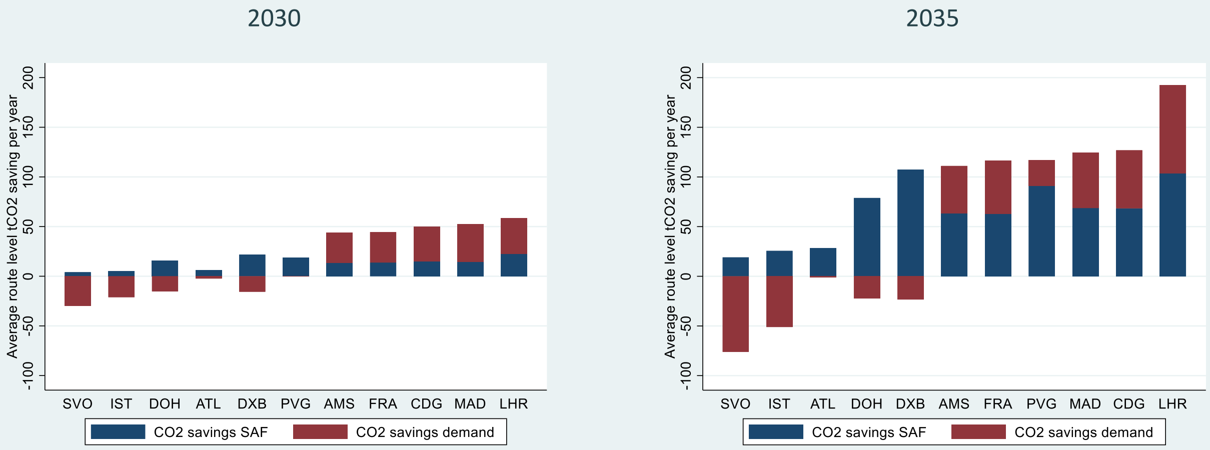
We can define the total amount of 'leaked' CO_2 as the sum of the net CO_2 increase over all the routes where emissions are higher than the reference scenario. This is the increase in emissions due to a demand increase on each route (red bars in the figure below), minus the (positive) CO_2 savings due to the SAF uptake on the first flight leg (blue bars). Applying this to all routes, we find that total carbon leakage adds up to 0.7 million tons of CO_2 in 2030 and 1.1 million tons in 2035 (see Table 4.3). This leakage occurs almost entirely on intercontinental routes. With respect to the total CO_2 savings on intercontinental routes (19.1 million tons), CO_2 leakage is around 6 percent of the total CO_2 savings in 2035. In 2030, CO_2 leakage is around 15 percent of the total CO_2 savings associated with Fit for 55. This share is higher because in 2030 the CO_2 reductions are for a larger share attributable to demand reduction, while the ReFuelEU mandate is lower. Such measures lead to relatively more carbon leakage.

Carbon leakage can be substantially higher on specific routes. The overall picture is different from the route-level examples as presented below and in the appendix, where carbon leakage can add up to 46% for flights originating from the EEA and exceed 100% for flights passing through the EEA (see Appendix B2 and B10). This follows from the fact that the highlighted routes are highly competitive long-haul routes, with a high risk of carbon leakage. On less contested markets, there is less risk of carbon leakage, while the amount of CO_2 emitted is still reduced as a result of the ReFuelEU SAF mandate.

Figure 4.8 Breakdown of CO_2 savings by SAF uptake and demand reduction, by hub

Breakdown of CO_2 savings by SAF uptake and demand reduction, by hub
(assuming 100 percent pass-through rate)

All routes on a selection of hubs



Source: SEO & NLR (2022)

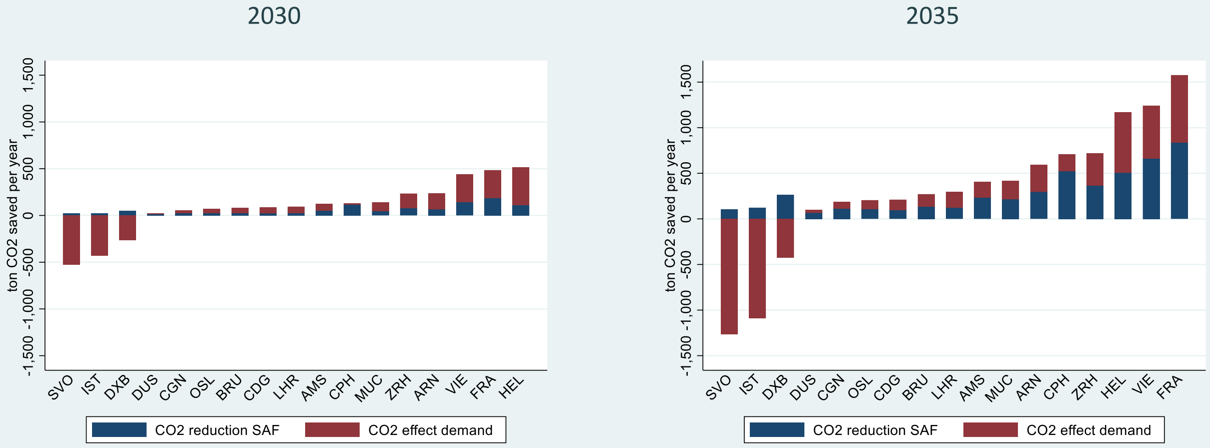
4.3.3 CO_2 impact and carbon leakage for Hamburg - Bangkok

In the case of Hamburg - Bangkok, we find that in sum for this route, the Fit for 55 policy leads to a CO_2 reduction of 8.6 kilotons per year via EU hubs, whilst carbon leakage leads to an increase of 2.2 kilotons of CO_2. In total, this yields an overall net CO_2 emissions decrease of 6.4 kilotons per year. This implies that carbon leakage is 34% of the overall net CO_2 savings – substantially higher than the average of 6%.

Figure 4.9 Ticket cost example for the Hamburg - Bangkok route with cost and CO_2 savings

Breakdown of CO_2 savings by SAF uptake and demand reduction, by hub

Hamburg (HAM) ↔ Bangkok (BKK)



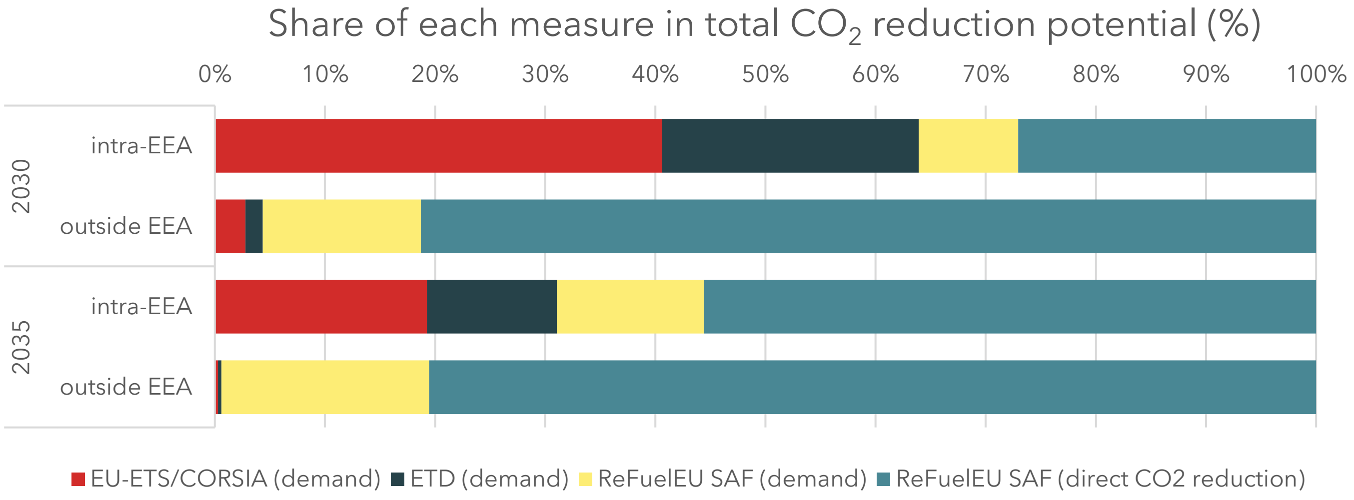
Source: SEO & NLR (2022)

4.3.4 Efficiency of CO_2 reduction measures

Fit for 55 measures can be compared by efficiency of CO_2 savings. This is not a straightforward comparison since the measures themselves contain various pathways towards CO_2 reduction, predominantly through increasing ticket prices as well as through direct CO_2 emission savings, most notably from the blending mandate with sustainable aviation fuels that directly remove CO_2 from the atmosphere. EU-ETS and the proposed kerosene tax have no a priori CO_2 reduction beyond the induced changes in demand due to higher ticket prices. With regards to CORSIA and EU-ETS, both mechanisms do contribute to a net reduction in CO_2 emissions due to offsetting, or buying credits to reduce emissions in other sectors. For both mechanisms the costs for reducing a ton CO_2 serves as input to our model (see also Table 3.1). For the kerosene tax this is different. Without revenues from this measure being directly earmarked for CO_2 prevention or capture, the further CO_2 reduction potential of the kerosene tax is non-existent. Therefore, is seems that Fit for 55 costs spent on the RefuelEU most directly contribute to CO_2 reduction, and a kerosene tax the least.

Figure 4.10 breaks the total CO_2 reduction potential of Fit for 55 down over the different measures, separating the demand induced effects of higher prices, and the direct in-sector reduction potential of SAF. Outside the EEA, the ReFuelEU measure accounts for the majority of CO_2 savings, as EU-ETS and the ETD apply only to intra-EEA flights. Within the EEA, all measures contribute to the total CO_2 reduction potential of Fit for 55. By 2035, the higher share of SAF blending increases the importance of SAF in comparison with the other measures.

Figure 4.10 CO_2 reduction potential of the different Fit for 55 measures



Source: SEO & NLR (2022)

The efficiency of measures for flights within and outside the EEA for the year 2030 and 2035 can also be compared in terms of carbon abatement costs (that is, the amount in euros required to save a ton of CO_2) for each measure (see Table 4.4). The Refuel Aviation (SAF) mandate has a combined demand and direct CO_2 reduction impact. By using SAF – without the demand impacts – the costs to mitigate 1 ton of CO_2 are € 586 in 2030 and € 483 in 2035. For flights outside the EEA the costs are lower – which is driven by the fact that the policy only applies to the outbound flight, but not for the inbound flight, while the costs are spread over two flight legs.[15] The additional demand

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[15] In our model, we estimate CO_2 savings on departing flights, aligning with UNFCCC's methodology on accounting emissions. However, we estimate the cost increase relative to a return flights – which means that the costs increase of the EU SAF mandate are distributed over the outbound and return flight.

effects of the higher costs of ReFuelEU lead to a further reduction in emissions, for which the total direct and demand-induced CO_2 abatement costs are lower.

This Table 4.4 shows the carbon abatement costs of the measures solely focusing on demand reduction are relatively high: between € 1016 and € 1873 depending on the year and route. This implies that measures only focused on reducing demand are relatively inefficient in comparison with measures that directly reduce CO_2. The 'abatement costs' of demand reducing measures do not differ across the measures, as the demand impacts of a euro cost increase are the same regardless of the measure. However, the carbon 'abatement costs' do differ over the markets and the years: for longer routes the CO_2 abatement costs of reducing demand are higher, as demand reduction for long-haul travel leads to more CO_2 saving.

For EU-ETS and ETD, the efficiency can be (much) higher based on the way revenues are used. Over the longer term, EU-ETS should function as a true 'carbon market' in which each euro spent can compensate the external effect of CO_2; that is, EU-ETS contributes to net zero emissions. In this case, the CO_2 abatement costs of these measures are lower, and depend on the efficiency of the measures for which the ETS/ETD revenues are used. For ETS and CORSIA the table also presents the assumed costs per ton of CO_2, that serve as an input to our model. Furthermore, all Fit for 55 costs directly related to emissions incentivize airlines to upgrade their fleets, potentially leading to additional in-sector CO_2 savings.

Table 4.4 Average CO_2 abatement costs (amount of euro needed to save a ton of CO_2)

	2030		2035	
	intra-EEA	**outside EEA**	**intra-EEA**	**outside EEA**
EU-ETS and CORSIA (demand) a)	€ 1,628 (EU-ETS: € 130)	€ 1,016 (CORSIA: € 20)	€ 1,873 (EU-ETS: € 175)	€ 1,134 (CORSIA: € 55)
ETD (demand)	€ 1,628	€ 1,016	€ 1,873	€ 1,134
ReFuelEU (demand)	€ 1,628	€ 1,016	€ 1,873	€ 1,134
ReFuelEU (direct CO_2 reduction)	€ 586	€ 334	€ 483	€ 276
ReFuelEU (total)	€ 431	€ 251	€ 384	€ 222

Source: SEO & NLR (2022)
Note: a): Only the demand induced effects of EU-ETS and CORSIA are presented here. EU-ETS and CORSIA are market-based mechanisms that (theoretically) achieve a net reduction of CO_2, respectively through buying credits from other sector or offsetting. The carbon abatement cost (that is, price per ton of CO_2) are included in parentheses.

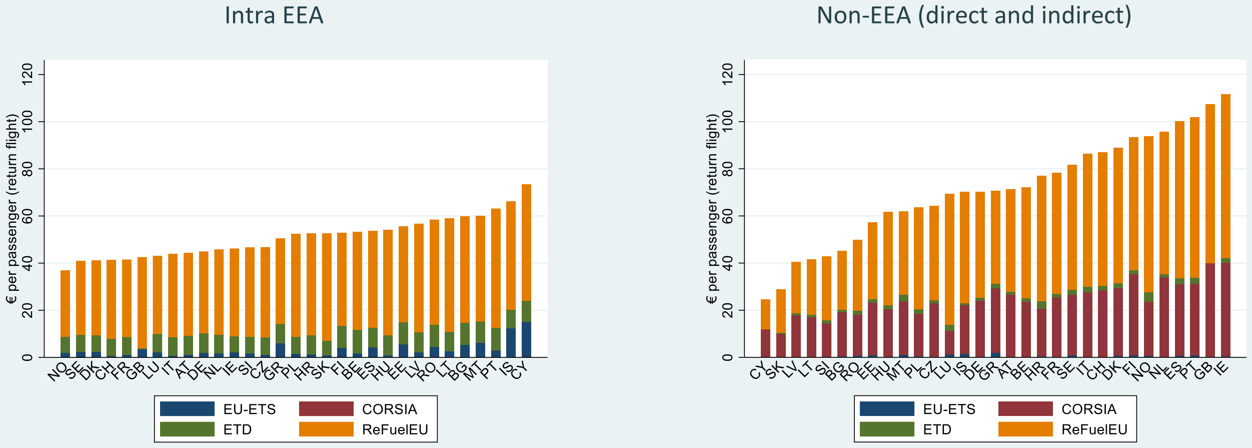
5. Outlook 2050

A forecast of sustainability regulation towards 2050 aviation prices is subject to large uncertainties. Given current information, costs for ReFuelEU appear to be much larger than all other costs on most routes within and outside the EEA.

The overall cost for Fit for 55 is expected to remain similar within the EEA and increase substantially for flights leaving the EEA, as detailed in Table 5.1. For all fights, the main cost component will be from ReFuelEU. Whereas flights to non-EEA members will experience large cost increase with respect to 2035, the cost within the EEA are similar but with different cost allocation among the policy components (see also Table 4.3). The cost for EU-ETS will decline since carbon emissions will be lower from SAF use. The ETD mandated kerosene tax, already at a maximum in 2035, will apply to a smaller ratio of fuel due to the higher SAF component, although non-advanced SAF are taxed. The cost between Intra EEA and Non-EEA have a smaller difference, largely dependent on the higher assumed CORSIA prices (which are highly uncertain). Should these costs reflect a reality by 2050 then competitive disadvantage for EEA airlines and hubs would be lower than in 2030 and carbon leakage would be smaller. Note however that cost of Fit for 55 in the Table 5.1 are per return flight and therefore similar prices for longer distance non-EEA flights suggest lower per pax-km prices than within the EEA.

Table 5.1 Ticket price increase per passenger by airport of origin in 2050

Ticket price increase (€ per passenger for return flights)


Intra EEA

Non-EEA (direct and indirect)

Source: SEO & NLR (2022)

There are various sources for uncertainty in long-term forecasts. One, this forecast does not take account the likely capacity expansion of some hubs outside of Europe. Second, the results do not anticipate the possibility of other countries outside of Europe introducing measures, which may be similar to the Fit for 55 proposals. Similarly, results do not account for possible voluntary measures by airlines. Third, assumptions on hypothetical technical operations of airplanes, especially fuel consumption and fleet composition have a high influence on long-term outcomes. Fourth, long-term outlooks are subject to change according to development in sustainability policy and technical environment. Lastly, the COVID-19 crisis has severely impacted the aviation industry already for over two years, and will continue to do so in the short term, casting further uncertainty over long-term forecasts. The reader is referred to a precursor study, Destination 2050, for a more detailed discussion on some of these uncertainties.

6. Conclusions

Fit for 55 policies reduce the demand for air travel and CO_2 emissions within the EEA due to increasing costs and the use of sustainable aviation fuels. For travel with non-EEA alternatives, a net shift in demand to non-EEA hub airports and routes occurs. In 2035, associated carbon leakages reduces the CO_2 emission reduction on intercontinental routes by 6 percent.

We assess the impacts of the Fit for 55 policies on the aviation sector. Based on a global passenger choice model, we estimate the impact on cost, ticket prices, demand for travel, CO_2 emissions and carbon leakage.

The **costs** of air travel increase due to these policies. Within the EEA, Fit for 55 increases the cost of a return flight of 3000 km within the EEA by about €45 per passenger in 2030 and €65 per passenger in 2035 compared to a no-policy scenario in those years. For flights to non-EEA destinations, costs increase for a return flight of 19.000 km (e.g. Frankfurt-Tokyo) accrue to around €50 per passenger in 2030 and by €105 in 2035.[16] Costs are an almost linear function of flight distance, both within and outside the EEA. However, there is variation in the average additional cost per airport. Since longer distances within the EEA imply higher costs, airports closer to EEA borders have a relative cost disadvantage in comparison to airports located more towards the centre of Europe. Airports just outside the EEA have a competitive cost advantage as an onward hub for indirect flights from the EEA. Depending on the pass-through rate to the consumers, ticket prices increase more or less.

The **demand** for air travel decreases due to the additional cost and resulting ticket price increases from Fit for 55 policies. If all costs were passed on to consumers, overall passenger volumes in 2030 would decrease by 8.4% compared to the no-policy scenario of the same year. This implies a decrease of 75 million passengers. This can be further split into intra-EEA flights losing 10.3% passengers (72 million) versus flights to non-EEA destinations 1.4% (minus 3 million). In 2035, the overall passenger volumes decrease by 11.6% compared the reference scenario, adding up to a total reduction of 119 million passengers. Intra-EEA passenger numbers are reduced by 13.9% (minus 110 million) and passenger numbers to non-EEA destinations by 3.8% (minus 9 million) with respect to no Fit for 55. The reason for the larger decrease in total passenger demand on intra-EEA routes is twofold: first and foremost, larger cost increases apply to intra-EEA flights. Secondly, for travelling between EEA and non-EEA destinations, passengers are able to circumvent the Fit for 55 measures and associated cost increases by rerouting via non-EEA hubs. The number of passengers traveling to a non-EEA destination, either directly or via an EEA hub, decreases by 6% in 2035 (minus 10 million passengers). On the other hand, the number of intercontinental passengers travelling through non-EEA hubs increases by 2% (plus 1.4 million passengers).

The **CO_2 savings and carbon leakage** depend directly on the demand impacts of Fit for 55. The higher cost per ticket reduces demand for air travel and Sustainable Aviation Fuel uptake has comparatively lower CO_2 emissions, resulting in combined CO_2 savings. For travel from the EEA to a destinations outside the EEA, Fit for 55 costs are lower, and demand for air travel via non-EEA hubs increases, thereby reducing overall CO_2 savings, i.e., causing carbon leakage.

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[16] Due to the remaining uncertainty around sustainable aviation fuel prices, price forecasts are conservative and therefore could be an underestimate. Larger SAF price forecasts used in industry estimates suggest even higher cost increases. Similarly, there are uncertainties related to other policies, such as RefuelEU applicability and carbon abatement cost.

Carbon leakage mainly occurs on routes arriving from or departing to outside the EEA. In 2035, the Fit for 55 policy leads to a net CO_2 reduction of 19 megatons per year (roughly the emissions of all passenger flights departing from France in one year), whilst carbon leakage leads to an increase of 1.1 megatons of CO_2 – equivalent to about 7,000 flights between Frankfurt and New York JFK. This implies that without carbon leakage total CO_2 savings could have been 6 percent higher. On certain specific routes with more competition from non-EEA hubs, carbon leakage impacts can be substantially higher. Carbon leakage is an unintended consequence of the Fit for 55 policy. Nevertheless, even including the net losses from CO_2 leakage, Fit for 55 reduces CO_2 substantially.

The current modelling results have been obtained with 100% cost pass-through. This assumption results in an upper bound on demand impacts and carbon leakage. In case actual cost pass-through is lower than 100%, leading to smaller increases in ticket prices, demand shifts and carbon leakage effects will be lower as well. Actual cost pass-through rates vary, between 45 and 95%. Demand and carbon leakage impacts scale linearly with the cost pass-through rate: a 50% pass-through rate, also explored in Appendix C, would yield half the demand impact and carbon leakage as presented in this study.

For intra-EEA routes, there is a limited risk of CO_2 leakage. Two sources for carbon leakage within the EEA are that indirect flights within the EEA use a non-EEA hub or that travellers substitute for non-EEA destinations. The former occurs for 0.2% of all within EEA travel in 2035. The latter requires analysing travellers' destination choices, which was **beyond the scope** of the current research.

Carbon leakage and competitive effects for routes between non-EEA countries through EU hubs are evaluated for selected set of route examples (Appendix B), since these passenger and flights are not the scope of the EU policy-makers. Further understanding of changes in passenger demand, CO_2 savings and carbon leakage on these routes warrants additional attention. Fuel tankering, while not studied here in detail, would pronounce the results we find, reducing competitiveness of EEA airlines and hubs while increasing CO_2 emissions. The fact that the ReFuelEU proposal limits tankering reduces this risk.

The results of this study are based on a global passenger choice model and a complex set of assumptions on policy choices, route composition, aviation data, and technological parameters. As such, the results do not take into account the potential expansion of airports and the implementation of sustainability mandates in non-EEA countries beyond the ones modelled.

Potential **policy improvements** are not part of this study and further research in this area recommended. For example, an alignment on sustainability policy with non-EEA members would result in higher CO_2 savings and reduce carbon leakage. Especially countries with airports with close proximity to the EU should be a target of policy alignment (e.g. Turkey, Russia and the UK). Another example of unexplored policy options is a support mechanism to SAF fuel mandate for non-EEA flights that ameliorates competition losses while maintaining or even improving CO_2 savings. Further, the possibility for an extension of a carbon border adjustment mechanism to aviation could be explored.

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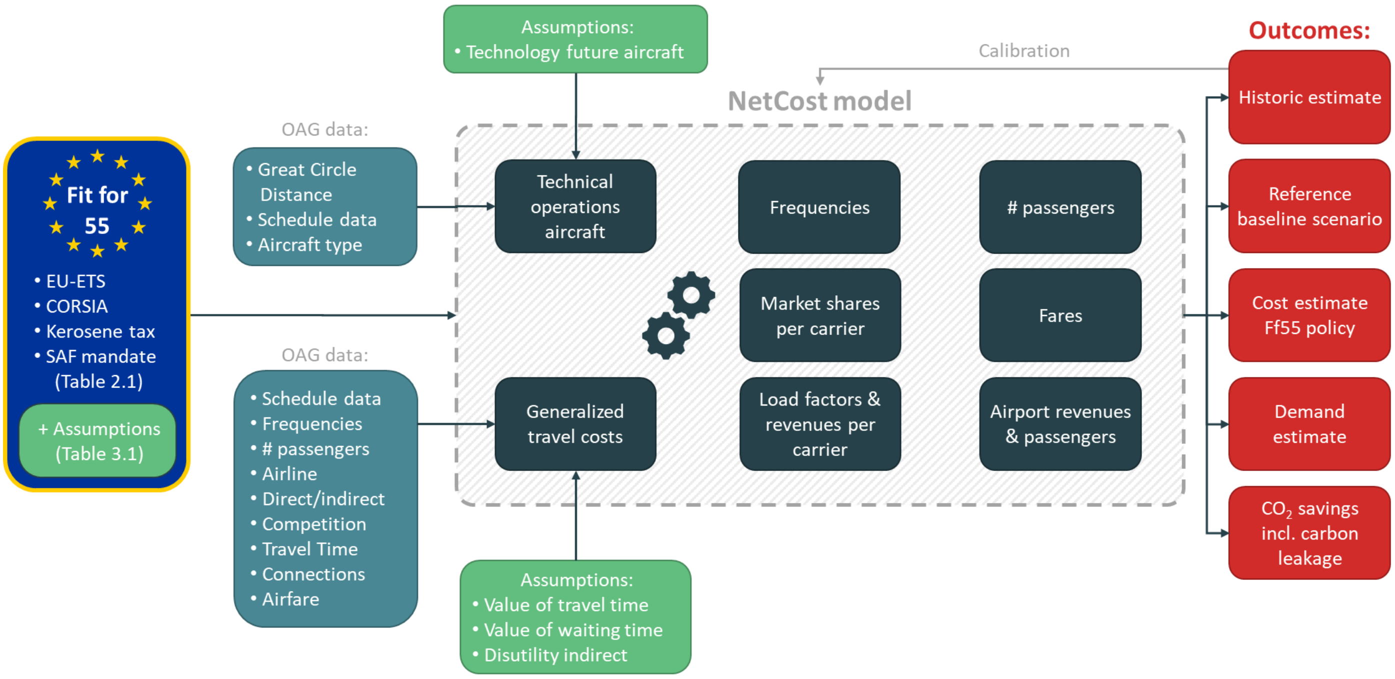
Appendix A Technical details NetCost passenger choice model

The NetCost model has been used to calculate demand impacts of the Ff55 measures. The same model was applied for the modelling in Destination 2050, to which we refer for the underlying demand forecasts. The model uses OAG schedule data for all direct and indirect alternatives to determine generalized costs and market shares for individual markets. The NetCost model was first presented in Heemskerk and Veldhuis (2006a, 2006b) and developed by Veldhuis and Lieshout (2009). NetCost has been used to compute generalized travel costs in the baseline and the Ff55 scenarios. NetCost allows to compute the average increase or decrease in travel costs per passenger and demand impacts as a result thereof.

Passenger demand are determined using a four-step approach:

1. Construct baseline airline networks for 2030, 2035 and 2050, based on OAG schedule data and passenger growth forecasts.
2. Determine generalized travel costs and consumer utility in each scenario using the NetCost price model.
3. Using price elasticities for business and leisure, compute the change in generalized travel costs between the baseline and Ff55 scenario. This results in total passenger demand impacts.
4. Break down the consumer benefits into time savings, cost savings, connectivity and capacity components.

Figure A.1 The NetCost model



Source: SEO Amsterdam Economics (2022)

Construction of future airline networks

Using passenger forecasts – taking into account expected COVID-19 developments, the 2018 baseline airline network has been extrapolated to the horizon years 2030, 2035 and 2050. For each European airport, a network for the horizon years has been forecasted.

The NetCost model also requires a 'beyond-network' for the horizon years to incorporate indirect travel alternatives to final destinations. This 'beyond-network' consists of all destinations that can be reached from Europe with a connection at an intermediate hub airport. Direct and indirect travel alternatives are used to determine the competition level in an OD market, which is an input variable for the fare model. For the extrapolation of the beyond network growth figures from non-European airports are also required. For these airports we apply growth figures as published by Airbus in its most recent Global Market Forecast.

Calculating generalized travel costs and consumer value

Generalized travel costs comprise of a fare, time and frequency component. Time costs are calculated using Values of Travel Time for business and leisure passengers, multiplied by the travel time of the respective route alternative. For indirect connections an average transfer time of 2.5 hours is assumed.

The frequency component denotes costs resulting from schedule delay. Schedule delay is the difference between the departure time preferred by the passenger and the actual departure time. Schedule delay decreases when the flight frequency increases. The costs associated with schedule delay equal the schedule delay (in hours) time multiplied by the Value of Waiting Time for the next flight. By calibration of the model, we found that market shares were represented best by using a Value of Waiting Time of zero dollars for leisure passengers and of five dollars for business passengers.

The NetCost fare model determines the airfare for an individual route alternative based on travel time, competition level, carrier type and connection type. One-way air fares in euros are estimated using Ordinary Least Squares (OLS) on passenger booking data.

After the generalized travel costs (GC) are calculated, a utility function is used to determine the Consumer Value (CV), having as base the frequency (*f*). A cost sensitivity parameter α is included. After calibrating the model, we find that $\alpha = 0.01$ for business passengers and $\alpha = 0.015$ for leisure passengers are the most appropriate values. The consumer value for route alternative *i* (CV_i) is given by:

$$CV_i = f \cdot e^{-\alpha \cdot GC_i}$$

Market shares of route alternatives are estimated using these consumer values. The market share of a route alternative *i* is given by:

$$MS_i = \frac{CV_i}{\sum_j CV_j}$$

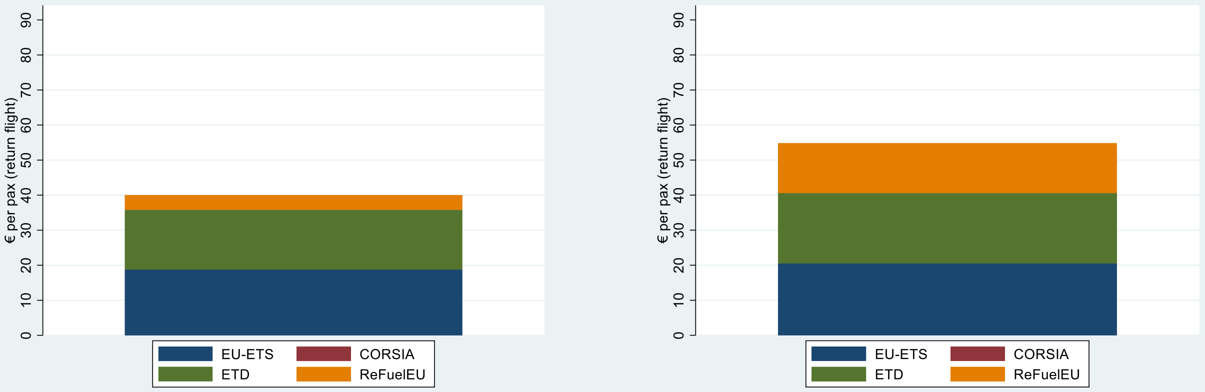
Using the Ff55 cost increases as input, we assess how changes in the passenger travel costs on certain route options lead to a change in market shares, to assess how many passengers divert to different routes. By assessing the change in total generalized travel costs over the total O&D market, we also determine the share of the passengers that stop travelling as a result of the overall cost increase.

Appendix B Route level factsheets

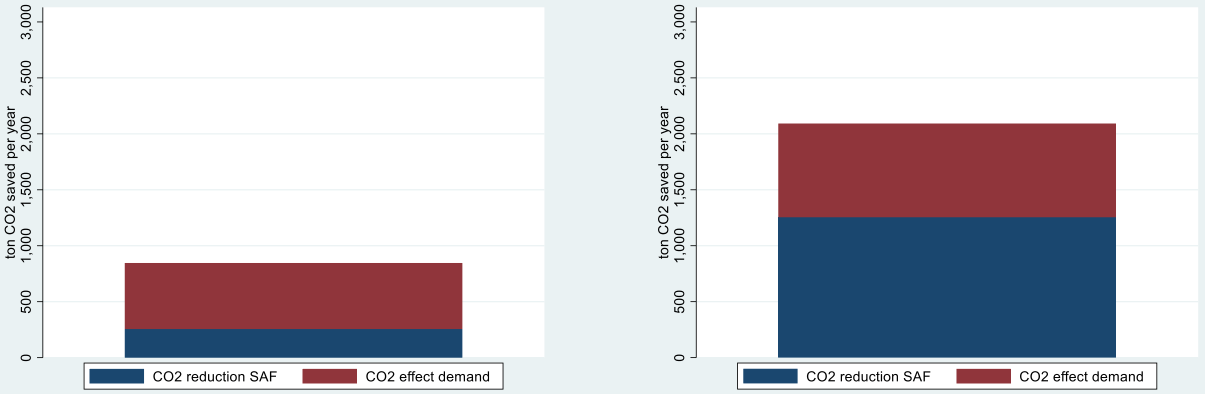
Table B.1 Ticket prices increases for the Amsterdam (AMS) - Budapest (BUD) route

Per transfer hub, the ticket price increase per passenger
Amsterdam (AMS) - Budapest (BUD)

2030 | 2035

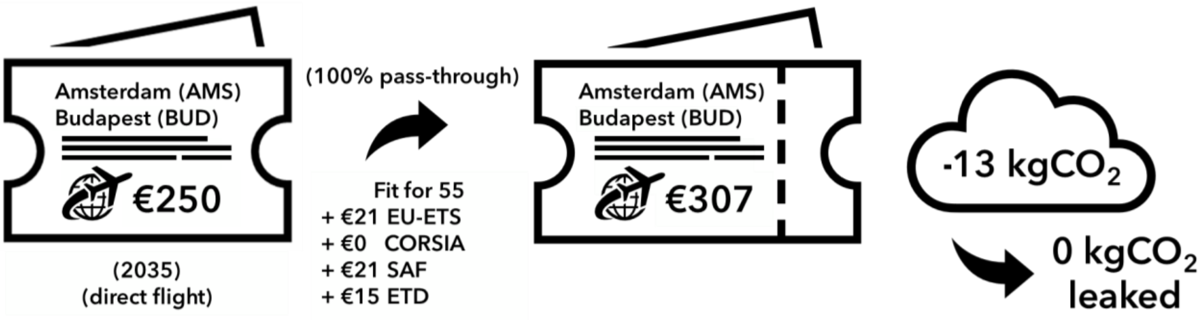


Breakdown of CO₂ savings by SAF uptake and demand reduction



Source: SEO & NLR (2022)

Figure B.1 Ticket cost example Amsterdam Budapest route with cost and CO₂ savings

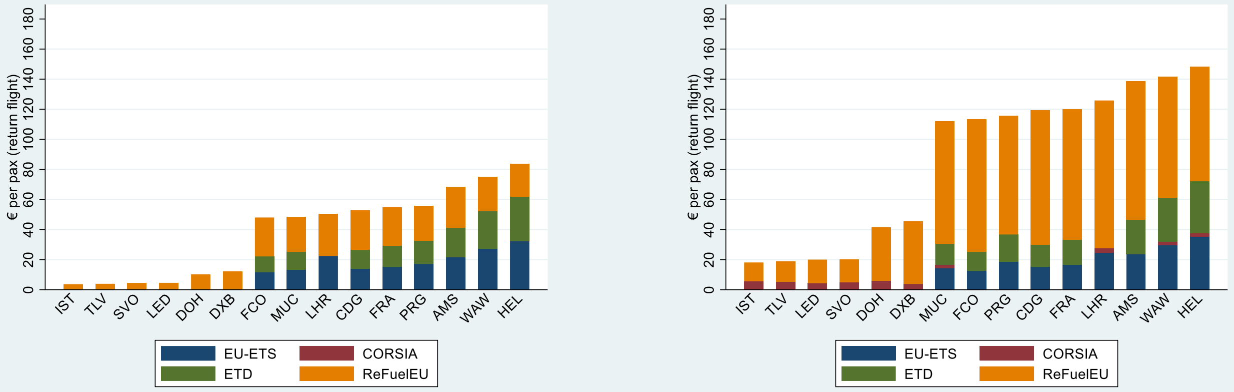


Source: SEO & NLR (2022)

Table B.2 Ticket prices increases for the Nice (NCE) - Seoul (ICN) route

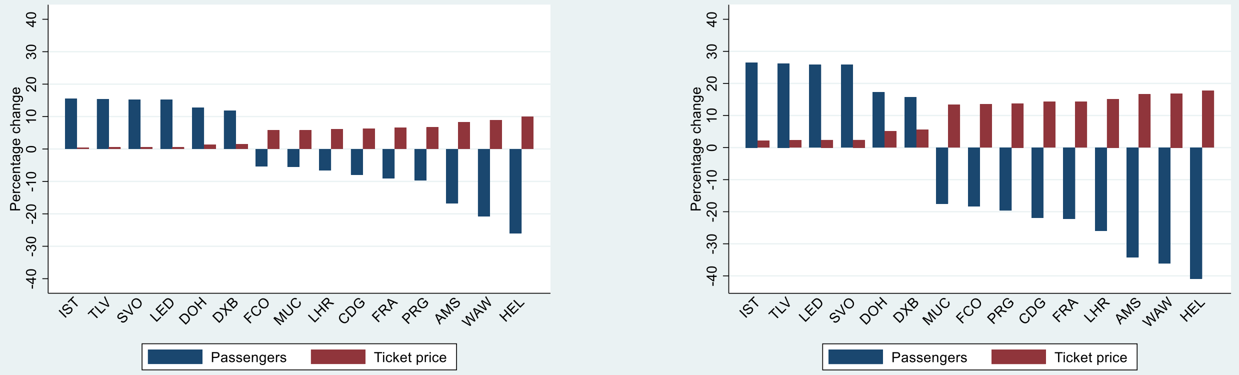
Per transfer hub, the ticket price increase per passenger
Nice (NCE) - Seoul (ICN)

2030 2035



Ticket price in €	+60 EEA	+6 non-EEA	+126 EEA	+27 non-EEA

Per transfer hub, the relative ticket price increase per passenger and the demand impact

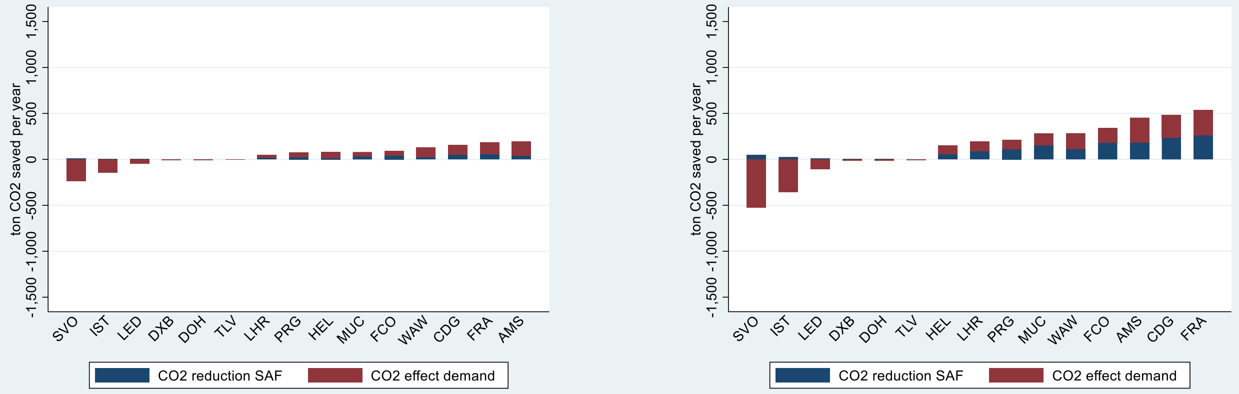


Per flight, change in passengers and ticket price with 100% pass-through.

Per flight, change in passengers and ticket price with 100% pass-through.

Pax demand	-10% EEA	+18% non-EEA	-20% EEA	+34% non-EEA

Breakdown of CO₂ savings by SAF uptake and demand reduction, by hub



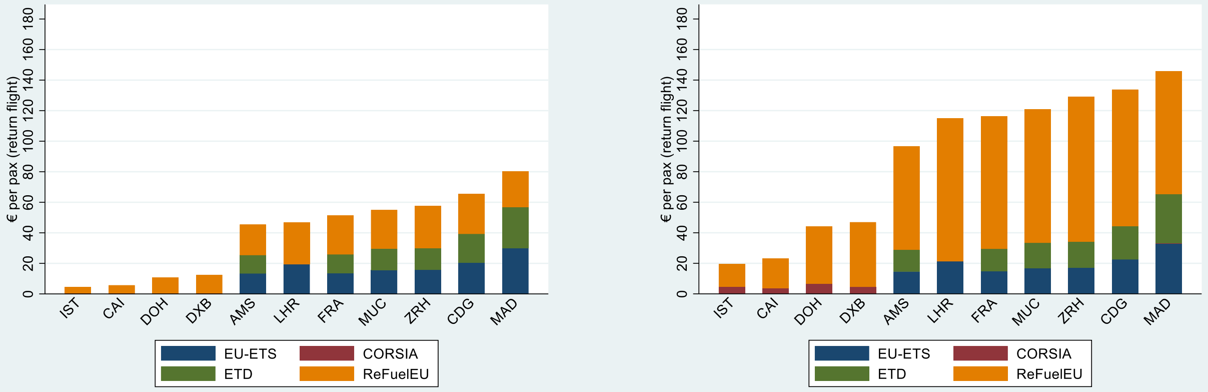
tCo2 save/leak	+624	-423	+2021	-926

Source: SEO & NLR (2022). Assuming 100 percent pass-through rate.

Table B.3 Ticket prices increases for the Copenhagen (CPH) - Johannesburg (JNB) route

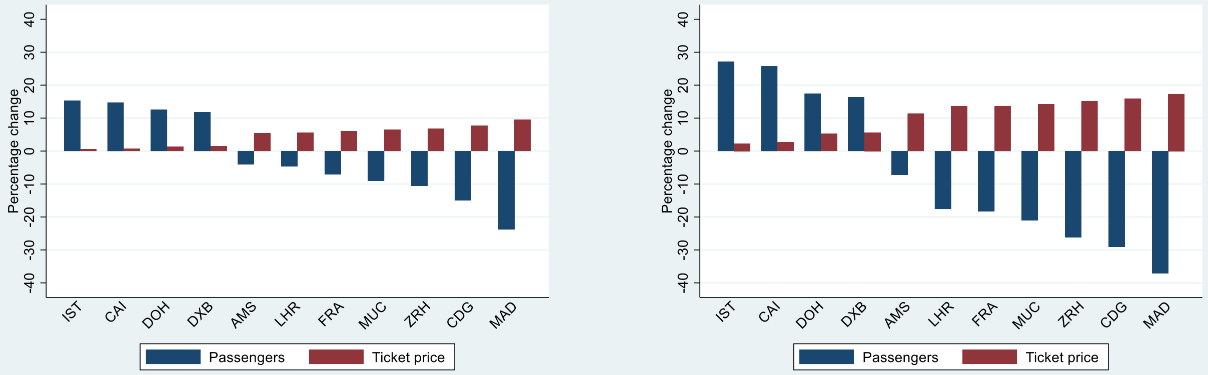
Per transfer hub, the ticket price increase per passenger
Copenhagen (CPH) - Johannesburg (JNB)

2030 2035



Ticket price in € +56 EEA +8 non-EEA +121 EEA +33 non-EEA

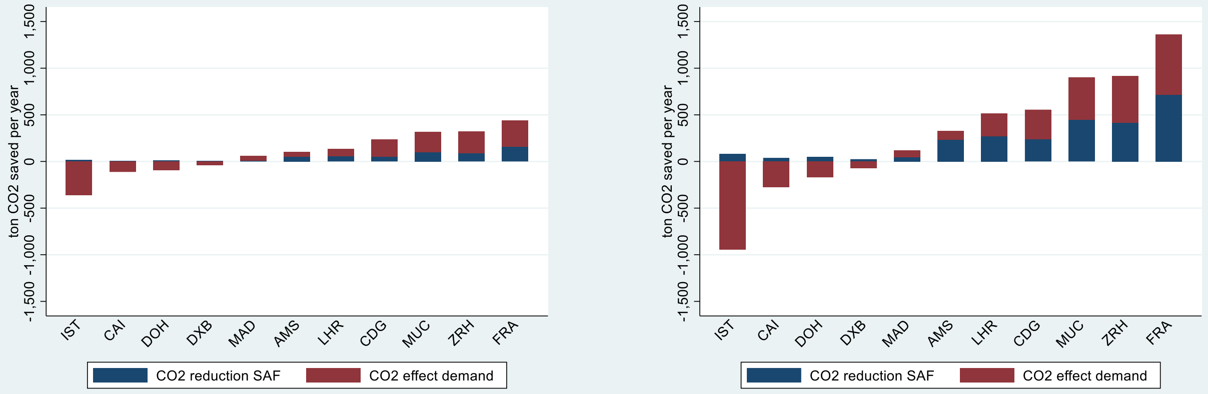
Per transfer hub, the relative ticket price increase per passenger and the demand impact



Per flight, change in passengers and ticket price with 100% pass-through. Per flight, change in passengers and ticket price with 100% pass-through.

Pax demand -7% EEA +17% non-EEA -16% EEA +33% non-EEA

Breakdown of CO_2 savings by SAF uptake and demand reduction, by hub



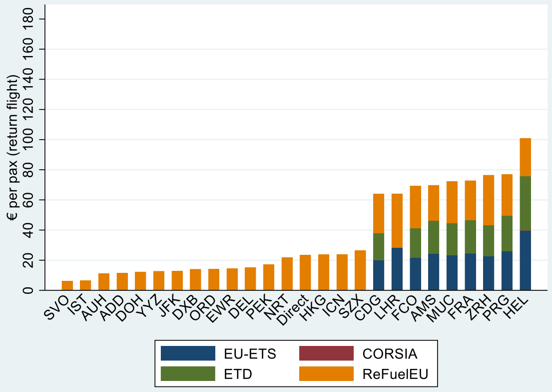
tCo2 save/leak +1181 -569 +3946 -1266

Source: SEO & NLR (2022). Assuming 100 percent pass-through rate.

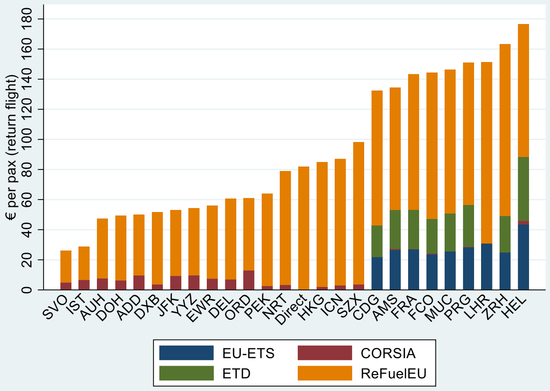
Table B.4 Ticket prices increases for the Madrid (MAD) - Shanghai (PVG) route

Per transfer hub, the ticket price increase per passenger
Madrid (MAD) - Shanghai (PVG)

2030

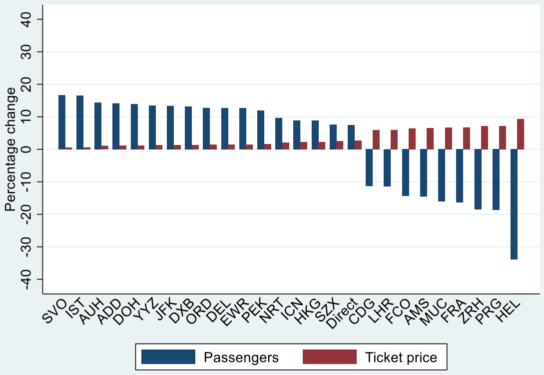


2035

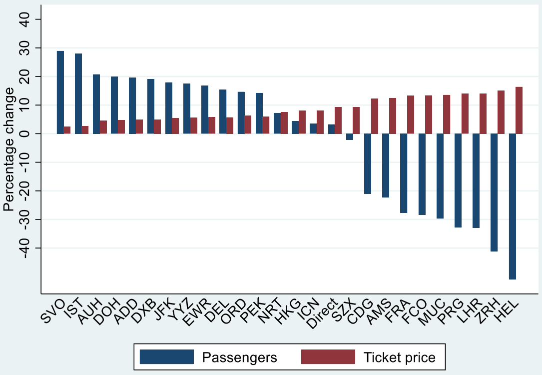


Ticket price in €	+66 EEA	+15 non-EEA	+137 EEA	+59 non-EEA

Per transfer hub, the relative ticket price increase per passenger and the demand impact



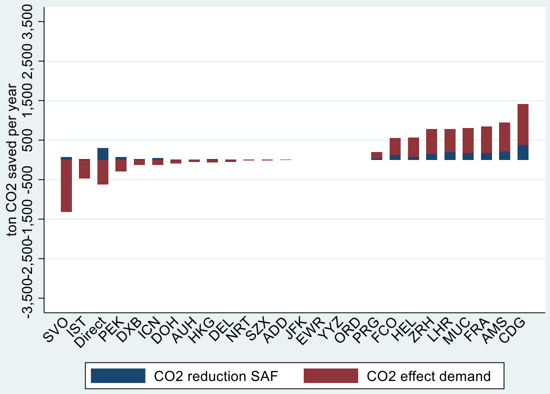
Per flight, change in passengers and ticket price with 100% pass-through.

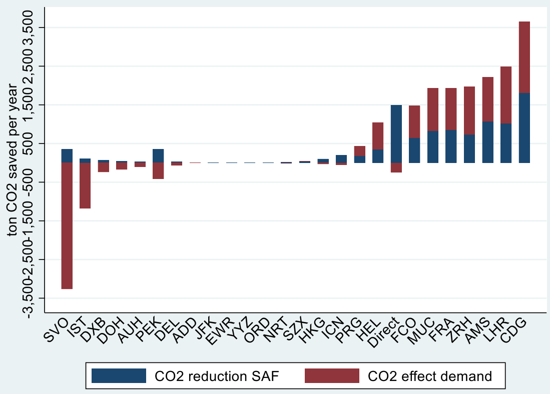


Per flight, change in passengers and ticket price with 100% pass-through.

Pax demand	-7% EEA	+17% non-EEA	-15% EEA	+30% non-EEA

Breakdown of CO_2 savings by SAF uptake and demand reduction, by hub





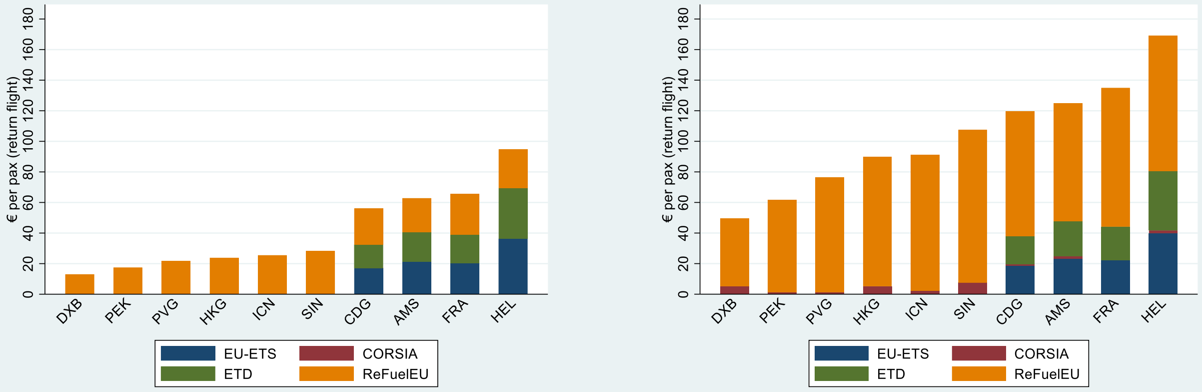
tCo2 save/leak	+4741	-2970	+17404	-4442

Source: SEO & NLR (2022). Assuming 100 percent pass-through rate.

Table B.5 Ticket prices increases for the Barcelona (BCN) - Osaka (KIX) route

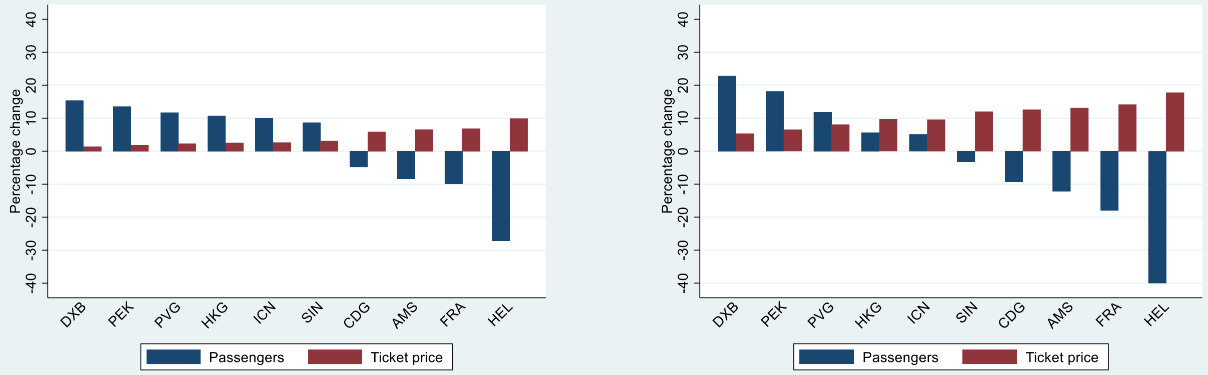
Per transfer hub, the ticket price increase per passenger
Barcelona (BCN) - Osaka (KIX)

2030 2035



Ticket price in € +70 EEA +22 non-EEA hub +137 EEA +81 non-EEA

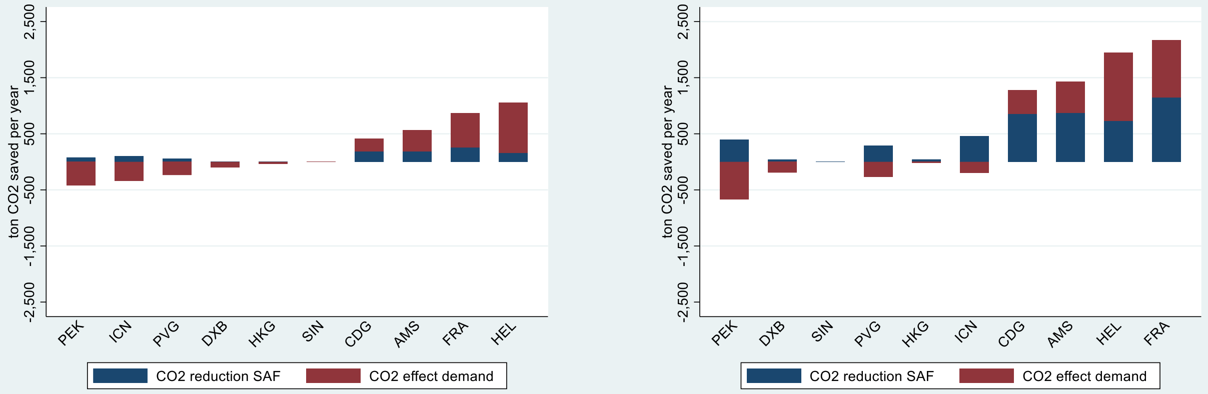
Per transfer hub, the relative ticket price increase per passenger and the demand impact



Per flight, change in passengers and ticket price with 100% pass-through. Per flight, change in passengers and ticket price with 100% pass-through.

Pax demand -10% EEA +13% non-EEA -15% EEA +13% non-EEA

Breakdown of CO_2 savings by SAF uptake and demand reduction, by hub



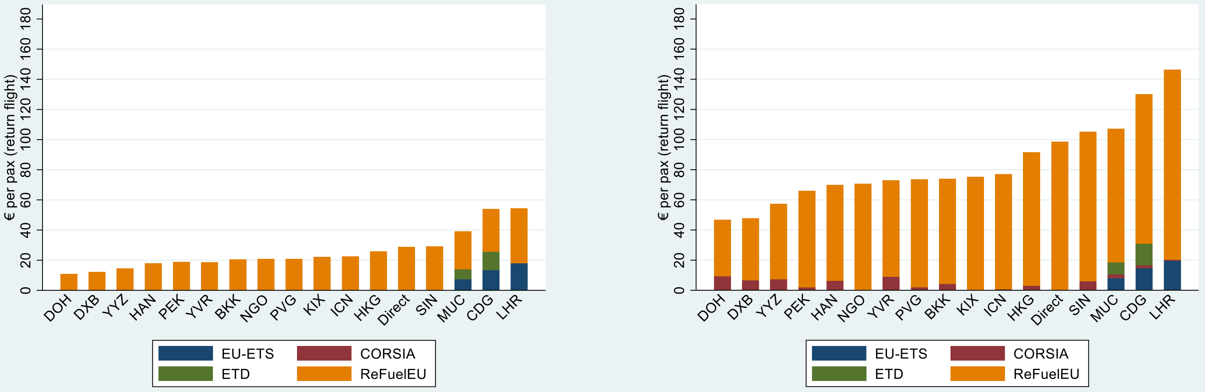
tCo2 save/leak +1790 -1109 +6976 -419

Source: SEO & NLR (2022). Assuming 100 percent pass-through rate.

Table B.6 Ticket prices increases for the Frankfurt (FRA) - Tokyo (HND) route

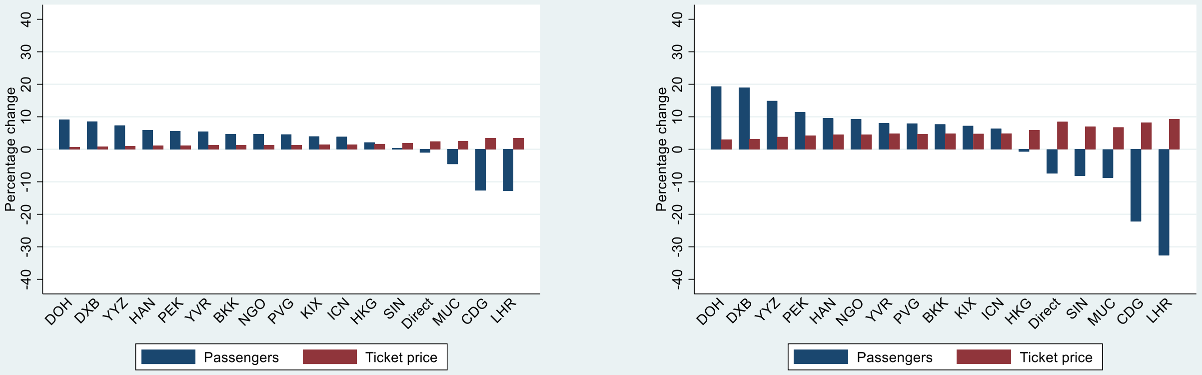
Per transfer hub, the ticket price increase per passenger
Frankfurt (FRA) - Tokyo (HND)

2030 2035



Ticket price in € +47 EEA +20 non-EEA hub +126 EEA +73 non-EEA

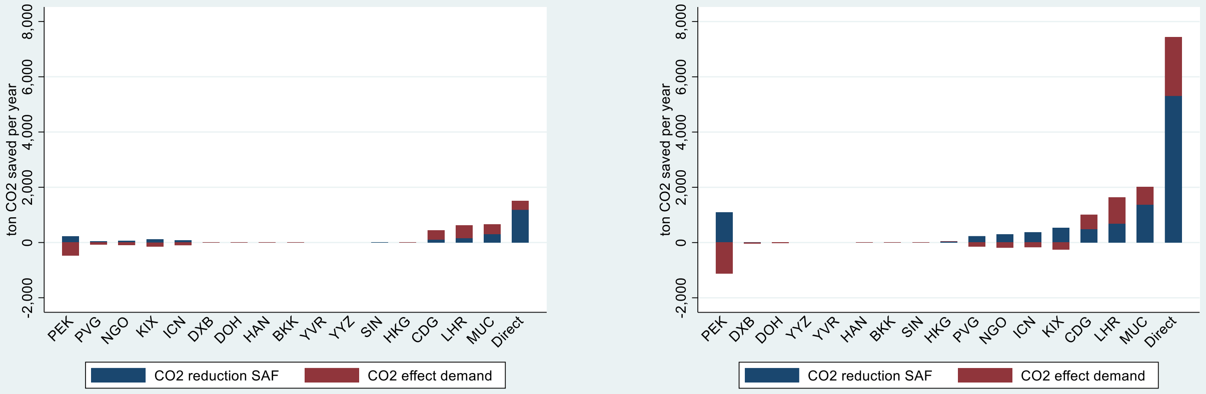
Per transfer hub, the relative ticket price increase per passenger and the demand impact



Per flight, change in passengers and ticket price with 100% pass-through. Per flight, change in passengers and ticket price with 100% pass-through.

Pax demand -4% EEA +5% non-EEA -10% EEA +10% non-EEA

Breakdown of CO_2 savings by SAF uptake and demand reduction, by hub



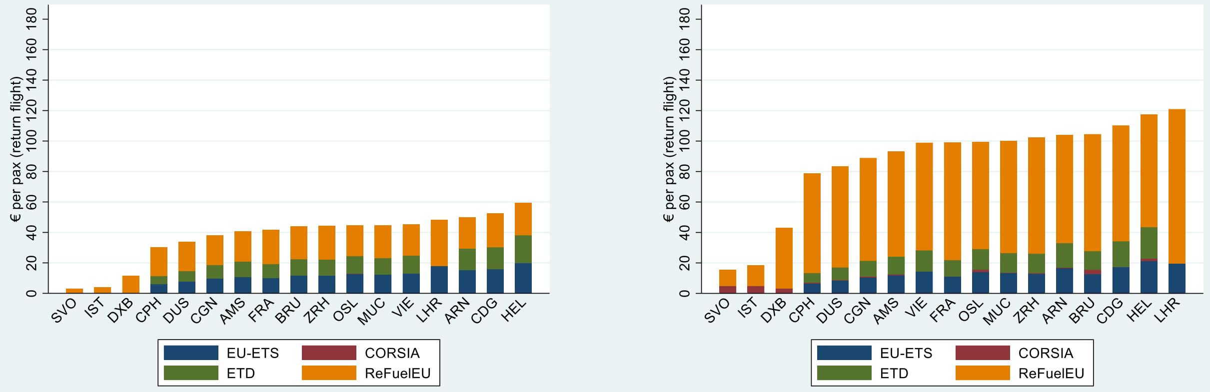
tCo2 save/leak +3878 -403 +15700 -70

Source: SEO & NLR (2022). Assuming 100 percent pass-through rate.

Table B.7 Ticket prices increases for the Hamburg (HAM) - Bangkok (BKK) route

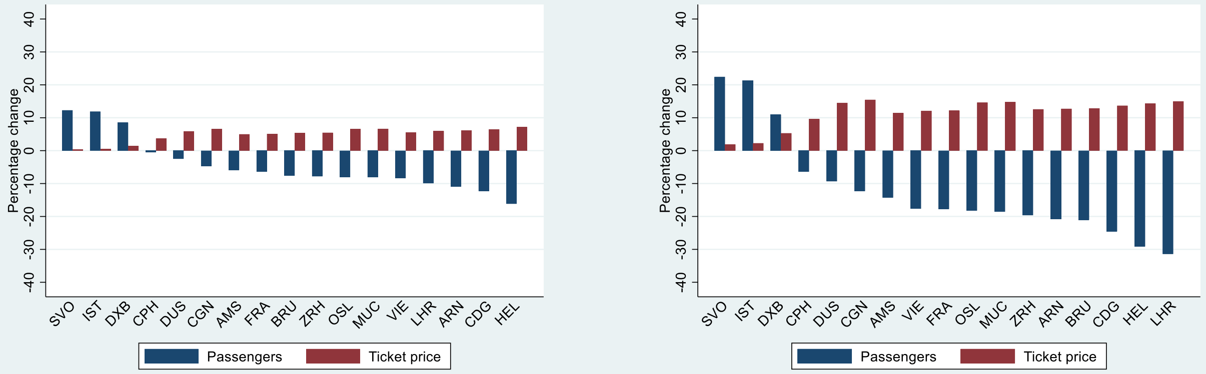
Per transfer hub, the ticket price increase per passenger
Hamburg (HAM) - Bangkok (BKK)

2030 2035



Ticket price in € +44 EEA +6 non-EEA +100 EEA +25 non-EEA

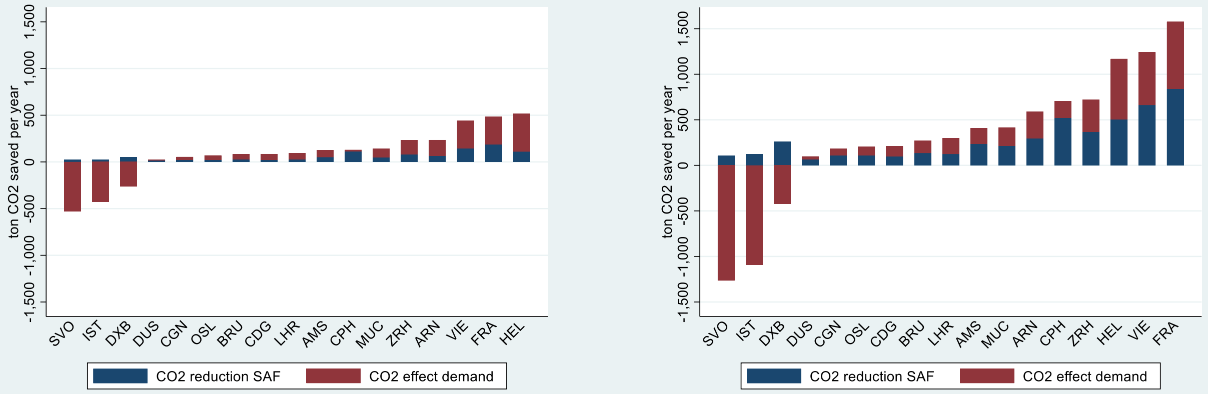
Per transfer hub, the relative ticket price increase per passenger and the demand impact



Per flight, change in passengers and ticket price with 100% pass-through. Per flight, change in passengers and ticket price with 100% pass-through.

Pax demand -7% EEA +13% non-EEA -15% EEA +24% non-EEA

Breakdown of CO₂ savings by SAF uptake and demand reduction, by hub



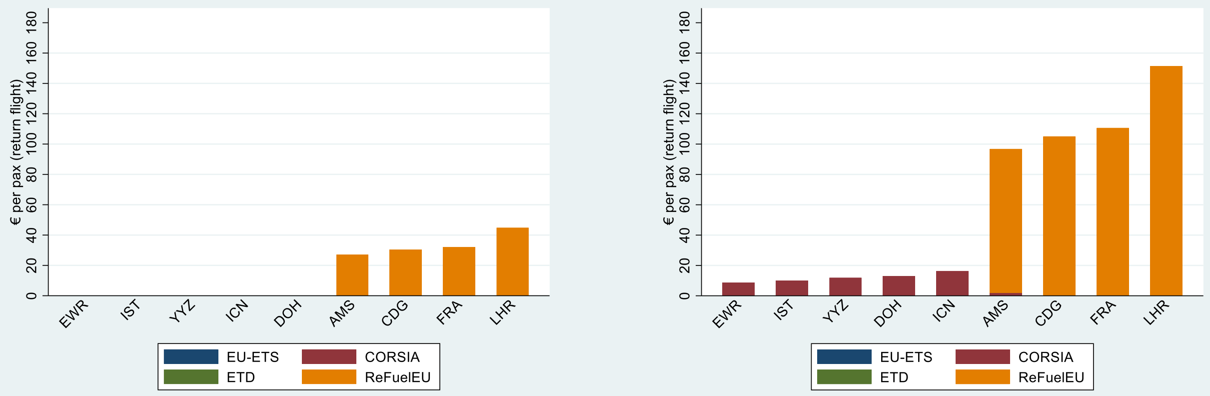
tCo2 save/leak +1799 -1123 +6429 -2289

Source: SEO & NLR (2022). Assuming 100 percent pass-through rate.

Table B.8 Ticket prices increases for the Atlanta (ATL) - Mumbai (BOM) route

Per transfer hub, the ticket price increase per passenger
Atlanta (ATL) - Mumbai (BOM)

2030 2035



Ticket price in €	+34 EEA	+17 non-EEA hub	+116 EEA	+12 non-EEA

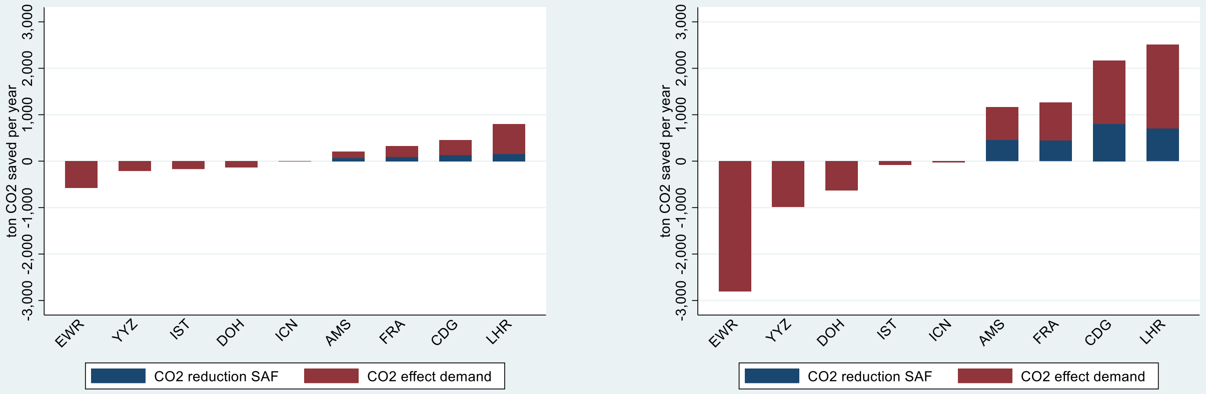
Per transfer hub, the relative ticket price increase per passenger and the demand impact

Per flight, change in passengers and ticket price with 100% pass-through.

Per flight, change in passengers to cost55/ticket-price ratio wiht 100% pass-through.

Pax demand	-11% EEA	+5% non-EEA	-32% EEA	+13% non-EEA

Breakdown of CO₂ savings by SAF uptake and demand reduction, by hub



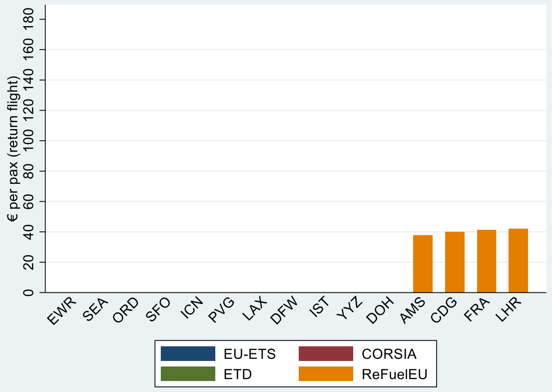
tCo2 save/leak	+674 EEA	-1104	+2589	-4521

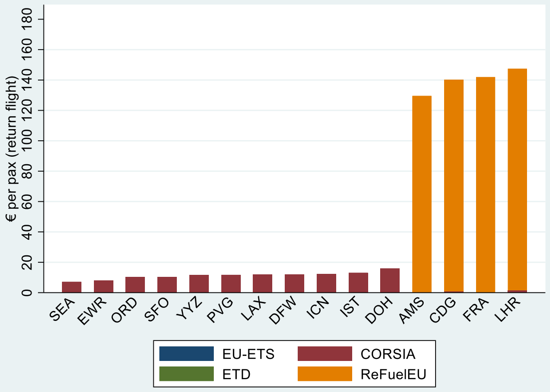
Source: SEO & NLR (2022). Assuming 100 percent pass-through rate.

Table B.9 Ticket prices increases for the Atlanta (ATL) - Hongkong (HKG) route

Per transfer hub, the ticket price increase per passenger
Atlanta (ATL) ↔ Hongkong (HKG)

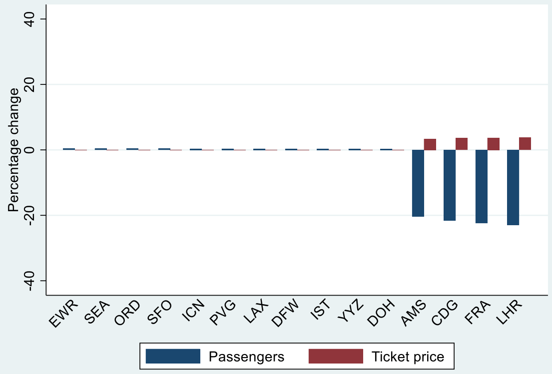
2030 2035



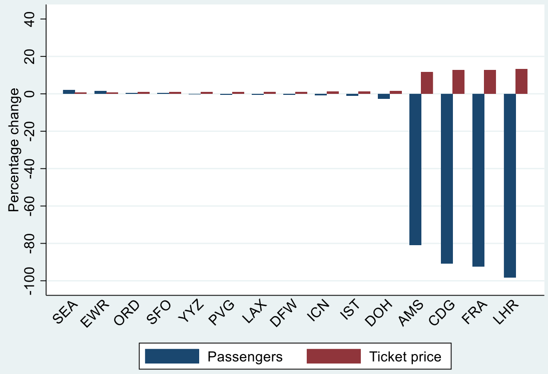


Ticket price in € +41 EEA +14 non-EEA hub +141EEA +11 non-EEA

Per transfer hub, the relative ticket price increase per passenger and the demand impact



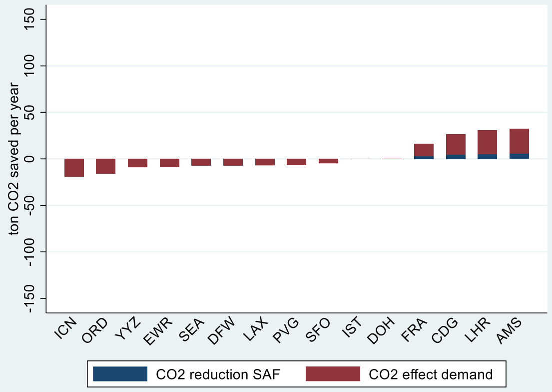
Per flight, change in passengers and ticket price with 100% pass-through.

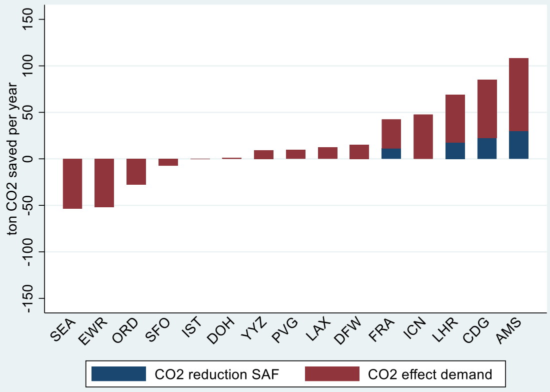


Per flight, change in passengers and ticket price with 100% pass-through.

Pax demand -18% EEA +0% non-EEA -47% EEA +0% non-EEA

Breakdown of CO_2 savings by SAF uptake and demand reduction, by hub





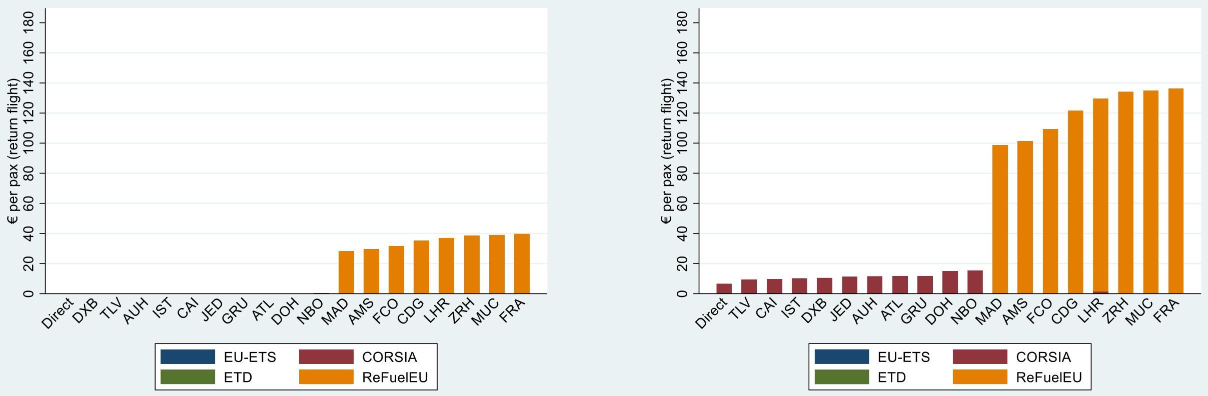
tCo2 save/leak +35 -101 +300 -22

Source: SEO & NLR (2022). Assuming 100 percent pass-through rate.

Table B.10 Ticket prices increases for the New York (JFK) - Johannesburg (JNB) route

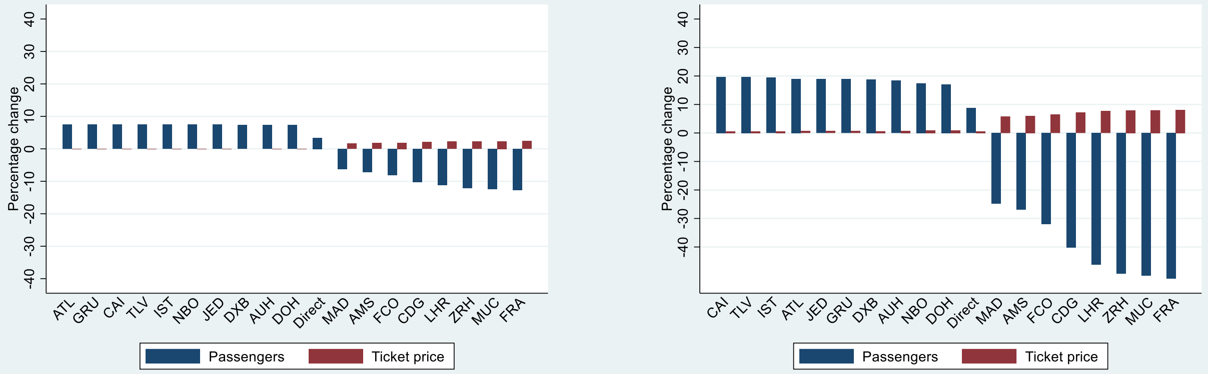
Per transfer hub, the ticket price increase per passenger
New York (JFK) - Johannesburg (JNB)

2030 2035



Ticket price in € +31 EEA +0 non-EEA +140 EEA +12 non-EEA

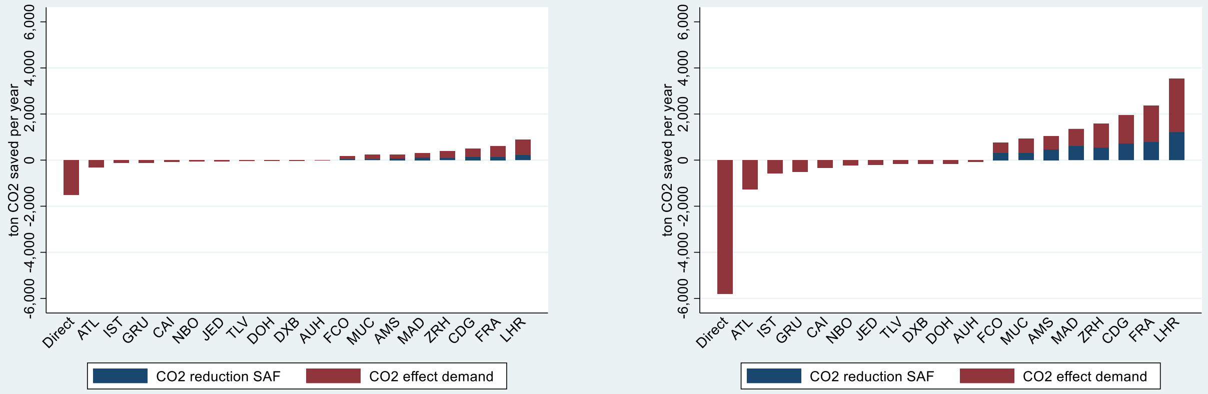
Per transfer hub, the relative ticket price increase per passenger and the demand impact



Per flight, change in passengers and ticket price with 100% pass-through. Per flight, change in passengers and ticket price with 100% pass-through.

Pax demand -1% EEA +8% non-EEA -5% EEA +23% non-EEA

Breakdown of CO$_2$ savings by SAF uptake and demand reduction, by hub



tCo2 save/leak +1721 -2500 +7061 -9974

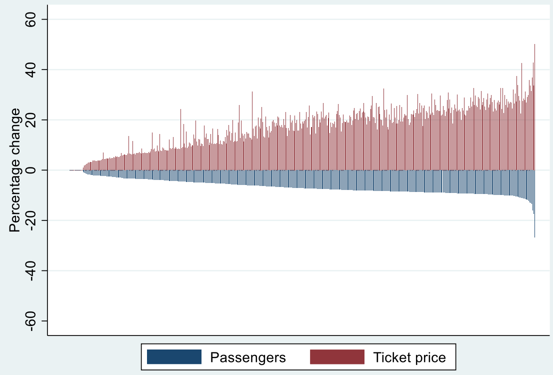
Source: SEO & NLR (2022). Assuming 100 percent pass-through rate.

Appendix C 50% Pass-through

Sensitivity Analysis 50% pass-through for 2035

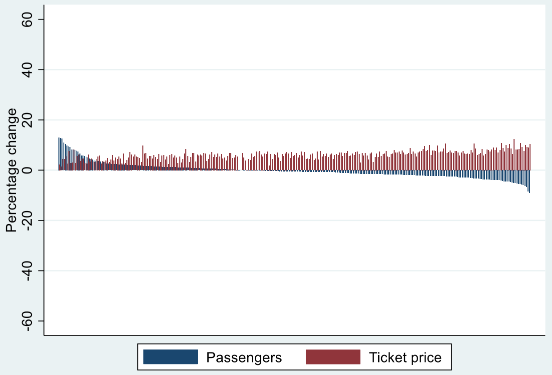
Average change in ticket price increases (red) versus passenger volume impact (blue)

EEA airports (by origin)
(direct and indirect intra-EEA flights)



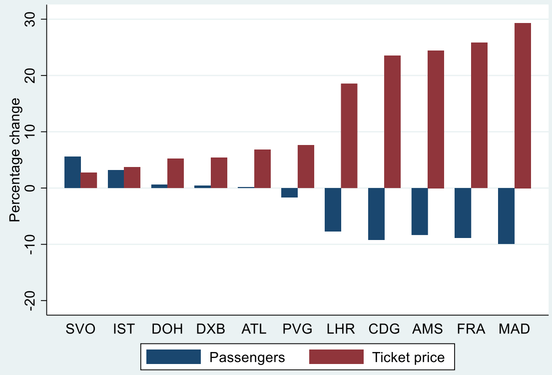
Per origin airport, change in passengers and ticket prices at 50% pass-through.

Non-EEA airports (by hub)
(indirect EEA ↔ non-EEA flight, transfer through non-EEA hub)



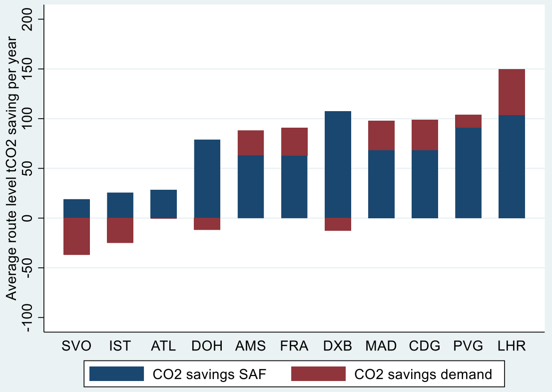
Per airport, change in passengers and ticket prices at 50% pass-through.

Average change in ticket price increases (red) versus passenger volume impact (blue)



For indirect flights via these hubs, change in passengers and ticket prices at 50% pass-through.

Breakdown of CO_2 savings by SAF uptake and demand reduction, by hub



Source: SEO & NLR (2022)

Appendix D SAF price premium

Table D. 1 SAF uptake and price premium with respect to fossil kerosene

	2030	2035	2050
Total SAF share	5%	20%	63%
Of which:			
Biofuel part A	18.9%	18.9%	41%
Biofuel part B	44.2%	44.2%	0%
Biofuel part C	36.8%	36.8%	59%
Weighted average SAF price	€2107	€1938	€1653
Kerosene price forecast[17]	€600	€623	€690
SAF price premium	€1507	€1315	€963

Note: Our price estimates are based on assumptions following Destination 2050 (NLR & SEO, 2021). Internal airline price estimates indicate price premiums of up to € 3000 per ton. Hence, our SAF price premiums are considered conservative.

Source: SEO & NLR (2022)

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[17] Source: U.S. Energy Information Administration - EIA - Independent Statistics and Analysis

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