Assessment of the impact of the Fit for 55 policies on airports

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Figures and tables

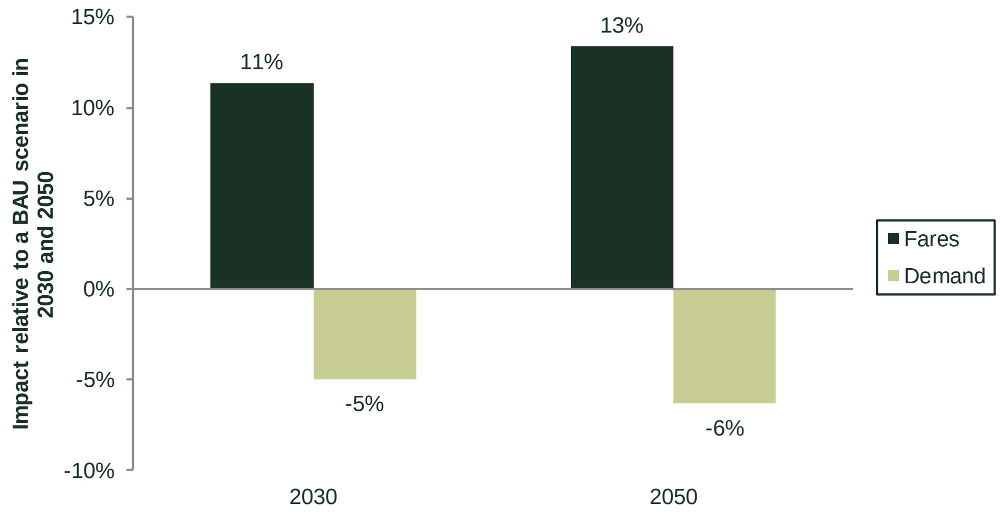
Executive summary

The European Commission has put forward the Fit for 55 proposals to achieve a 55% reduction in carbon emissions by 2030 relative to 1990 levels, and to meet net zero targets by 2050. In particular, to address the aviation sector's impact on the environment, the European Commission has proposed mandating the use of sustainable aviation fuels (in its ReFuelEU Directive), requiring the supply of electricity to stationary aircraft (in the Alternative Fuels Infrastructure Regulation, AFIR), and putting an effective price on CO_2 emissions and jet fuel (through the EU Emission Trading System, ETS, implementation of CORSIA, and the European Taxation Directive, ETD). These policies are targeted at reducing carbon emissions associated with aviation and do not address non-CO_2 warming effects, such as those caused by contrails.

Our analysis shows that the Fit for 55 proposals will lead to additional costs that will need to be borne by airports, airlines, and/or passengers. For example, the AFIR will require airports to upgrade or change their infrastructure to ensure that electricity supply can be provided to aircraft at gates and stands. The other proposals will lead to increased costs to airlines—e.g. by introducing a tax for kerosene. The extent to which airlines mitigate, absorb or pass through these cost increases to passengers, and how passengers respond to any fare changes, will determine the effect of these proposals on carbon emissions, and demand and revenue at airports.

The Fit for 55 proposals will reduce demand at European airports compared to a scenario where these policies are not implemented (i.e. a business-as-usual scenario). Relative to a business-as-usual scenario, fares on direct flights are expected to increase by 11% in 2030 and 13% in 2050, leading to a reduction in demand of 5% in 2030 and 6% in 2050 (see figure below). However, compared to 2019, demand for air travel is still expected to increase, even after accounting for the policies' impact. This is due to the effects of other demand drivers, such as economic growth and rising income. Therefore, while demand growth will be lower than it would have been in the absence of such policies, there will still be an increase in the number of passengers travelling.

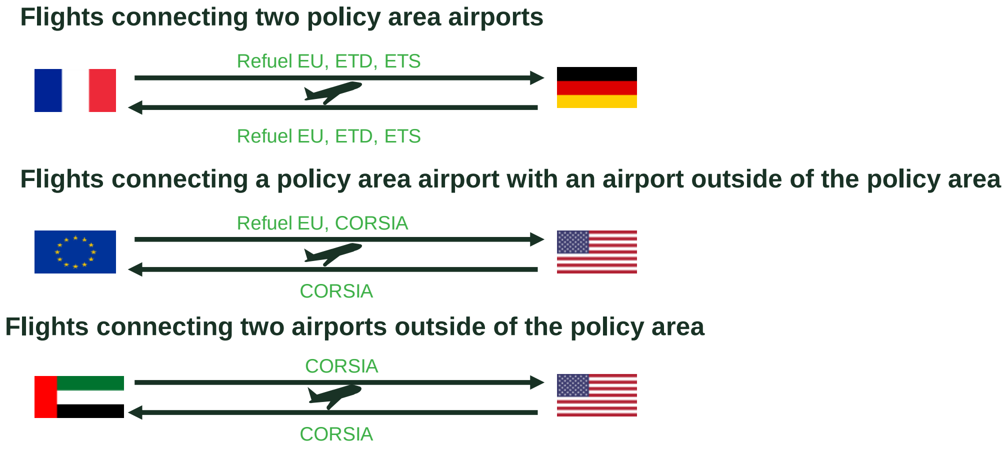
Passenger demand on direct flights in 2030 and 2050 with the implementation of the Fit for 55 proposals, relative to a business-as-usual scenario



Source: Oxera analysis.

Of the five policies evaluated, demand in 2030 is most affected by the implementation of the ETD and the ETS, while the SAF mandate in the ReFuelEU proposal has the largest effect on demand in 2050. The Fit for 55 policies affect flights that operate within the policy area—which includes the EEA plus the UK and Switzerland in our analysis—more than flights between Europe and other regions. For example, the ETS and ETD only apply to flights within the EEA and EU respectively, while RefuelEU applies on flights between two EU airports, and from an EU to a non-EU airport (though not on the return journey—see below). Therefore, the cost increases and demand reductions on flights within the EU will be much greater than on flights between EU and non-EU airports. As a result, the proposals reduce carbon emissions per passenger by 54% in 2050 on flights within the EU, but only by 20% on flights that connect EU and non-EU airports.

Application of Fit for 55 policies on direct flights

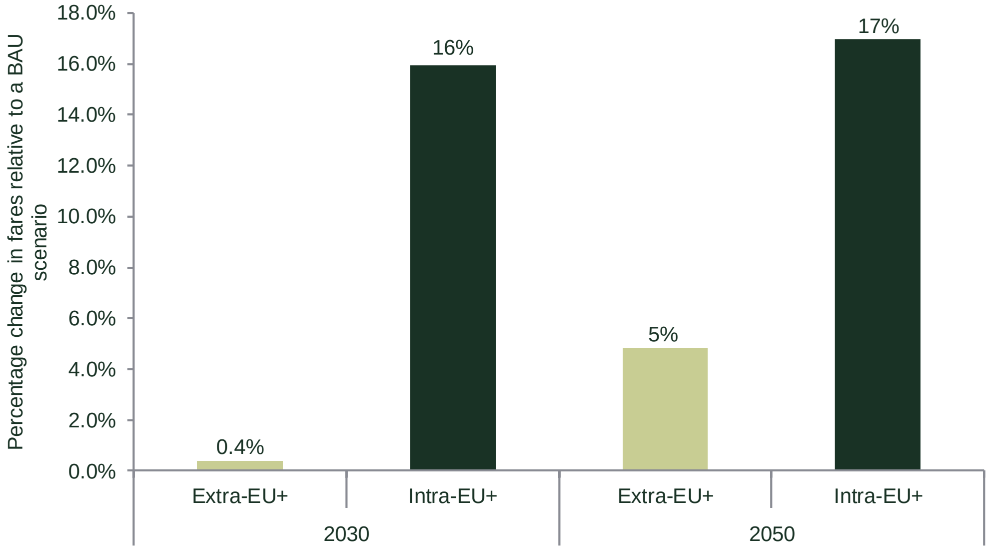


Source: Oxera analysis.

The Fit for 55 proposals have a more significant effect on demand and carbon emissions on direct intra-European flights compared to direct extra-European flights (see the figure below). For this reason, regional airports with a large share of intra-EU traffic will be most affected. In addition, regional airports tend to have a higher proportion of low-cost carriers operating at the airport with lower average fares. The Fit for 55 proposals represent a higher proportional increase in air fares for low-cost carriers, leading to a greater demand response. This may, in turn, lead to a loss in connectivity at these airports.

As a result of the Fit for 55 policies, some passengers will choose not to travel, some may use other modes, and some may divert to other routes. For instance, a passenger who previously travelled from Paris to Mallorca may instead choose to travel from Paris to Agadir to avoid the costs of the ETD and the ETS. As a result, the demand on extra-EU routes is expected to increase.

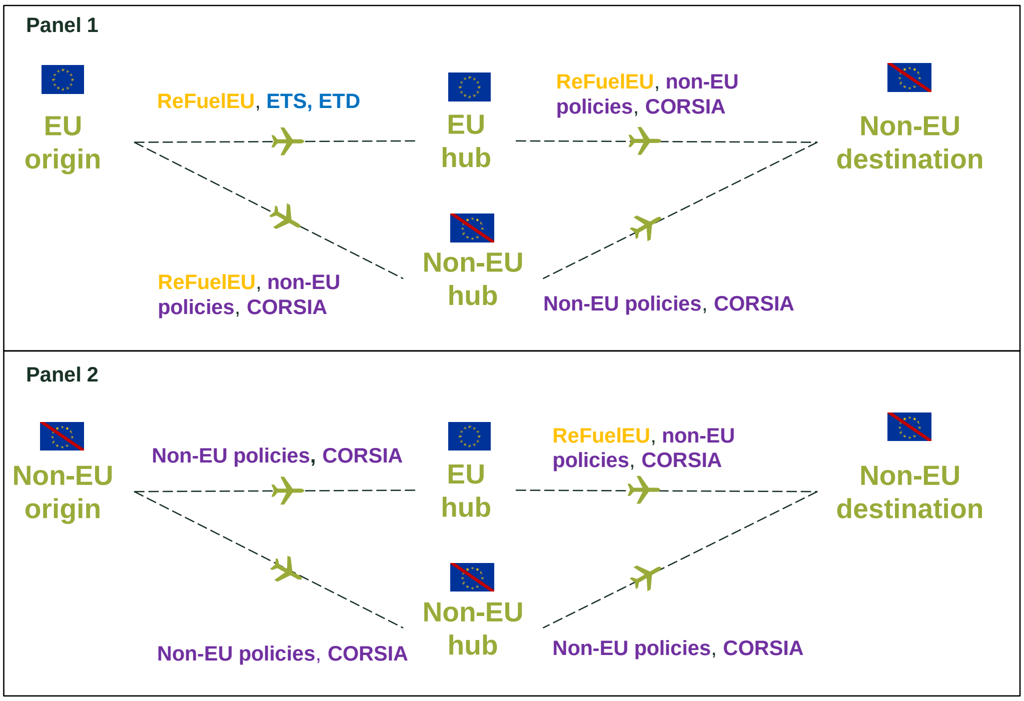
Impact of the Fit for 55 policies on fares on direct flights, by region



Source: Oxera analysis.

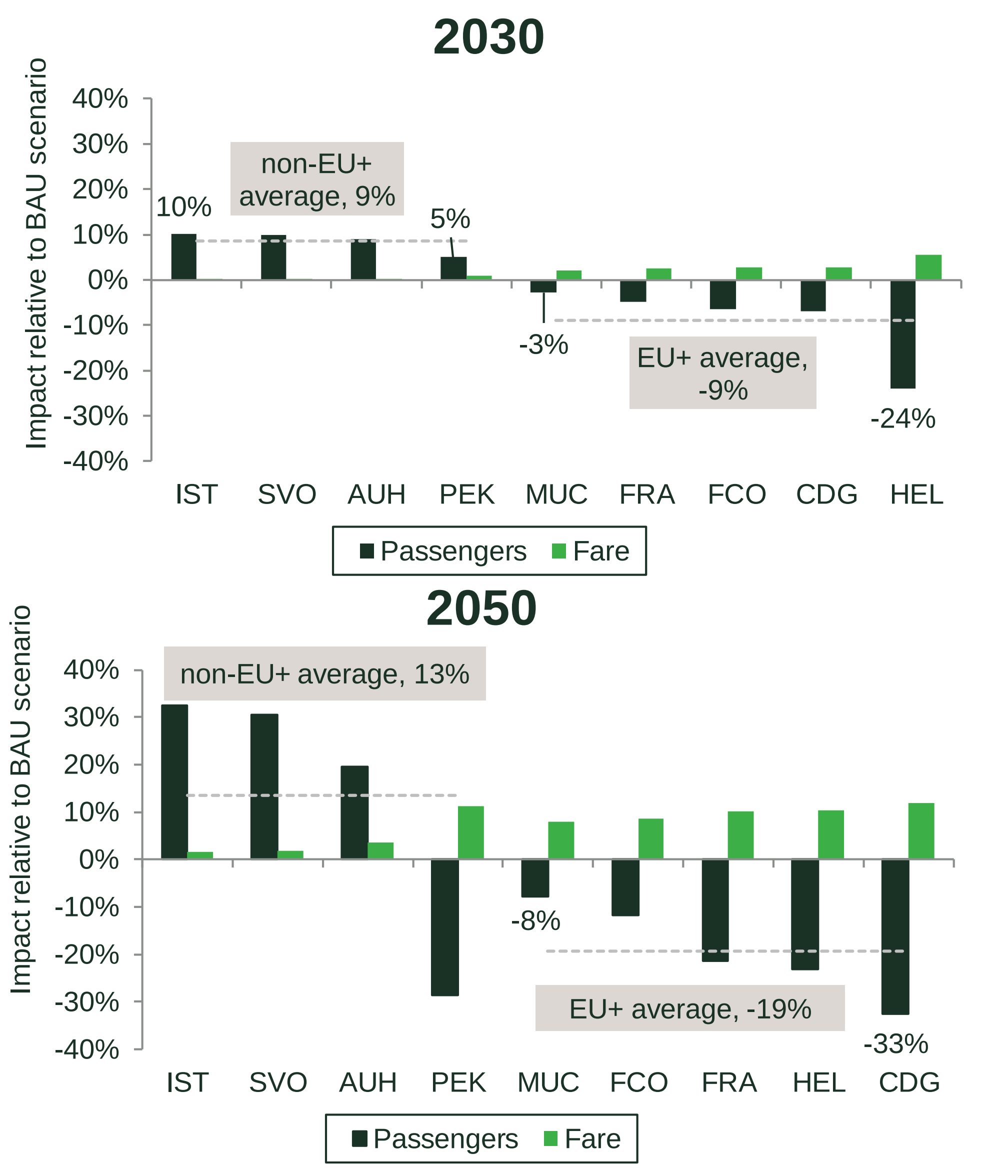
The Fit for 55 policies will have a much greater impact on airlines and passengers travelling through EU hubs compared to non-EU hubs, leading to a distortion of competition and the leaking of carbon emissions outside of the EU. Therefore, passengers could alter their journeys to avoid the fare increases associated with these policies. For instance, a connecting passenger travelling from Munich to Lima could choose to hub in Atlanta rather than Madrid.

Relevant Fit for 55 proposals for different types of connecting itineraries



As a result, EU hubs will lose connecting passengers, who will choose to hub through non-EU airports instead. For example, on the route between Seoul Incheon and Milan Malpensa, there are a number of potential hubs that a passenger can use, as shown in the figure below. The introduction of the Fit for 55 policies leads to a loss of connecting passengers at EU hubs, ranging from 3% at Munich to 24% at Helsinki in 2030. The lost passengers divert to non-EU hubs, such as Istanbul, Abu Dhabi and Moscow airports, which experience increases in demand of 9% on average in 2030.

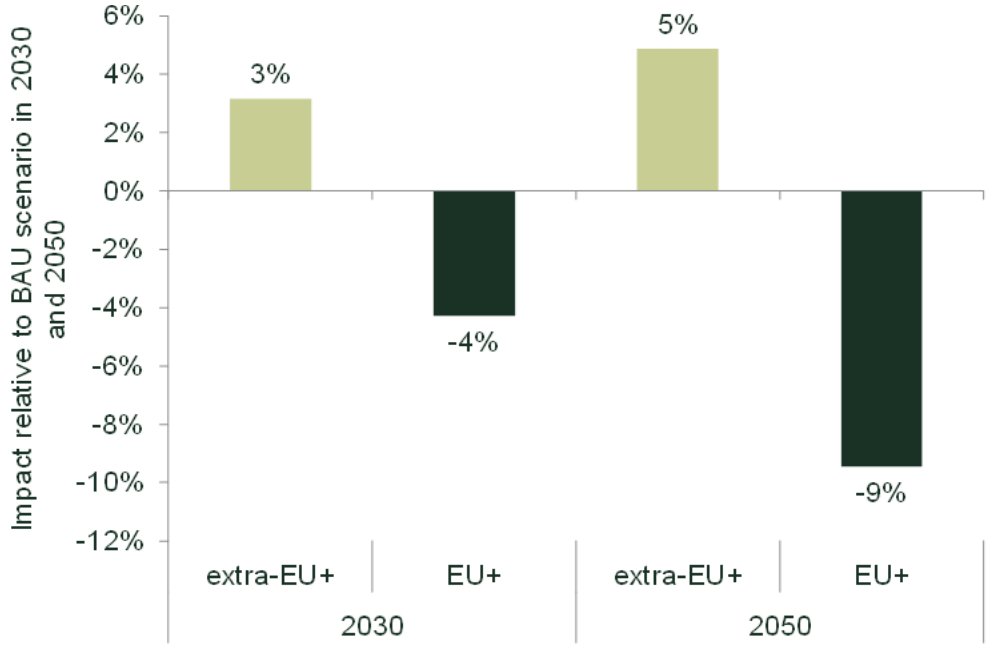
Demand changes on connecting itineraries between Milan Malpensa and Incheon airports



Source: Oxera analysis.

Overall, across the connecting routes considered, we find that EU hub airports will face a loss in connecting traffic of 4% in 2030 and 9% in 2050. While the average impact on connecting itineraries is less than that of direct flights, we estimate a significant loss in connecting traffic for certain hubs and on certain routes, creating a loss of connectivity for many passengers. Connecting traffic at non-EU hubs will increase by 3% in 2030 and 5% in 2050 as a result of the diversion of passengers from EU hubs due to the Fit for 55 proposals.

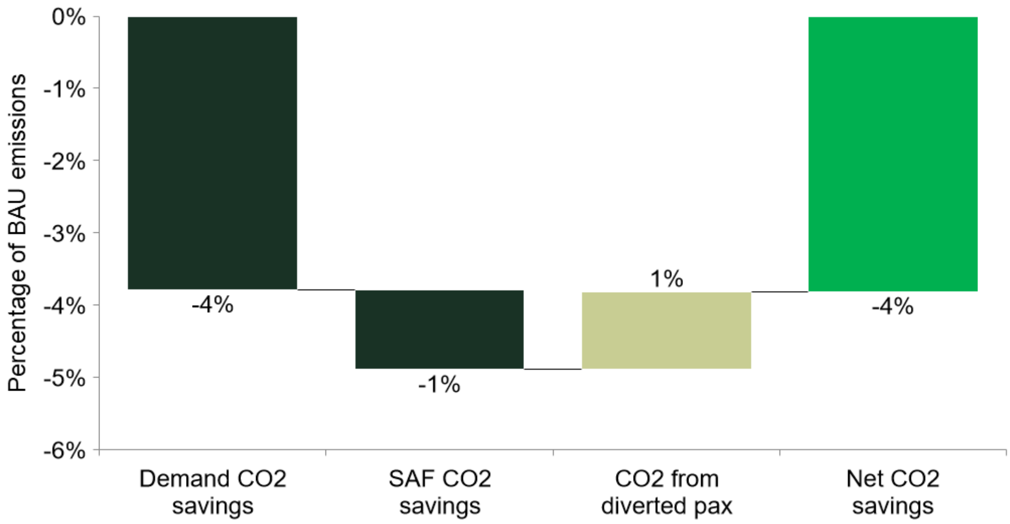
Demand changes on connecting itineraries by region, 2030 and 2050



Source: Oxera analysis.

The Fit for 55 policies will lead to a reduction in net carbon emissions. While carbon emissions at non-EU airports are likely to increase, this will not offset the overall carbon savings associated with the Fit for 55 policies. For example, on direct journeys in 2030, the Fit for 55 policies will lead to CO_2 savings through reductions in demand (4%) and the use of SAF (1%). These savings are offset by 1% as a result of passengers continuing to fly to/from other airports, leading to a total net CO_2 saving of 4% on direct journeys.

Effect of Fit for 55 proposals on carbon emissions for direct traffic in 2030

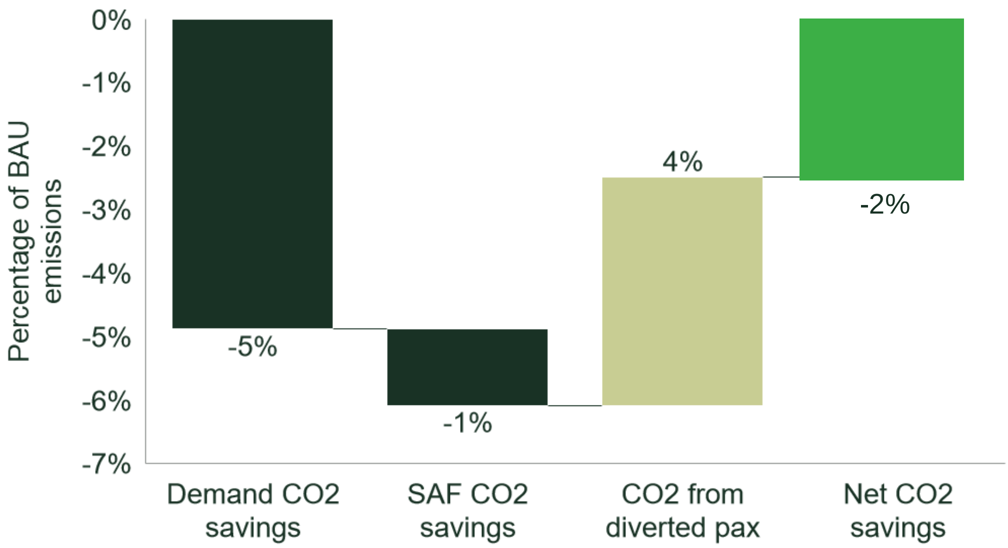


Source: Oxera analysis.

The same is true for connecting journeys, though the CO_2 from diverting passengers on these journeys offsets the CO_2 savings from demand reductions and the use of SAF by more than half in 2030. These figures include carbon emission savings across all of the itineraries analysed. Because

European airports are more affected by the policies, carbon emission reductions at EU+ airports will tend to be larger than the average figures cited here.

Effect of Fit for 55 proposals on carbon emissions for connecting traffic in 2030



Source: Oxera analysis.

Both for direct and connecting journeys, the net CO_2 savings are much larger in 2050 than 2030. For example, for connecting journeys, net carbon savings are more than 13 times larger, at 27% in 2050.

1 Introduction

Oxera has been commissioned by ACI EUROPE to consider the impact of the European Commission's Fit for 55 proposals on airport operators.

In setting out the Fit for 55 package, the European Commission has the objective to reduce greenhouse gas (GHG) emissions by at least 55% by 2030, compared to 1990 levels, on the way to becoming climate neutral by 2050. These comprehensive proposals cover a number of areas, including the application of emissions trading to new sectors, increased use of renewable energy and measures to prevent carbon leakage.

In particular, there are a number of policies that will have direct effects on the aviation industry, such as targets for the use of sustainable aviation fuel and the taxation of kerosene. These policies will reduce emissions from the aviation sector, but they will also lead to additional costs that will need to be borne by airports, airlines, and/or passengers. There is therefore much debate about the extent to which these policies will affect the competitiveness of the EU aviation sector and lead to carbon leakage.

The effect of these policies on airports and carbon emissions depends on a number of factors, such as:

- policy design in the EU and elsewhere—for instance, whether the emissions trading scheme (ETS) is applied only to intra-European flights or applies to flights to/from Europe as well;
- industry response—e.g. the extent to which airlines respond in terms of using additional sustainable aviation fuel or pass on the additional costs of the policies to passengers through fare rises;
- passenger demand response—the extent to which passengers stop travelling, use other modes of transport, choose destinations outside the EU or use non-EU hubs for connecting flights.

This study considers the responses of airlines in mitigating, absorbing or passing through those costs, as well as the responses of passengers to potential fare rises. This will, in turn, determine the impact of Fit for 55 policies on carbon emissions, as well as passenger demand. We assess the impact on airports in 2030 and 2050 given that the Fit for 55 policies will be phased in over the next few decades.

This report is structured as follows.

- Section 2 sets out an overview of the Fit for 55 proposals that will have an effect on the aviation industry.
- Section 3 explains the methodology used to analyse the effect of the Fit for 55 policies on airport operators.
- Section 4 outlines the potential for carbon leakage as a result of the Fit for 55 policies.
- Section 5 provides the results of our analysis.
- Section 6 sets out additional sensitivity analysis.
- Section 7 concludes.

The appendices provide more detail on our analysis.

2 Overview of the Fit for 55 proposals

2.1 Introduction

On 17 September 2020, in her State of the Union address, European Commission President Ursula von der Leyen updated the EU's 2030 emissions reduction target from a 40% reduction in emissions by 2030 (relative to 1990 levels) to a 55% reduction by 2030. In July 2021, the European Commission accompanied this increased ambition with the Fit for 55 package, which contains a comprehensive set of legislative proposals, including legislation on land use and forestry, renewable energy, energy efficiency, emission standards for new cars and vans, and taxation. The goal of this ambitious set of proposals is to reduce GHG emissions in all sectors across the EU as part of the effort to become climate neutral by 2050.

There are a number of proposals in this package that directly impact the aviation sector. In particular, the following five proposals are expected to have a significant impact on the EU aviation industry:

- **the Alternative Fuels Infrastructure Regulation (AFIR)**, which mandates the supply of electricity to stationary aircraft;
- **ReFuelEU aviation**, which mandates the use of sustainable aviation fuels (SAF);
- **a proposal for a revision of the Energy Taxation Directive (ETD)**, which introduces a tax on kerosene;
- **a general ETS reform**, which reduces the free allowances granted to the aviation sector;
- **implementation of CORSIA**, which will cover flights originating or terminating outside of the EEA.

The policy proposals still need be ratified by the European Parliament and Council of the EU. In this report, we consider the policies as they are currently described in the Fit for 55 proposals, but we note that there may be changes during the legislative process.

2.2 Fit for 55 proposals with impacts on the aviation sector

Table 2.1 sets out a summary of the elements of the key policy proposals that are relevant to the aviation sector, and describes their potential impacts.[1] We focus on the effect on passenger traffic, though we note that the cargo segment of the market is also likely to be affected.

[1] Other policy proposals, such as the Amendment of the Renewable Energy Directive or the proposal to extend the emissions trading scheme to the building and roads sectors, may have some limited impacts on the aviation industry. However, as these impacts are not expected to be significant, we have not assessed these policies in detail.

Table 2.1 Overview of Fit for 55 proposals with impacts on the aviation industry

Proposal	Summary of proposal
Alternative Fuels Infrastructure Regulation (AFIR)	Under the AFIR, airports will need to provide electricity supply to stationary aircraft by:[2] • 1 January 2025 at all gates; • 1 January 2030 at all outfield posts (i.e. remote stands). As of 1 January 2030 at the latest, the electricity supply needs to come from the electricity grid or be generated on site as renewable energy.[3] Therefore, diesel ground power units (GPUs) will no longer be allowed, and electric-powered GPUs (eGPUs) with electricity sourced from the grid or produced on-site as renewable energy will be needed. Member states will also need to develop a deployment plan for alternative fuels infrastructure at airports other than for electricity supply to stationary aircraft, in particular for hydrogen and electric recharging for aircrafts.[4] These proposals will affect TEN-T core and comprehensive network airports.[5] Given that the market for alternative fuels infrastructure is still in the early stages of development and technology is evolving quickly, the Commission states it should review this proposal by the end of 2026.[6]
ReFuelEU aviation	Airports covered by this Regulation need to ensure that all the necessary infrastructure is provided for delivery, storage and refuelling of sustainable aviation fuel.[7] In addition, fuel providers need to ensure that the following share of SAF is uplifted at airports in the EU.

Date (1 January)	2025	2030	2035	2040	2045	2050
SAF share (%)	2	5	20	32	38	63
Synthetic aviation fuels share (%)	0	0.7	5	8	11	28

[2] European Commission (2021), 'Proposal for a regulation of the European Parliament and of the Council on the deployment of alternative fuels infrastructure, and repealing Directive 2014/94/EU of the European Parliament and of the Council', p. 38, https://bit.ly/31Ub6jV.
[3] Ibid.
[4] Ibid., p. 39.
[5] European Commission (2021), 'Regulation (EU) No 1315/2013 of the European Parliament and of the Council of 11 December 2013 on Union guidelines for the development of the trans-European transport network and repealing Decision No 661/2010/EU Text with EEA relevance', annex II, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2013.348.01.0001.01.ENG.
[6] Ibid., para. 54.
[7] European Commission (2021), 'Proposal for a regulation of the European Parliament and of the Council on ensuring a level playing field for sustainable air transport', para. 22, https://bit.ly/31YcDoP.

	SAF is considered as having 'zero emissions' under the EU ETS, though not under CORSIA.[8] To avoid tankering, airlines must ensure that the yearly quantity of aviation fuel uplifted at an EU airport is at least 90% of the yearly aviation fuel required. This requirement applies to the amount of aviation fuel necessary to operate the totality of commercial air transport flights of an airline. This will only be applied to airlines operating at least 729 flights per annum, and at airports where there are at least a million passengers per annum.[9]
Proposal for a revision of the Energy Taxation Directive (ETD)	There are two key aspects of this proposal.[10] 1. There is a new structure of tax rates based on the energy content and environmental performance of fuel and electricity rather than volume. Minimum rates will be based on the energy content (expressed in euros per gigajoules, GJ). Proposed minimum rates will be automatically adjusted annually based on Eurostat consumer price figures. 2. It broadens the taxable base by including more products in scope and by removing some current exemptions and reductions. However, certain reduced rates will remain—e.g. for advanced energy products from renewables. As a result of the above, kerosene is no longer fully exempt from energy taxation for intra-EU journeys. The proposal sets out that tax will be introduced gradually over ten years (by one tenth each year) before it reaches the minimum rate in 2033. Sustainable and alternative fuels will have zero minimum tax rate for a transitional period of ten years, and then will be taxed. The taxes for different fuels are as follows. • Conventional fossil fuels (gas oil and petrol) and non-sustainable biofuels will have a minimum rate of €10.75/GJ when used as a motor fuel. This rate also serves as a reference rate for other categories. • Natural gas, LPG, and non-renewable fuels of non-biological origin will have a rate of €7.17/GJ (two-thirds of the reference rate) when used for motor fuel for a period of ten years, and will then be taxed at the same rate as fossil fuels. • Sustainable fuels, but not advanced biofuels, will be taxed at €5.38/GJ (half the reference rate) when used as motor fuel. • The lowest minimum rate of €0.15/GJ applies to electricity, advanced sustainable biofuels and biogas, and renewable fuels of non-biological origin (RFNBO). Low-carbon hydrogen and related fuels will also benefit from that same rate for a transitional period of ten years. Kerosene will fall into the conventional fossil fuels category, and hence will be subject to the €10.75/GJ rate. SAF will be in one of the latter two categories. Cargo-only flights are exempt but private jets will be taxed at the minimum rates from 2023.

[8] Ibid., p. 19.
[9] European Commission (2021), 'Proposal for a regulation of the European Parliament and of the Council on ensuring a level playing field for sustainable air transport', p. 20, https://bit.ly/31YcDoP.
[10] European Commission (2021), 'Revision of the Energy Taxation Directive (ETD): Questions and Answers', 14 July.

Reform of EU ETS and ICAO CORSIA	Aviation was added to the EU's Emissions Trading Scheme (ETS) in 2012, with the scheme originally implemented in other sectors in 2005.[11] The scheme was set up to cover every flight originating, terminating, or travelling between airports within the EEA. However, in light of the development of CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation), this was restricted to intra-EEA flights only from 2016.[12] If no further amendments are made to the coverage of the ETS, then the scheme will cover flights originating or terminating outside of the EEA (while terminating or originating in the EEA respectively) from 2024.[13] This reversion will be dependent on whether CORSIA uses a baseline of the average of 2019 and 2020 emissions data or 2019 only. The EU has indicated that an average of both years should be used, and if the emissions from 2019 only are used then the ETS will revert to its original scope in 2024.[14] CORSIA involves estimating emissions from all airlines and limiting or offsetting any growth in emissions after 2020. This means that airlines must purchase a certain number of offsets of sufficient quality to stabilise the growth in their emissions from 2020. In light of COVID-19, the benchmark emissions is based on 2019 data only, rather than on an average of 2019 and 2020 emissions.[15] The ETS scheme, under current prevailing prices, is significantly more expensive for an airline, and is projected to continue to be so over the next decade.[16]
General ETS reform	The progressive phase-out of free allowances to aircraft operators is proposed to take place over the next five years, with reductions of 25% in 2024, 50% in 2025, and 75% in 2026, and a complete phase-out by 2027. The Commission has also proposed reducing the emissions cap (i.e. the linear reduction factor, LRF) by 4.2% annually (instead of the current 2.2%). The increased LRF is combined with a one-off downward adjustment of the cap, so the new LRF has the same effect as it would had it applied from 2021. This will ensure that the cap declines at an increased annual rate, resulting in an overall emission reduction for sectors under the EU ETS of 61% by 2030 compared to 2005. The EU ETS would continue to apply to intra-EEA flights, as well as to flights to the UK and Switzerland, exempting those flights from CORSIA offsetting requirements. Exemptions exist until 2023 for flights between EEA territories on the European continent and outermost regions, as well as between outermost regions as defined in Article 349 of the Treaty on the Functioning of the European Union.[17]

[11] European Commission (2021), 'Development of EU ETS (2005-2020)', https://ec.europa.eu/clima/eu-action/eu-emissions-trading-system-eu-ets/development-eu-ets-2005-2020_en.
[12] European Commission (2021), 'Reducing emissions from aviation', https://ec.europa.eu/clima/eu-action/transport-emissions/reducing-emissions-aviation_en.
[13] Ibid.
[14] European Commission (2021), 'Directive of the European Parliament and of the Council amending Directive 2003/87/EC as regards aviation's contribution to the Union's economy-wide emission reduction target and appropriately implementing a global market-based measure', 14 July, pp. 13, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021PC0552
[15] ICAO (2020), 'ICAO Council agrees to the safeguard adjustment for CORSIA in light of COVID-19 pandemic', 30 June, https://www.icao.int/Newsroom/Pages/ICAO-Council-agrees-to-the-safeguard-adjustment-for-CORSIA-in-light-of-COVID19-pandemic.aspx.
[16] van Velzen, A., de Bruyn, S., Bachaus, A. (2019), 'Costs of EU ETS and CORSIA for European aviation', November, https://www.transportenvironment.org/discover/costs-eu-ets-and-corsia-european-aviation/.
[17] For more information on the exemptions see Deutsche Emissionshandelsstelle (2021), 'Geographical scope: Which flights are subject to EU ETS?', 9 December, https://www.dehst.de/SharedDocs/antworten/EN/Aviation/LV_005_scope.html.

2.3 The impact of Fit for 55 policies on airports

The impact of the Fit for 55 policies on airports can be separated into two broad categories.

- **Direct impacts** are those that lead to airports directly bearing the costs of the policy—for example, by requiring airports to carry out additional investments or to incur additional operating costs.
- **Indirect impacts** are those that lead to cost increases for airlines, which may then be passed on to passengers as higher fares, leading to lower passenger demand and revenue for airports.

These two impacts are discussed further below. In Appendix A1, we consider the potential wider economic impacts of the Fit for 55 proposals on employment and GDP in the European aviation sector.

2.3.1 Direct impacts on airports

There are two Fit for 55 proposals that may create direct costs for airports: the Alternative Fuels Infrastructure Regulation and the ReFuelEU proposal.

The Alternative Fuels Infrastructure Regulation

As discussed in section 2.2, the AFIR requires airports to supply electricity to stationary aircraft, though airports can decide how they implement this regulation. For example, airports could use electrical ground power at gates and stands, electric GPUs ('eGPUs'), or a combination of different solutions.[18]

The costs of meeting the AFIR depend on a range of factors. For example, if airports already supply electricity to gates and stands for other purposes, then ACI EUROPE estimates that the extra costs of providing fixed electrical ground power will be approximately €100,000 per gate or stand. However, if electricity provision needs to be set up from scratch, which may be the case at a number of smaller airports, then the additional costs of meeting the AFIR will be higher, at approximately €200,000 per gate or stand.[19] In addition, costs will differ depending on the proportion of wide- or narrow-bodied aircraft served by an airport, as the costs of supplying electricity to stands serving wide-body aircraft are approximately double those of serving narrow-body aircraft.[20]

Table 2.2 below sets out the number of contact gates and remote stands at airports of different sizes, classified into five groups.

[18] If GPUs are used, there is no expectation that there will be one GPU per stand; one GPU may be used to serve several stands.
[19] The European Commission notes that based on a 2018 ACI Europe survey of 51 airports, 42 of them provide fixed electrical ground power to aircraft on-stand, but this does not work for all types of operation, particularly low-cost airlines with short turnaround times. See European Commission (2021), 'Commission Staff Working Document. Evaluation of Directive 2014/94/EU of the European Parliament and of the Council on the deployment of alternative fuels infrastructure accompanying the Proposal for a Regulation of the European Parliament and of the Council on the deployment of alternative fuels infrastructure, and repealing Directive 2014/94/EU of the European Parliament and of the Council', 14 July, p. 15.
[20] We have asked a number of airports about the costs of providing fixed electrical ground power. While we have not received a sufficient number of responses to draw general conclusions, the cost estimates we have received fall broadly in line with the figures described in the text. For example, one airport reported that the investment costs of providing fixed electrical ground power from scratch to narrow-body aircraft is €170,000 per stand, and €340,000 for wide-body aircraft. Another airport reported that the cost of providing fixed electrical ground power is around €250,000 per stand, although it did not specify what type of aircraft these stands were serving, or if electrical power was already provided for other purposes.

Table 2.2 Contact gates and remote stands, by airport size

		Contact Gates			Remote stands		
Group	**Group traffic band (mppa)**	**Average**	**Max**	**Min**	**Average**	**Max**	**Min**
Group 1	>25	41	99	9	59	149	10
Group 2	15–25	23	29	9	49	110	17
Group 3	5–15	7	17	0	37	111	12
Group 4	1–5	3	9	0	15	32	0
Group 5	<1	0	6	0	4	18	0

Source: ACI EUROPE, based on a sample of 217 airports in 2019.

We estimate the potential direct costs for airports to comply with the AFIR by using fixed electricity supply in Table 2.3 below. We multiply the costs of supplying electricity as described above by the average number of contact gates and remote stands for each airport group. (Figures using the minimum and maximum number of stands and gates for each group can be found in Appendix A2.)

As we do not have data on how many gates and stands have existing electricity supply or serve wide- vs narrow-body aircraft at airports of different sizes, we provide a range of estimates. These estimates should therefore be treated as indicative of the potential costs of complying with the AFIR.

We calculate the costs of the AFIR assuming that there is no existing electricity supply to any gates/stands and compare this to the cost if all gates/stands already have existing electricity supply for other purposes. We also illustrate the costs if an airport has 50% of gates or stands serving wide-body aircraft compared to if the airport only serves narrow-body aircraft. However, we note that for airports in Groups 3–5, there is unlikely to be a significant number of stands for wide-body aircraft.

Table 2.3 Investment costs of AFIR assuming an average number of remote stands and contact gates by airport group, €m

		All narrow-body aircraft		With 50% of gates/stands for wide-body aircraft	
Group	**Group traffic band (mppa)**	**With existing electricity supply for other purposes**	**No existing electricity supply**	**With existing electricity supply for other purposes**	**No existing electricity supply**
Group 1	>25	10.0	20.0	15.0	30.0*
Group 2	15–25	7.2	14.4	10.8	21.6
Group 3	5–15	4.4	8.8	6.6	13.2
Group 4	1–5	1.8	3.6	2.7	5.4
Group 5	<1	0.4	0.8	0.6	1.2

Note: The grey cells indicate that it is unlikely smaller airports will have a significant number of stands for widebody aircraft. OAG data indicates that more than 95% of departures from these airports are short-haul flights of less than six hours in duration. * Zurich Airport has produced a calculator of the costs of providing fixed electricity and pre-conditioned air to aircraft. We have used the calculator as a cross-check and note that it provides very similar estimates to this figure. The calculator also estimates that there will be additional costs of around €346k per annum for airports, although airlines will benefit and have lower costs by about €13m per annum.

Source: Oxera analysis of data provided by ACI.

The results show that for the smallest airports (Group 5), the costs of meeting the AFIR are likely to be between €0.4m and €0.8m, while for the largest airports (Group 1), average costs could be between €10m and €30m. For the largest airports in Group 1, we estimate that costs could range from €37m to €74m. This reflects the initial investment costs of providing fixed electricity supply, but we note that there may be additional operating costs for airports.

Another way to provide electricity to stationary aircraft is to use eGPUs. If eGPUs are used to provide electricity, there is an initial investment cost of around €170,000 per eGPU, as well as the costs of providing the relevant charging infrastructure.[21] However, there is also potentially an operational cost saving of using eGPUs compared to diesel GPUs.[22] ACI EUROPE estimates that in ten years of average use (six hours per day), the total operating costs of using a diesel GPU could be €557,800 compared to €249,800 for eGPUs. However, the costs of using eGPUs are not yet fully known. For example, there is still uncertainty over how long the batteries within eGPUs may last. Therefore, further information is needed to provide more definitive estimates of the costs of eGPUs and fixed electrical ground power.

Any costs incurred as a result of the AFIR may be met directly by airports, passed on (in part or in full) to airports by their suppliers (e.g. at some airports, the ground handlers own mobile assets such as eGPUs), or passed onto airlines in the form of higher airport charges. Airlines may then pass on the costs to passengers as higher fares, leading to lower passenger demand, and aeronautical and non-aeronautical revenues for airports. However, given the uncertainty around the additional costs of meeting the AFIR and the extent to which they would be passed through,[23] we do not quantify these indirect effects of the AFIR in this study.

The ReFuelEU proposal

The Refuel EU proposal (Article 6) states that airport management is exclusively responsible for the provision of infrastructure for the delivery, storage and uplifting of SAF. However, in most cases, airport managing bodies do not own or operate the fuel supply infrastructure and thus cannot be exclusively responsible for the provision of the fueling infrastructure. Instead, they are more likely to be in the role of facilitating SAF use at airports.

For this reason, this policy is not expected to require (significant) additional infrastructure investment by airport operators. The European Commission states that SAF is fully fungible with conventional aviation fuel. SAF will be blended with jet fuel, and all fuel arrives blended at the airport. The Commission states that while logistical adaptations will be required in upstream parts of the SAF supply chain, this obligation is on fuel suppliers and is not expected to affect airports. Therefore, the need for additional infrastructure at airports may be limited.[24]

The ReFuelEU proposal may also lead to indirect impacts on airports due to its effect on airline costs and passenger demand. This is considered in the following section.

[21] We do not have sufficient data to determine the costs of providing additional charging infrastructure for electricity GPUs.
[22] Based on information from ACI.
[23] The extent to which these costs are passed-through and the time period over which the costs are recovered, may depend in part on the regulatory regime in place at the airport.
[24] European Commission (2021), 'Proposal for a regulation of the European Parliament and of the Council on ensuring a level playing field for sustainable air transport', 14 July, section 1.4, https://bit.ly/35qd2C9.

2.3.2 Indirect impacts on airports

In addition to the direct impacts considered above, the Fit for 55 proposals, once adopted, will have indirect impacts on airports by affecting airlines' costs and fares, and therefore passenger demand. As the Fit for 55 proposals have different geographical scopes, the impact of the proposals will depend on a passenger's travel itinerary. An itinerary (in this context) is a specific path taken from an origin to a destination airport. For example, a passenger travelling from Munich to Lima may have a choice of two different itineraries—transferring at either Madrid Airport or Atlanta Airport. If the passenger hubs through Madrid, their itinerary would be composed of an intra-EU leg (Munich–Madrid) and an EU to non-EU leg (Madrid–Lima). This would be subject to different impacts of the Fit for 55 proposals to an itinerary in which the passenger hubs through Atlanta, as their itinerary would then be composed of an EU to non-EU leg (Madrid–Atlanta) and a leg between two non-EU airports (Atlanta–Lima). Therefore, to determine the impact of the Fit for 55 proposals, it is necessary to examine each leg of a passenger's itinerary—see Box 2.1 below.

Box 2.1 Defining 'route', 'itinerary' and 'leg' of a journey

A **route** is the starting and end point of a journey—i.e. Munich–Lima.

An **itinerary** is the passenger journey to get from the origin to the destination—i.e. Munich–Madrid–Lima.

A **leg** is an individual flight in an itinerary. The itinerary Munich–Lima via Madrid has two legs: Munich–Madrid and Madrid–Lima.

For direct flights, the route, itinerary and leg are identical.

Source: Oxera.

We distinguish between four types of itineraries—direct intra-EU; direct EU to non-EU; direct non-EU to non-EU; and connecting. Below we discuss the Fit for 55 proposals that are relevant for each type of itinerary, and how they interact with one another. We quantify these effects in section 5.

Direct intra-EU itinerary

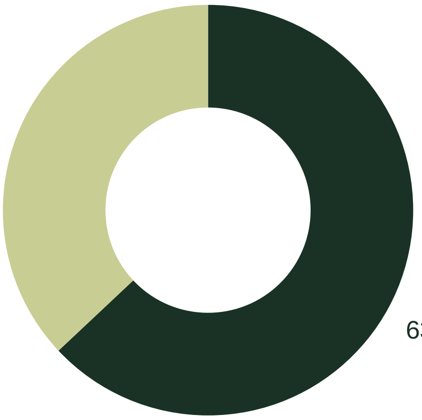
Airlines operating intra-EU flights will be subject to the ReFuelEU proposal, and will therefore be required to uplift a certain proportion of SAF (5% by 2030 and 63% by 2050) at both ends of the journey. For the remaining fuel not covered by the ReFuelEU mandate, airlines will have a choice as to how to power their aircraft. This is illustrated in Figure 2.1 below using 2050 as an example.

- Airlines could continue to use traditional jet fuel to abate their remaining emissions. In this case, the ETS carbon price would apply to emissions from this fuel, and it would be taxed under the ETD.
- Airlines may choose to use SAF to abate all carbon emissions. While the current blending limit for SAF is 50%, it is anticipated that this will be lifted to 100% in the future.[25]
- Airlines may choose an alternative technology to abate emissions—for instance, hydrogen or electric aircraft. However, these technologies will

[25] Aviation Benefits Beyond Borders, 'Producing sustainable aviation fuel', https://aviationbenefits.org/environmental-efficiency/climate-action/sustainable-aviation-fuel/producing-sustainable-aviation-fuel/.

likely not be available until around 2040 or 2050, and even then are likely to be focused on short-haul flights.[26]

Figure 2.1 Fuel choices in 2050, intra-EU itineraries



Source: Oxera.

Depending on the cost of SAF and the availability of hydrogen fuels and electric aircraft, airlines may uplift a higher proportion of SAF than the minimum mandated under ReFuelEU. This is particularly likely as the application of the EU ETS and the ETD on these itineraries will provide further incentives to use SAF.

- Under the ETS, SAF is considered to have zero emissions, thereby reducing an airline's reported emissions, and the number of ETS allowances it has to purchase.[27]
- According to the ETD, SAF is considered to be an 'advanced biofuel', and is therefore subject to the lowest ETD tax rate. Furthermore, during the transitional period, SAF is not taxed under the ETD.[28]

However, it is also possible that there will not be sufficient SAF, due to technological challenges or lack of supply, to exceed or even meet the SAF mandates, and airlines will need to use more traditional kerosene than is set out under the ReFuelEU proposal. This is considered further in our modelling of different sensitivities in section 6.

Direct EU to non-EU itineraries

The main Fit for 55 proposal affecting these itineraries is ReFuelEU. However, as ReFuelEU only applies to departing flights from the EU, the mandated SAF proportions would not apply to flights arriving into the EU.

Non-EU countries may decide to impose similar policies. For example, the USA has set out actions to promote the use of SAF and aims to reduce

[26] Airbus stated that the A320's medium-haul category of 150–250 seats would be powered by 'potentially some hydrogen' from 2050. A smaller niche of aircraft between 100–150 seats using electric power, hydrogen and/or SAF may be available from 2040. Bateman, T. (2021), 'Hydrogen planes won't take off until 2050, Airbus had admitted to the EU', *Euronews.com*, https://www.euronews.com/next/2021/06/10/hydrogen-planes-won-t-take-off-until-2050-airbus-has-admitted-to-the-eu.

[27] European Union Aviation Safety Agency, 'Sustainable aviation fuels', https://www.easa.europa.eu/eaer/climate-change/sustainable-aviation-fuels.

[28] We consider all SAF as 'advanced biofuels' under the ETD. The ETD is expected to come into force from the first of January 2023. The transitional period will last for ten years. See European Commission (2021), 'Proposal for a council directive restructuring the Union framework for the taxation of energy products and electricity (recast)', https://ec.europa.eu/info/sites/default/files/revision_of_the_energy_tax_directive_0.pdf.

aviation emissions by 20% by 2030 compared to a business-as-usual scenario.[29] In our modelling, we assume that other countries will require use of a certain proportion of SAF (see section 3.2), and therefore that inbound flights to the EU would be subject to these requirements.

CORSIA will apply to the remainder of the emissions that are not abated by the use of SAF. Unlike the ETS, SAF is not considered as having zero emissions under CORSIA, so any carbon emitted through the use of SAF will still need to be offset.[30]

Direct non-EU to non-EU itineraries

The Fit for 55 policies do not directly affect these itineraries. Non-EU countries may implement their own environmental policies, and aviation emissions will need to be covered under CORSIA.[31]

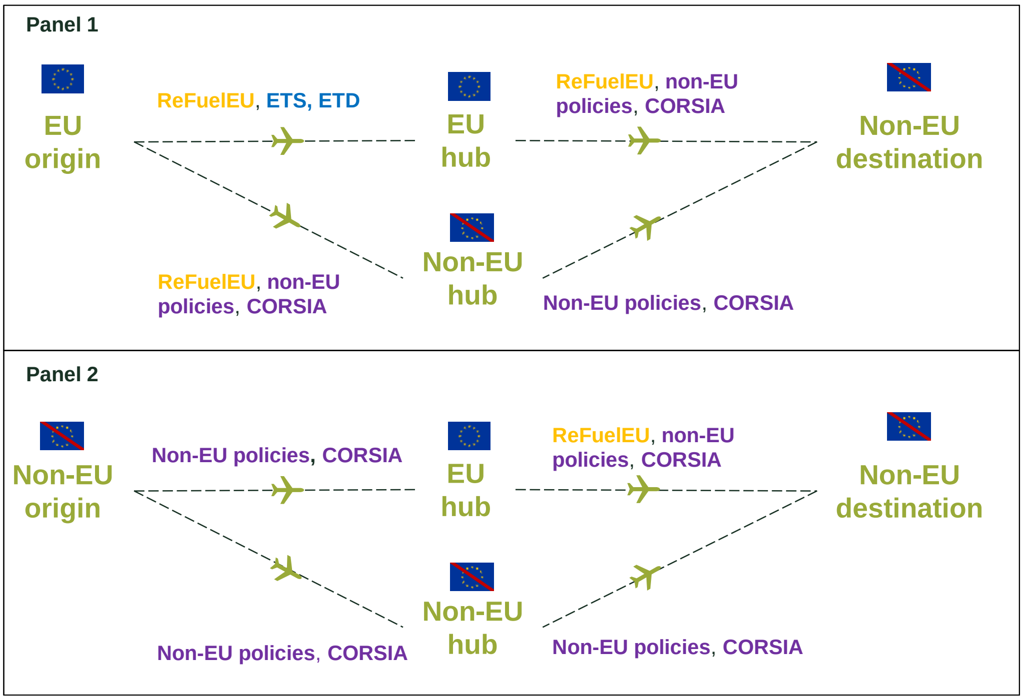
Connecting itineraries

Connecting itineraries are affected by the Fit for 55 policies differently depending on whether each leg of the itinerary is intra-EU, EU to non-EU or between two non-EU airports.

For an intra-EU leg, the relevant proposals would be those set out in the 'direct intra-EU itinerary' section above—i.e. ReFuelEU, ETS and ETD will all apply.[32] For a leg between an EU and non-EU country, the ReFuelEU proposal will apply to the outbound leg, the environmental policies of the other country would apply to the inbound leg and CORSIA would cover the remaining emissions. For a leg between two non-EU countries, CORSIA and the policies of the non-EU countries would apply. The relevant proposals for different types of connecting itineraries are shown in Figure 2.2 below.

[29] The White House (2021), 'FACT SHEET: Biden administration advances the future of sustainable fuels in American aviation', 9 September, https://www.whitehouse.gov/briefing-room/statements-releases/2021/09/09/fact-sheet-biden-administration-advances-the-future-of-sustainable-fuels-in-american-aviation/.
[30] ICAO (2019), 'ICAO Environmental Report 2019, Chapter 6 – An Overview of CORSIA Eligible Fuels (CEF)', https://www.icao.int/environmental-protection/pages/SAF.aspx.
[31] When calculating emissions under CORSIA, we take into account the fact that using SAF is still likely to emit a small amount of carbon for most feedstocks. Based on the blend of feedstocks used to produce SAF in 2030 and 2050, we estimate the carbon savings from using SAF relative to traditional jet fuel to be 86% and 93% in 2030 and 2050 respectively.
[32] Connecting flights within Europe are currently subject to the EU ETS. See Dreyer, S. (2021), 'Feedback from Bundesverband der Deutschen Luftverkehrswirtschaft - BDL e.V.', 17 May, https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12993-Emissions-trading-system-flights-from-UK-to-be-excluded-from-ETS/F2325993_en.

Figure 2.2 Relevant Fit for 55 proposals for different types of connecting itineraries



Source: Oxera.

Panel 1 in Figure 2.2 shows two itineraries from an EU airport to a non-EU airport via two potential hubs: an EU hub and a non-EU hub. An example of this is a passenger travelling from Munich to Lima, who has a choice of hubbing in Madrid or Atlanta. The itinerary via Madrid comprises an intra-EU leg and an EU to non-EU leg. The intra-EU leg will be subject to the ReFuelEU, ETS and ETD proposals, while the EU to non-EU leg would be subject to ReFuelEU (only on the outbound leg), the policies of the non-EU country (in our modelling we assume a certain proportion of SAF on the inbound leg), and CORSIA. The itinerary via Atlanta is comprised of an EU to non-EU and non-EU to non-EU leg, with the relevant policies applied to each. Overall, the routing via the EU hub is subject to the more stringent Fit for 55 policies on both legs of the journey, and will therefore face a larger cost increase than the itinerary via the non-EU hub. This creates a risk of competitive distortions and carbon leakage,[33] which is discussed in section 4.

Panel 2 in Figure 2.2 above shows a different type of connecting itinerary, where the origin and destination of the itinerary are outside of the EU, and passengers have a choice between an EU and a non-EU hub. An example of this is a passenger travelling from Hong Kong to New York, who can hub in either Paris or Dubai. The relevant policies for each leg of these two itineraries are shown in Panel 2. As in Panel 1, routing via the EU hub leads to a higher cost increase than the routing via the non-EU hub, and therefore potentially disadvantages airlines and passengers that travel via a hub in the EU.

[33] Carbon leakage is when the reduction in carbon emissions within the EU is offset by an increase in carbon emissions outside the EU. This occurs if passengers or airlines divert from EU to non-EU routes in response to the Fit for 55 proposals.

2.4 Summary

In Table 2.4 below, we summarise the relevant proposals for different types of itineraries. The methodology for modelling these proposals is discussed in the next section.

Table 2.4 Relevant proposals by type of itinerary

Type of itinerary		Relevant proposal	
Direct itineraries			
Intra-EU direct		**ETS + ETD + ReFuelEU.** The minimum SAF volumes in ReFuelEU apply; SAF is taxed in the 'advanced biofuels' category according to the ETD and is considered to have zero emissions under the ETS. Airlines can choose what fuel to use for the remainder of the fuel required. Depending on a range of factors, this could include greater use of SAF, hydrogen and/or electric aircraft. If kerosene is used, then the ETS and ETD would apply.	
EU to non-EU direct		**ReFuelEU + CORSIA.** The ReFuelEU mandate applies only to departing flights. Non-EU countries may also implement their own environmental policies. In our modelling, we assume that inbound flights from non-EU countries uplift a certain proportion of SAF (see section 3.2). The remaining emissions are covered under CORSIA.	
Non-EU to non-EU direct		**CORSIA.** Non-EU countries may implement their own environmental policies. The remaining emissions are covered under CORSIA.	
Connecting itineraries			
Endpoints	**Via**	**First leg**	**Second leg**
EU to non-EU	EU	**ETS + ETD + ReFuelEU**	**ReFuelEU + CORSIA**
EU to non-EU	Non-EU	**ReFuelEU + CORSIA**	**CORSIA**
Non-EU to non-EU	EU	**CORSIA**	**ReFuelEU + CORSIA**
Non-EU to non-EU	Non-EU	**CORSIA**	**CORSIA**

Source: Oxera.

3 Methodology

3.1 Introduction

This section describes the methodology used to evaluate the impact of the Fit for 55 policies on airports. In particular, we set out the assumptions (section 3.2) and data (section 3.3) that we have used in the analysis, and the model set-up (section 3.4), including demand forecasts, the calculation of pass-through, and elasticities. More detail on the methodology can be found in Appendices A3–A9.

3.2 Description of policy assumptions

As set out in section 2, the Fit for 55 policies will be phased in over the next several decades. For example, free emission allowances to airlines are expected to be gradually phased out over the period to 2030, while the kerosene tax will be increased linearly on an annual basis over a ten-year period from 2023. Similarly, the SAF mandate under the ReFuelEU proposal is expected to increase from 5% in 2030 to 63% in 2050. In order to capture the effects of these proposals on airports, we assess the impacts at two different points in time—in 2030 and 2050.

We forecast demand and emissions in 2030 and 2050 in the scenario in which the policies are introduced as currently proposed—the '**policy scenario**'—and in the scenario where the policies are *not* introduced—the **'business-as-usual scenario**'. The difference between these two scenarios provides an estimate of the impact of the Fit for 55 policies on demand and emissions.

The Fit for 55 policies are expected to apply in the EU (or EEA for the ETS), but we assume that the UK, Iceland, Liechtenstein,[34] Norway and Switzerland will implement similar policies to the EU.[35,36] The EU plus the UK, Iceland, Norway and Switzerland are therefore considered to have the same policies, and we refer to these countries as the '**policy area**' or **'EU+**'.

In order to model the policy and business-as-usual scenarios, we make a number of assumptions on fuel efficiency improvements, jet fuel and SAF prices, as well as costs of emission allowances. Some of the assumptions are not influenced by the policy proposals, and are therefore the same between the two scenarios. Other assumptions, such as kerosene taxes and SAF uptake, are directly impacted by the policy proposals, and therefore differ across the two scenarios. Table 3.1 sets out the key assumptions for the policy and business-as-usual scenarios. We also model two sensitivities—techno optimist and policy pessimist—with different assumptions to the baseline. These are set out in section 6.

[34] We note there are no commercial passenger traffic airports in Liechtenstein.
[35] Department for Transport (2021), 'Jet zero: our strategy for net zero aviation', 14 July, https://www.gov.uk/government/consultations/achieving-net-zero-aviation-by-2050; Federal Office for the Environment, 'Linking the Swiss and EU emissions trading systems', https://www.bafu.admin.ch/bafu/en/home/topics/climate/info-specialists/reduction-measures/ets/linking-swiss-eu.html.
[36] However, if the UK Government does not implement similar measures to the EU, this could lead to competitive distortions with EU hubs.

Table 3.1 Modelling assumptions for the baseline analysis

Input assumption	Business-as-usual scenario (without Fit for 55 policies)	Policy scenario (with Fit for 55 policies)	Business-as-usual scenario (2030/50)	Policy scenario (2030/50)	Units
Fuel efficiency[1]	Fuel efficiency will grow in line with its long-term average of 1.3%.	Fuel efficiency will grow in line with its long-term average of 1.3%.	1.3	1.3	Average annual percentage reduction in emissions per seat-km
Conventional jet fuel/kerosene prices[2]	Forecasts predict the price of kerosene will increase from €600 to €690 between 2030 and 2050.	Forecasts predict the price of kerosene will increase from €600 to €690 between 2030 and 2050.	600/690	600/690	EUR per tonne
Average industry seat load factor	Based on 2019 data for global average seat load factor	Based on 2019 data for global average seat load factor	82.6	82.6	Percentage of seats filled by passengers
SAF take-up[3]	SAF uptake would be significantly lower without the EU's ETD and SAF mandates. However, given global climate ambitions, it is likely that there would be some SAF uptake even if the policies are not introduced. We assume that global uptake would be similar to Germany's previously outlined mandate of 2% in 2030 increasing by 1% every two years. This would imply a mandate of 12% in 2050.	SAF uptake in line with ReFuelEU proposal.	2/12	5/63	SAF use as percentage of total fuel use
SAF prices before tax[4]	SAF unit costs are a combined estimate from the Clean Skies for Tomorrow report, the ReFuelEU impact assessment produced by the European Commission, and the Destination 2050 report. 10% mark-up applied to all SAF unit costs to account for other business costs and profits.	SAF unit costs are a combined estimate from the Clean Skies for Tomorrow report, the ReFuelEU impact assessment produced by the European Commission, and the Destination 2050 report. 10% mark-up applied to all SAF unit costs to account for other business costs and profits.	1960/68	1960/68	EUR per tonne produced
Taxes on kerosene and SAF[5]	No ETD implemented; kerosene not taxed	ETD implemented in line with policy proposal	-	462.25 (kerosene); 6.45 (all SAFs)[10]	EUR per tonne of fuel burnt

EU ETS prices (auction price)[6]	Without the policies, the market ETS price will be lower due to higher supply of free allowances and lower demand for auctioned emission allowances.	If the policies are implemented, we assume higher prices due to the withdrawal of free allowances and the inclusion of new sectors in the EU ETS.	60/81	129/212	EUR per tonne of CO_2 emission allowance (market price)
EU ETS prices (effective price)[7]	Only 15% of allowances are auctioned, and an average of 44% of aviation allowances are bought from secondary markets. This implies that the effective price paid for an aviation emission allowance is lower than the market price.	According to Fit for 55 proposals, free allowances are phased out by 2030, so the effective price is equal to the market price.	31/42	129/212	EUR per tonne of CO_2 emission allowance (effective prices given free allowances)
CORSIA prices[8]	In line with the EU's own impact assessment	In line with the EU's own impact assessment	7	7	EUR per tonne of CO_2 emissions offset

Source: [1] ICCT (2015), 'Fuel efficiency trends for new commercial jet aircraft: 1960 to 2014', September 3, https://theicct.org/publication/fuel-efficiency-trends-for-new-commercial-jet-aircraft-1960-to-2014/.

[2] Destination 2050 (2021), 'A Route to Net Zero European Aviation', February, https://www.destination2050.eu/.

[3] European Commission (2021), 'Commission Staff Working Document: Impact Assessment Accompanying the Proposal for a Regulation of the European Parliament and of the Council on ensuring a level playing field for sustainable air transport', July 14, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021SC0633&from=EN.

[4]World Economic Forum (2020), 'Clean Skies for Tomorrow: Sustainable Aviation Fuels as a Pathway to Net-Zero Aviation', November, https://www3.weforum.org/docs/WEF_Clean_Skies_Tomorrow_SAF_Analytics_2020.pdf.

[5] European Commission (2021), 'Revision of the Energy Taxation Directive (ETD): Questions and Answers', July 14, https://ec.europa.eu/commission/presscorner/detail/en/qanda_21_3662.

[6] Bloomberg, L.P. (2022), Market price data for EUA futures allowances. Retrieved from Bloomberg database; Department for Business, Energy and Industrial Strategy (2021), 'Valuation of greenhouse gas emissions: for policy appraisal and evaluation', September 2, https://www.gov.uk/government/publications/valuing-greenhouse-gas-emissions-in-policy-appraisal/valuation-of-greenhouse-gas-emissions-for-policy-appraisal-and-evaluation; Pietzcker, R.C., Osorio, S. and Rodrigues, R. (2021), 'Tightening EU ETS targets in line with the European Green Deal: Impacts on the decarbonization of the EU power sector', July 1, https://www.sciencedirect.com/science/article/pii/S0306261921003962.

[7] European Commission (2021), 'Allocation to aviation', https://ec.europa.eu/clima/eu-action/eu-emissions-trading-system-eu-ets/free-allocation/allocation-aviation_en#ecl-inpage-1206

[8] European Commission (2021), 'Proposal for a directive of the European Parliament and of the Council amending Directive 2003/87/EC as regards aviation's contribution to the Union's economy-wide emission reduction target and appropriately implementing a global market-based measure' July 14, https://ec.europa.eu/info/sites/default/files/revision_of_the_eu_emission_trading_system_for_aviation.pdf.

[9] Statista (2021), 'Passenger load factor of commercial airlines worldwide from 2005 to 2022', October 5, https://www.statista.com/statistics/658830/passenger-load-factor-of-commercial-airlines-worldwide/#:~:text=The%20combined%20passenger%20load%20factor,dropped%20to%20below%2060%20percent.

[10] The Commission expressed ETD tax rates in €/GJ. We convert these tax rates to a tax per tonne of jet fuel by applying a tonne to gigajoule factor of 43.9 gigajoules per tonne of fuel. See BP (2021), 'Approximate conversion factors', *Statistical Review of World Energy,* https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2021-approximate-conversion-factors.pdf.

3.3 Description of data

Our analysis is based on capacity data from OAG, and carbon emissions and airline fares data from Google Flights.[37] We also use ACI demand forecasts, which are described in more detail in section 3.4.1 and Appendix A4.

The OAG dataset contains data on scheduled flights in 2019, and in particular the total number of seats on each flight. It covers all flights departing from or arriving in the policy area. To calculate the total number of passengers in 2019 on each route (at the airport-pair level),[38] we calculate the total number of seats in 2019 for each route, and apply an industry-average load factor (as set out in section 3.2).[39] We then exclude connecting traffic by multiplying the total number of passengers by the proportion of connecting passengers at the top ten connecting airports in the policy area, and exclude these passengers from our dataset.[40] This is then forecasted to 2030 and 2050 (see section 3.4.1).

We obtain data on carbon emissions per passenger[41] and airline fares for return flights from Google Flights, based on data from April 2021 to February 2022.[42] We account for a range of passenger preferences in the way that we gather the data (e.g. business or other time-sensitive travellers are likely to book flights closer to the departure date, and therefore pay a higher fare). Further details are provided in Appendix A3.

We estimate fuel use per passenger using ICAO's estimate of carbon emissions per kg of fuel burnt—3.16kg CO_2 per kg of fuel—and apply this to the carbon emissions from the Google Flights dataset.[43] These fuel volumes are used to calculate the volumes of SAF used in the model (see section 3.4.2).

The Google Flights and OAG datasets are then merged to create a single dataset of route-level fares, carbon emissions and passenger demand. This forms the basis for the rest of the model.

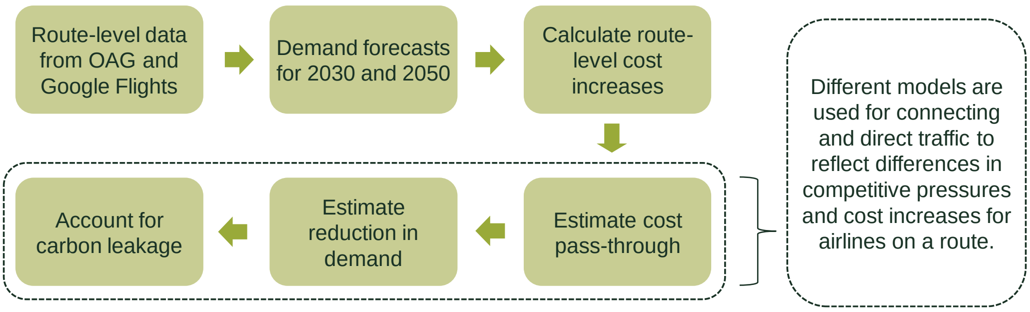
[37] OAG is a global travel data provider. The OAG dataset has been used in prior analysis—for example, in European Commission analysis of the extent of competition in the aviation industry.
[38] When estimating the level of cost pass-through, a relevant consideration is the competitiveness of the routes on which the airlines operate. In this case, we use origin and destination city-pairs rather than airport pairs, in line with European Commission precedent. See section 3.4.3 for further details.
[39] We aggregate seats in both directions of a given route. For example, we obtain the total number of seats between Charles de Gaulle and Frankfurt airports by adding seats on flights from Charles de Gaulle to Frankfurt to seats from Frankfurt to Charles de Gaulle.
[40] We obtain the proportion of connecting passengers for each of the top connecting airports: Frankfurt, Amsterdam, Charles de Gaulle, Munich, London Heathrow, Madrid, Zurich, Vienna, Rome Fiumicino and Helsinki. We apply this proportion to all passengers arriving or departing at these airports to calculate connecting traffic volumes, and remove these passengers from our dataset.
[41] Google Flights estimates carbon emissions per passenger using the European Environmental Agency (EEA) methodology. This takes into account factors including origin, destination, aircraft type, number of seats in each seating category, and the fuel efficiency of aircraft. For further details on how Google Flights estimates carbon emissions, see Google, 'Check carbon emissions on Google Flights', https://support.google.com/travel/answer/9671620?hl=en-GB.
[42] The data from Google Flights was gathered over a period when the aviation industry was affected by COVID-19, which may affect the fares data. However, we understand from ACI that yields in 2021 were only around 1% higher than in 2019. In addition, data from Eurostat shows that the price of air travel in 2020 and 2021 was only about 5% lower than in 2019. The ECB noted that during the initial lockdowns in the second quarter of 2020, firms may have preferred to delay price changes until restrictions were lifted to avoid additional menu costs. Eurostat (2022), 'HICP – annual data (average index and rate of change). [prc_hicp_aind]', https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=prc_hicp_aind&lang=en; Lis, E. and Nordeman, J. (2021), 'Prices for travel during the COVID-19 pandemic: is there commonality across countries and items?', https://www.ecb.europa.eu/pub/economic-bulletin/focus/2021/html/ecb.ebbox202101_06~bcb28cb255.en.html.
[43] ICAO (2018), 'ICAO carbon emissions calculator methodology, version 11', June, https://bit.ly/35gd2C9.

3.4 Model set-up

The steps in constructing the model are set out below, with an overview provided in Figure 3.1.

- **Demand forecasts**. Starting from the data described above, we forecast demand to 2030 and 2050.
- **Calculate route-level cost increases**. We calculate the costs of the proposals at a route level, using the assumptions set out in section 3.2. The cost increases in the policy scenario (i.e. with the Fit for 55 policies) are calculated relative to the business-as-usual scenario (i.e. without the Fit for 55 policies).
- **Estimate cost pass-through**. We estimate the proportion of the cost increase that is passed through to passengers as higher prices. We estimate the pass-through rate using an economic model that takes account of the structure of competition on each route, as economic theory predicts that markets with more competitive pressures will have a higher rate of pass-through than markets with less competition.
- **Estimate the reduction in demand**. The rise in prices will lead to lower passenger demand. To estimate these demand effects, we apply demand elasticities based on a review of the literature.
- **Account for carbon leakage**. Carbon leakage is when the reduction in carbon emissions within the EU is offset by an increase in carbon emissions outside the EU. This occurs if passengers or airlines divert from EU to non-EU routes in response to the introduction of the Fit for 55 policies. Our methodology for assessing carbon leakage is described in section 4.

Figure 3.1 Overview of the model



Source: Oxera.

3.4.1 Demand forecasting

The starting point for forecasting demand is the 2019 OAG dataset, which provides estimates of capacity in 2019. We estimate the number of passengers by applying industry average load factors, as specified in section 3.2.

In order to forecast demand to 2030 and 2050, we require passenger growth rates for European airports. Our starting point for deriving these growth rates is the ACI World Airport Traffic Forecasts, which provides forecasts of passenger growth for different regions of the world—for instance, North America, Asia-Pacific, Africa. We then estimate growth rates between Europe and each of these regions by applying a number of high-level assumptions. Further details on how we have forecasted demand can be found in Appendix A4.

Table 3.2 Demand growth rates by region

Route	2019–30	2019–50
Europe to Africa	4.1%	2.4%
Europe to Asia-Pacific	5.6%	3.8%
Europe to Latin America-Caribbean	5.0%	3.6%
Europe to Middle East	5.8%	4.1%
Europe to North America	4.6%	3.0%
Intra-EU*	2.5%	2.5%

Note: * Intra-EU growth rates are taken from ICAO's long-term traffic forecasts.

Source: Oxera.

3.4.2 Application of policy assumptions

We apply the assumptions set out in section 3.2 to calculate the costs in the policy scenario. We estimate the effects of each proposal individually, as well as their combined effects, taking into account the interaction between the proposals. The costs of each policy is modelled as follows.

- **ReFuelEU**. We apply the proportion and costs of SAF (section 3.2) to the fuel use estimates per passenger (section 3.3) to derive the additional costs per passenger of using SAF, taking into account that improvements in fuel efficiency over time will result in lower SAF requirements. The ReFuelEU proposal applies to all flights departing from the policy area.
- **ETS**. We apply the effective ETS carbon prices (section 3.2) to the carbon emissions estimates (section 3.3), taking into account improvements in fuel efficiency over time and the fact that SAF is considered a zero emissions fuel under the ETS. The ETS applies to flights within the policy area.
- **ETD**. The ETD taxes are applied per gigajoule. We convert these to a tax per tonne of jet fuel by applying a gigajoule per tonne of fuel factor, and apply this to the fuel volumes we have estimated, taking into account improvements in fuel efficiency over time.[44] Different tax rates are applied to traditional jet fuel and SAF. The ETD applies to flights within the policy area.
- **CORSIA**. CORSIA requires airlines to buy offsets for any increases in carbon emissions relative to the average of 2019 and 2020 levels. For each route we calculate the average of 2019 and 2020 emissions, and apply estimated CORSIA unit costs (section 3.2) to carbon emissions that exceed the average 2019/20 emissions.[45] We take account of carbon emissions that are abated due to the use of SAF and improvements in fuel efficiency over time.[46]

The combined effects of the proposals is the sum of each of the proposals above. We compare the costs of the proposals under the policy scenario to the

[44] BP, 'Approximate conversion factors', Statistical Review of World Energy, https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2021-approximate-conversion-factors.pdf.
[45] While ICAO has changed the baseline for the transitional period to 2019 only, they have yet to finalise the baseline from 2024 so we use an average of 2019/20 due to this uncertainty.
[46] When calculating emissions under CORSIA, we take account of the fact that using SAF is still likely to emit a small amount of carbon for most feedstocks. Based on the blend of feedstocks used to produce SAF in 2030 and 2050, we estimate the carbon savings from using SAF relative to traditional jet fuel to be 86% and 93% in 2030 and 2050 respectively.

business-as-usual scenario. We carry out these calculations at the route level and obtain the cost increase as a result of the Fit for 55 policies on each route.

3.4.3 Calculation of pass-through

The pass-through rate is the proportion of the cost increase that is passed on to passengers as higher fares. The pass-through rate depends on a number of factors, such as the structure of competition between airlines on a given route,[47] the strategic interactions between airlines, and the number of airlines on each route. There will be higher pass-through rates on routes with a greater number of competitors.

We model competition on a route using a Cournot model.[48] This model is supported and calibrated on market evidence in the literature. On direct intra-EU routes, all airlines are subject to the ETD, ETS and RefuelEU proposals. For a route between an EU and a non-EU airport, all airlines have to uplift the level of SAF mandated by ReFuelEU when departing from the EU. The pass-through rate when all airlines on a route are affected by similar cost shocks can be estimated using the formula $N/(N+1)$, where N is the number of competitors on the route.

To determine the number of competitors on a route, we take an origin and destination ('O&D') city-pairs approach, in line with the European Commission's decisional practice.[49] For example, we consider Paris Charles de Gaulle and Paris Orly airports as part of the same market, as they are both in the city of Paris. This means that we consider that airlines flying from Paris Orly to Cyprus compete with airlines flying from Paris Charles de Gaulle to Cyprus.

Figure 3.2 below shows the number of routes and the pass-through rates on each route, split by the number of competitors on each route. Of the 6,615 routes, there is only one airline operating on approximately 41% of routes (2,700 routes). Using the methodology above, the pass-through rate on these routes is 50%—i.e. only half of the cost increase associated with the Fit for 55 proposals would be passed on as higher fares to passengers. The higher the number of competitors on a route, the greater the intensity of competition[50] and therefore the higher the pass-through rate.

The average number of competitors across all routes is 2.3, with an average pass-through rate of 64%.

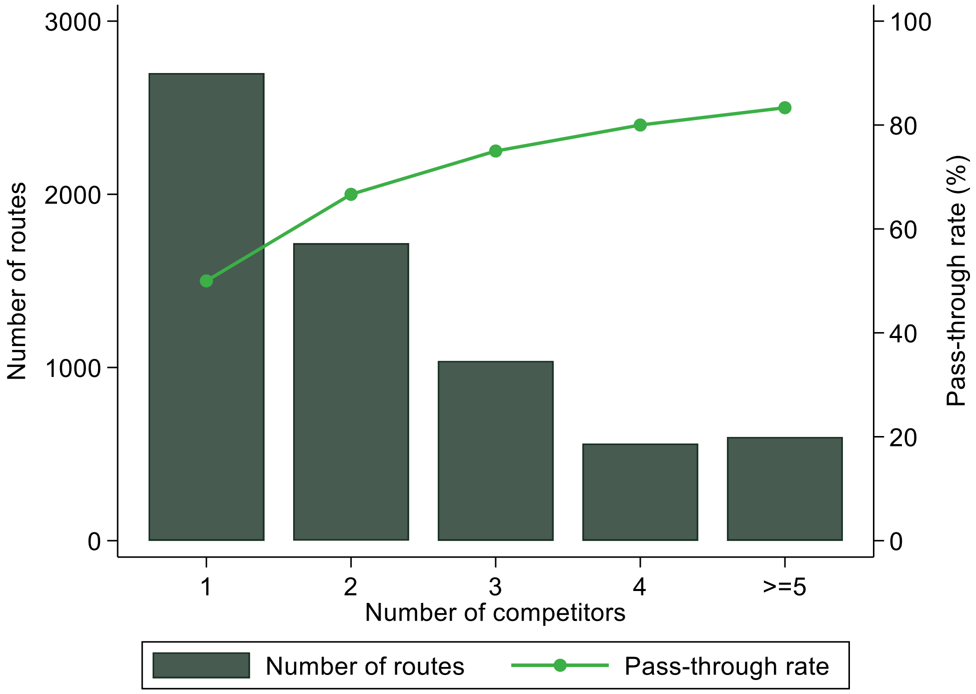
[47] Firms can compete either on the basis of prices (Bertrand competition) or quantities (Cournot competition). A Cournot model is one in which airlines compete by setting the quantity of seats they wish to sell on a given route. Economic theory suggests that, under a number of assumptions, markets in which firms set capacity and then price may be simply modelled by quantity competition. See Koopmans, C. and Lieshout, R. (2016), 'Airline cost changes: to what extent are they passed through to the passenger?', *Journal of Air Transport Management*, **53**, June, pp. 1–11.

[48] In the framework of game theory, which is widely used within industrial organisation models in economics, competition on an O&D city-pair can be viewed as a 'game' in which airlines first choose their capacity, and then set prices to fill up the capacity. A capacity-then-price game, under a number of additional assumptions, can be modelled as if airlines compete on the basis of quantities—i.e. a Cournot model.

[49] A full market definition exercise would include an assessment of the relevant geographic and product markets in terms of demand- and supply-side substitution. This would need to account for a range of different route-specific factors. However, for the purposes of modelling the impact of the policies, we use an O&D city-pair approach as this likely approximates the structure of competition on most route markets.

[50] A full assessment of competition would require considering a wider set of factors, such as the similarity of the business models of the airlines operating on the route.

Figure 3.2 Number of routes and pass-through rates by number of competitors on the route: direct routes



Note: There is an average of 2.3 competitors per route, with a pass-through rate of 64%. The pass-through rate for routes with five or more competitors ranges between 83% (for five competitors) and 91% (for ten competitors, the maximum number of competitors on any route).

Source: Oxera analysis.

The competitive dynamics determining the pass-through rate on connecting itineraries need to be modelled differently to direct ones. This is because different airlines operating on connecting itineraries may be subject to different policies, and therefore experience different cost shocks. This is in contrast to direct itineraries, where all airlines are subject to the same proposals and experience similar cost shocks. Therefore, to model the pass-through rate on connecting itineraries, we use a more general version of the Cournot model that allows for each airline on a route to have different cost increases. This is set out in Appendix A8.

3.4.4 Applying elasticities to calculate the demand impact

Price elasticities of demand measure the sensitivity of demand on a given route to a change in fares. In response to an increase in fares, passengers may either stop flying altogether, take a flight to another destination that is less expensive, or use another mode of transport. The higher the price elasticity, the more sensitive passengers are to a change in fares.

The price elasticity depends on the factors driving the change in demand. For example, studies that consider the impact of fare changes on individual routes are more likely to find higher elasticities than those that consider fare changes across a number of routes. This is because in the latter case, passengers are less able to switch to other routes when the fare on their original itinerary rises.

Therefore, we consider literature that estimates elasticities for similar shocks as the Fit for 55 proposals, such as air passenger taxes. Based on a sample of selected studies (see Appendix A5), we obtain an average price elasticity of demand of -0.63. To calculate the demand effects on direct flights, the fare increase is multiplied by the demand elasticity. This is because all airlines will be affected by the same proposals, and so it is less likely that there will be significant strategic interactions between airlines that mean that some airlines are disproportionately affected compared to others.

However, on connecting routes, as different airlines are affected by different proposals depending on where they hub (see section 4), some airlines will experience larger cost shocks than others. Airlines with large cost increases may have to reduce their flight frequencies, which would allow airlines with smaller cost increases to expand their operations and absorb these passengers. We account for these strategic interactions in our model for connecting flights, as set out in Appendix A8.[51]

3.5 Summary

The Fit for 55 policies will increase airlines' costs on all routes to/from European airports, but will do so in different ways. The extent to which airlines pass through this cost increase to passengers in the form of higher fares will depend on the extent of competition on each route. For this reason we have created a route-level model that estimates the impact of the introduction of the Fit for 55 policies for each route and compares these to a business-as-usual scenario, without the introduction of these policies. In addition, the introduction of these policies may lead to passengers changing their flight patterns to avoid the increased costs. The methodology we have used to estimate carbon leakage is discussed in the next section.

[51] In more technical terms, the demand elasticity provides an estimate of the slope of the demand curve. If all airlines experience the same cost shocks, they will all move along the demand curve in the same way. However, if each airline experiences different cost shocks, then airlines with larger cost shocks will experience a larger reduction in demand than airlines with smaller cost shocks.

4 Assessing carbon leakage

4.1 Introduction

Carbon leakage is a situation where, for example, as a result of Country A introducing stringent environmental policies, companies relocate to Country B that has less strict requirements. In this way, overall carbon emissions may remain the same—they just occur in Country B rather than in Country A.

In the case of the aviation sector, carbon leakage can occur when passengers who would fly to European destinations or hub through European airports decide to fly to, or hub through, non-European destinations as a result of the Fit for 55 policies. This would lead to a reduction in emissions within the EU, but an increase in the total emissions outside of the EU, and could therefore reduce the effectiveness of Fit for 55 policies. Box 4.1 below provides further detail regarding how we define carbon leakage in this study.

Box 4.1 Defining carbon leakage

If a factory moves to a non-EU country because of strict environmental policies in the EU, and emits the same amount of emissions there, carbon has leaked. This is straightforward because the carbon can clearly be assigned to a country based on the location of the factory. It is much more difficult to assign emissions from air travel: do the emissions created on a return flight between London and New York belong to the UK or the USA?

This report accounts for all carbon emitted on flights to and from the EU+ region (i.e. the policy area), as well as on the ten example connecting routes. For the purposes of this report, carbon leakage is defined as the ratio between the increase in emissions as a result of actions taken by passengers to avoid the Fit for 55 policies and total emissions in the business-as-usual scenario. If our analysis of carbon savings and carbon leakage only considered the emissions from the leg departing from the EU, the effectiveness of the Fit for 55 policies would be higher. However, for the purposes of determining the impact of the Fit for 55 policies on European airports, we consider that it is relevant to include both legs of the flight.

Example calculation 1: direct flights

Consider a route from Milan Bergamo (BGY) to Palma de Mallorca (PMI). In the business-as-usual scenario, 100 people travel on this route and emit 100t of carbon. As a result of the Fit for 55 policies, only 70 people continue travelling on this route, emitting 60t of carbon. 25 people no longer travel, but five passengers choose to fly to Antalya instead as that is less affected by the Fit for 55 policies, and emit 5t of carbon. The carbon leaked would amount to 5% of business-as-usual emissions.

Business-as-usual emissions: 100tCO_2

Increase in carbon due to passengers diverting: 5tCO_2

Carbon leakage: 5%

Example calculation 2: connecting flights

Consider the route from Orlando (ORD) to Johannesburg (JNB). Passengers on this route can choose between two itineraries: via Amsterdam Schiphol (AMS) or Dubai (DXB). In the business-as-usual scenario, 50 people travel on each of the two itineraries and emit 1000t of CO_2 in total. As a result of the Fit for 55 policies, only 30 passengers continue travelling via AMS, ten no longer travel at all, and another ten passengers now choose to fly via DXB instead and emit 100t of carbon. The carbon leaked would amount to 10% of business-as-usual emissions.

Business-as-usual emissions: 1,000tCO_2

Increase in carbon due to passengers diverting: 100tCO_2

Carbon leakage: 10%

Source: Oxera.

The Intergovernmental Panel on Climate Change (IPCC) adopts a different definition of carbon leakage. The IPCC defines carbon leakage as ‘the increase in CO_2 emissions outside the countries taking domestic mitigation action divided by the reduction in the emissions of these countries’.[52] While this definition is easily applicable to economic activity where emissions can be attributed to a specific country, this is more difficult in the case of the aviation sector (e.g. should emissions on a return flight between Paris and New York be attributed to France or the USA?).

Furthermore, by using carbon savings as the denominator, the IPCC definition does not distinguish between a scenario where the increase in CO_2 emissions outside the policy area is 1t and the reduction in the policy area is 2t, and another scenario where the increase and reduction in CO_2 is 100t and 200t respectively. Both scenarios would have a carbon leakage figure of 50% under the IPCC definition. This is important because the application of the Fit for 55 proposals changes over time (e.g. increasing the stringency of the SAF mandates between 2030 and 2050), and therefore using the IPCC definition may not accurately reflect the degree of carbon leakage that occurs over time.

In this report, we also present results using the IPCC definition given that it is a widely adopted approach to defining carbon leakage in other sectors (see sections 5.2.2 and 5.3.4 for further details and results).

The risk of carbon leakage varies across sectors and may be higher in certain industries, such as manufacturing. To prevent carbon leakage, the EU has traditionally provided free emission allowances to sectors with high carbon leakage risk, and has proposed a Carbon Border Adjustment Mechanism (CBAM). The CBAM aims to equalise the price of carbon between EU production and imports to ensure that the EU’s climate objectives are not undermined by production relocating to countries with less ambitious climate policies. Aviation has not been included in the list of sectors with high risk of carbon leakage.

This section explains how the introduction of the Fit for 55 policies could lead to carbon leakage (section 4.2), describes how we model the risk of carbon leakage (section 4.3), and sets out the potential carbon leakage in the aviation sector from switching to rail (section 4.4).

4.2 Potential risks of carbon leakage arising from the Fit for 55 proposals

There is a risk that the Fit for 55 policies will lead to an increase in carbon emissions from air travel outside of the policy area as follows.

- **ReFuelEU**: while the ReFuelEU proposal contains provisions to limit tankering, there is still a risk of carbon leakage. This is because ReFuelEU only applies to flights departing from the EU. This means that intra-EU flights will be most affected by this policy. For example, only the departing leg from the EU on a return itinerary between an EU and non-EU airport would be subject to the SAF mandate. Assuming that the cost increase is passed through to passengers in the form of higher fares, this could incentivise travellers to fly to a further destination outside of the EU, thereby increasing instead of decreasing carbon emissions. Furthermore, airlines

[52] IPCC (2007), ‘Climate change 2007: Working Group III: Mitigation of Climate Change’, https://bit.ly/3KArjfB.

could choose to hub at a non-EU airport rather than EU airport in order to avoid the SAF mandate.

- **ETD**: there is a risk of leakage as the ETD only applies to intra-EU flights. This means that passengers may choose to hub outside the EU, or choose alternative destinations outside the EU.
- **ETS**: under the current proposals, only intra-EEA flights are covered by the EU ETS scheme—all other flights are covered by the much less stringent CORSIA scheme. There is thus an incentive for passengers to use non-EEA airports on direct and/or connecting journeys. As long as a price differential exists between CORSIA and the EU ETS, carbon emissions could leak to regions outside of the EEA.[53]

4.3 Methodology for modelling leakage

Direct flights: diversion from EU+ destinations (i.e. the policy area) to destinations outside of the EU+

Direct passengers can be divided into three groups according to their likelihood of diversion:

1. passengers that originate from an EU+ airport and travel to a non-EU+ airport—e.g. passengers in Paris travelling on holiday to Agadir;
2. passengers that originate from a non-EU+ airport and travel to an EU+ airport—e.g. passengers from New York travelling to Frankfurt on business;
3. passengers travelling on intra-EU+ routes—e.g. passengers travelling between Milan and Palma de Mallorca.

There is unlikely to be significant diversion for the first group of passengers. This is because all departures from the EU will be subject to the ReFuelEU proposal, so passengers are unable to avoid it by changing their destination.

The second group of passengers will be affected by the ReFuelEU proposal on the return leg of their flight from the EU, but would not be affected by any other Fit for 55 policies. In principle, these passengers could avoid the ReFuelEU proposal by travelling to a different destination. For example, a North American passenger could travel to the Middle East instead of Europe. However, as the ReFuelEU proposal only affects the departing leg from the EU, the proposal is likely to lead to a small fare increase (less than 5% of the overall return fare—see section 5). In particular, for long-haul passengers, which are likely to account for the majority of CO_2 emissions, the cost of ReFuelEU may be small compared to the overall fare. Therefore, we do not expect there to be a significant amount of destination switching for these passengers.

As a result, we focus our analysis of diversion on the third group, passengers travelling on intra-EU+ flights. Passengers on flights between two EU+ airports will likely experience larger fare increases than passengers in the other groups set out above due to the geographic scope of the Fit for 55 proposals. As a result, passengers may divert from an intra-EU+ flight to an extra-EU+ flight, resulting in an increase in carbon emissions outside of the policy area.

[53] The risk of carbon leakage as a result of the EU ETS largely depends on the price differential between the EU ETS and CORSIA. Current policy discussions mention the possibility that the EU ETS will apply to all flights that originate or terminate in the EU+ after 2024. This would reduce the incentive to hub outside of the EU+ further, and therefore lower the risk of carbon leakage from 2024 onwards. See European Union Aviation Safety Agency, 'Th EU Emissions Trading System', https://www.easa.europa.eu/eaer/topics/market-based-measures/the-eu-emissions-trading-system.

The extent to which carbon emissions outside of the policy area increase depends on the availability of substitutable extra-EU+ routes. Ideally, a comprehensive analysis would involve a route-by-route assessment, taking account of a range of demand- and supply-side substitution factors. For example, on the demand side, leisure passengers looking for a beach holiday may consider a range of different routes to be substitutable. However, passengers visiting friends and relatives or travelling on business will likely not find alternative destinations to be substitutable. On the supply side, airlines need to have sufficient aircraft, and airports need to have enough capacity, to support the diverted passengers. However, a detailed route-by-route analysis is not within the scope of this report.

To obtain high-level estimates of the risk of carbon leakage, we identify whether a direct intra-EU+ route has extra-EU+ substitutes. We calculate the 'generalised journey cost' ('**GJC**') of flights in our dataset, which is the sum of the fare and the time cost of the journey (calculated as €27.47/hour multiplied by the duration of the journey).[54] We then identify whether there are any extra-EU+ routes departing from either airport on the intra-EU+ route that have a lower GJC than the intra-EU+ route. For example, for the route between Milan Bergamo and Palma de Mallorca, we would identify all extra-EU+ routes departing from either Bergamo or Palma de Mallorca that have a lower GJC than the Bergamo–Palma de Mallorca route. We calculate the GJC of each route under the assumptions of the policy scenario, which takes into account that intra-EU+ routes will be more heavily affected than extra-EU+ routes.

We consider that an extra-EU+ route is a potential substitute if the GJC for that route is at least 10% lower the intra-EU+ route.[55] We choose a threshold of 10% to account for the fact that there are likely to be search costs incurred by passengers when looking for flights. It is also not likely that there would be significant switching in response to small differences in GJC. Given that we make the assumption (discussed in the following paragraphs) that routes with a sufficient number of substitutes will have 100% diversion rates, we require the substitute routes to have a meaningfully lower generalised journey cost.

We determine how many potential substitutes each intra-EU+ route has in Table 4.1 below. Of the 4,792 intra-EU+ routes, there are no potential substitutes on 49%, and 15% of routes have one potential substitute. Only 13% of the routes have more than six potential substitutes. Therefore, most routes do not have a large number of potential alternatives.

[54] We base our value of travel time on an average of studies cited by Transport & Environment (2022), 'Assessment of carbon leakage potential for European aviation. Direct flights stopping over in non-EU airports', January 2022. In particular, the studies are: Merkert, R. and Beck, M. (2017), 'Value of travel time savings and willingness to pay for regional aviation', *Transportation Research Part A: Policy and Practice*, **96**, pp. 29–42; FAA Office of Aviation Policy and Plans (2021), 'Economic Values for FAA Investment and Regulatory Decisions, a Guide: 2021 Update (No. see Section 1)'; Ennen, D., Allroggen, F. and Malina, R. (2019), 'Non-stop versus connecting air services: Airfares, costs, and consumers' willingness to pay (No. ICAT-2019-03)', *MIT International Centre for Air Transportation*; and National Academies of Sciences, Engineering, and Medicine. (2015), 'Passenger Value of Time, Benefit-Cost Analysis and Airport Capital Investment Decisions, Volume 1: Guidebook for Valuing User Time Savings in Airport Capital Investment Decision Analysis', *The National Academies Press*, Washington, DC.
[55] We choose a 10% threshold to avoid identifying extra-EU routes that only have a small GJC advantage as potential substitutes as there is unlikely to be significant switching to these routes.

Table 4.1 Number of potential substitutes, intra-EU+ routes

Number of potential substitutes	Number of routes	Proportion of routes (%)
0	2,358	49
1	727	15
2	398	8
3	306	6
4	250	5
5	145	3
>=6	608	13
Total	**4,792**	**100**

Source: Oxera analysis.

If there is only one potential substitute route available, there is unlikely to be significant diversion. For there to be significant diversion, most or all passengers would need to be aware of the one potential substitute (among all the other routes they could choose from) and consider the potential substitute to be a feasible and attractive alternative to their original route. Given that there are search costs, and passengers have different preferences, we consider that there is unlikely to be significant diversion on routes where there is only one potential substitute available.

Therefore, we only consider the potential risk of carbon leakage from destination switching for intra-EU+ routes that have two or more potential substitutes. We consider a scenario where 100% of the lost demand (as calculated in section 3.4.4) on these routes would divert to the substitute routes, which places an upper bound on leakage volumes.

To calculate carbon leakage, we estimate the carbon emissions of these diverted passengers by taking an average of the carbon emissions of the identified potential substitute routes, weighted by passengers.

Connecting flights: diversion from EU+ hubs to non-EU+ hubs

Flights within the EU+ region are affected more by the Fit for 55 policies than flights with only one leg starting/terminating in the EU+, while flights between non-EU+ airports are not affected at all. In practice, this means that connecting flights that hub at an EU+ airport will be subject to a larger cost increase than connecting flights that hub outside the EU+, creating a risk of carbon leakage.

As for direct flights, there are three types of connecting routes that are relevant to consider:

1. flights that start and end in the EU+ (EU+ to EU+);
2. flights that start in the EU+ and terminate outside of the EU+ (EU+ to non-EU+ and vice versa);
3. flights that start and end outside of the EU+ (non-EU+ to non-EU+).

Of these three types of routes, the first one is unlikely to be affected by carbon leakage, as it is highly unlikely that flights between two EU+ airports would hub outside of the EU+ area. The following analysis therefore focuses on the two remaining types of connecting routes: EU+ to non-EU+ (and vice versa) and non-EU+ to non-EU+.

To facilitate the carbon leakage analysis for connecting flights, we have split the two types of routes into regional pairings as shown in table below. For each of the regional pairs we have selected an example route to evaluate the effect of the Fit for 55 policies.

In selecting the example routes, we have chosen a number of large airports that connect via EU+ hubs to ensure that our analysis captures a significant share of connecting passengers. The route pair Rome–San Francisco, for instance, connects through some of the largest hubs: CDG in Paris, FRA in Germany, JFK in the USA and LHR in the UK. Table 4.2 shows the largest hubs that connect the airports on the routes selected. Further detail on the methodology used to select the routes is presented in Appendix A7.

Table 4.2 Connecting routes potentially affected by Fit for 55 policies

	Regional pairs	Route pairs	Largest potential hubs on route
EU+ to non-EU+	EU–North America	Rome (FCO)–San Francisco (SFO)	CDG, FRA, JFK, LHR, LIS, MUC, ZHR
	EU–Asia	Madrid (MAD)–Delhi (DEL)	AUH, DOH, DXB, FCO, SVO
	EU–Asia	Hamburg (HAM)–Bangkok (BKK)	DXB, HEL, SVO, VIE, FRA, IST, ZHR
	EU–Asia	Milan Malpensa (MXP)–Seoul (ICN)	SVO, AUH, PEK, CDG, HEL, FRA, MUC, FCO, IST
	EU–Asia	Lyon (LYS)–Bangkok (BKK)	CDG, DXB, SVO, IST, VIE, FRA
	EU–Africa	Amsterdam (AMS)–Cairo (CAI)	AMM, ATH, CDG, FCO, FRA, IST, LHR, MUC, VIE
	EU–South America	Munich (MUC)–Lima (LIM)	AMS, BOG, CDG, MAD
Non-EU+ to non-EU+	North America–Middle East	Atlanta (ATL)–Dubai (DXB)	AMS, BOS, CDG, FLL, IST, JFK, LHR
	North America–Africa	Chicago (ORD)–Johannesburg (JNB)	ADD, AMS, ATL, DOH, DXB, FRA, LHR
	Asia–South America	Singapore (SIN)–São Paolo (GRU)	ADD, DOH, DXB, IST, LHR

Source: Oxera analysis.

For each of the route pairs, we assess the risk of carbon leakage using a Cournot model. In our model, each route is treated as its own market. The model treats the implementation of the Fit for 55 policies as a partial cost shock that affects a share of the market—the EU+ hubs—more than others—the non-EU+ hubs. The intuition behind the model is that if a hub is affected by an above-average cost shock, it will lose passengers, whereas a hub that experiences a below-average cost shock will gain passengers. Appendix A8 explains the analysis in greater detail.

To calculate the carbon leakage impact on connecting flights, we use the same input parameters as for direct flights. In particular, we assume the demand elasticities, CO_2 emissions from kerosene and SAF, and cost of kerosene and SAF are those set out in section 3. In terms of demand, we use 2019 passenger figures from the OAG traffic analyser. We use data from Google Flights for fares on these flights.[56]

4.4 Diversion to other modes

In addition to passengers no longer travelling or diverting to other routes, it is possible that passengers could choose to use other modes of transport instead, such as rail, car, bus/coach or ferry.

The extent to which these other modes can be substituted for air travel is limited by a number of factors. For example, in many cases, there may not be rail options available or road transport may not be feasible due to geography (e.g. islands). In addition, passenger substitution to other modes may be limited by journey duration. Over half of the 150 most popular aviation routes within the EU take over eight hours by rail, and only 14% of the most popular routes take less than four hours.[57]

Our analysis indicates that only 10% of routes are less than 500km, which is the distance that many governments are focusing on in terms of flight taxes or short-haul flight bans, as they are the routes for which passenger diversion to rail is most likely. These routes account for only around 3% of all CO_2 emissions on flights arriving in or departing from the EU+. Furthermore, not all of these routes will be substitutable with rail given factors such as geography, whether a rail line with a good service actually exists,[58] and the capacity of the existing rail network. Therefore, for the purposes of our analysis of carbon impacts in 2030, diversion to rail is unlikely to have a significant impact on carbon emissions.

By 2050, it is possible that new rail infrastructure will have been constructed and that there is greater substitution of rail for air transport—for instance, on longer distance journeys. However, given the uncertainty regarding the extent to which there will be more rail options available, we do not take this into account in our analysis.

[56] Prices for the selected routes have been collected on 11 to 14 February 2022 for a seven-day trip between 25 February 2022 and 4 March 2022 (i.e. 14 days ahead).
[57] Greenpeace (2021), 'Get on track: the alternative to short-haul flights in Europe', October.
[58] The European Court of auditors note that the high0speed network in Europe forms an 'ineffective patchwork' with poor connectivity and connections compared to air. See European Court of Auditors (2018), 'EU high-speed rail: an ineffective patchwork of lines without realistic long-term plan', https://www.eca.europa.eu/en/Pages/NewsItem.aspx?nid=10388.

5 Results

5.1 Introduction

In this section, we present the overall impacts of the Fit for 55 policies on airline fares and passenger demand at airports, as well as the impacts of the policies on carbon savings. We present the results separately for direct traffic and the connecting routes analysed.

5.2 Impact of Fit for 55 proposals on direct passenger traffic

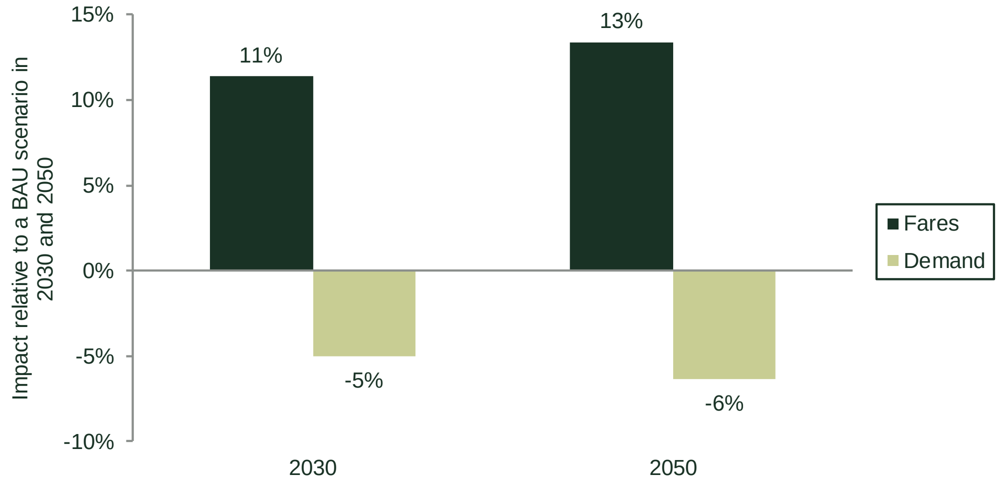
5.2.1 Airline fares and demand

Overall impact

As illustrated in Figure 5.1, we estimate that on average[59] across all direct flights the Fit for 55 proposals increase fares by 11% and 13% in 2030 and 2050 respectively, relative to a 'business-as-usual' (BAU) scenario where the Fit for 55 policies are not implemented. This leads to a reduction in demand of 5% and 6% relative to a BAU scenario in 2030 and 2050 respectively.

While demand is lower than it would be in absence of the Fit for 55 policies, demand still grows relative to 2019 levels. Even with the Fit for 55 proposals, demand is still expected to grow by 25% and 101% in 2030 and 2050 respectively compared to 2019 levels. Therefore, while the proposals reduce demand compared to a business-as-usual scenario, there is still expected to be demand growth in the aviation sector.

Figure 5.1 Impact of Fit for 55 policies on demand on direct flights



Note: The figures above represent percentage changes relative to the BAU scenario in 2030 and 2050.

Source: Oxera analysis.

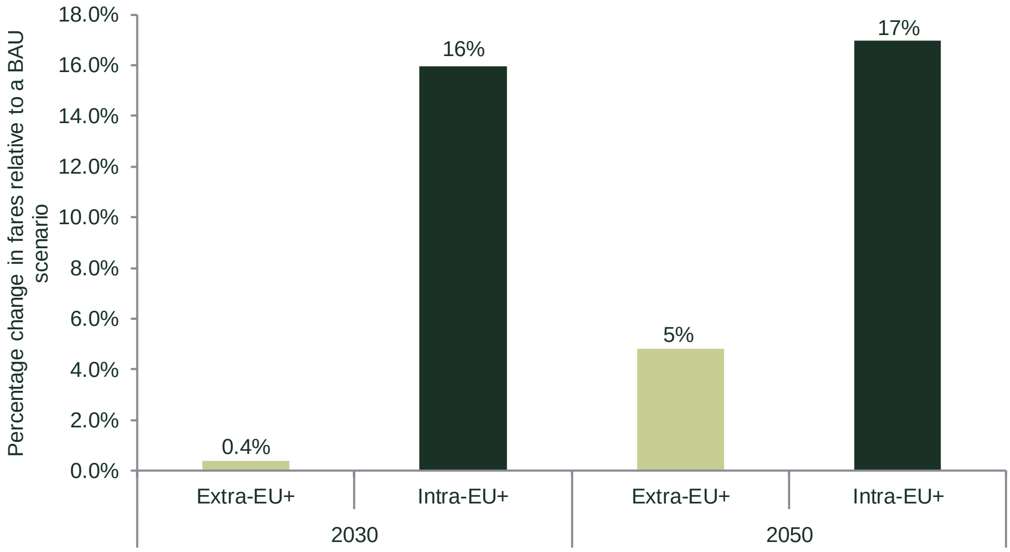
Impact on intra-EU+ and extra-EU+ routes

The Fit for 55 proposals affect intra-EU+ and extra-EU+ routes differently. Intra-EU+ routes are subject to the ETS, ETD and the SAF mandate at both ends of the route, while extra-EU+ routes are only subject to the ReFuelEU proposal for departing flights from the EU, with the rest of the emissions covered under CORSIA.

[59] All of the averages in this section are weighted averages, where the weights are the number of passengers.

Figure 5.2 below shows the increase in fares for extra-EU+ and intra-EU+ routes. On average, intra-EU+ routes experience larger fare increases than extra-EU+ routes. Fares increase by 16% in 2030 and 17% in 2050 for intra-European routes, while the average increase in fares for extra-European routes is only 0.4% in 2030 and 5% in 2050.

Figure 5.2 Impact of the Fit for 55 policies on fares, by region



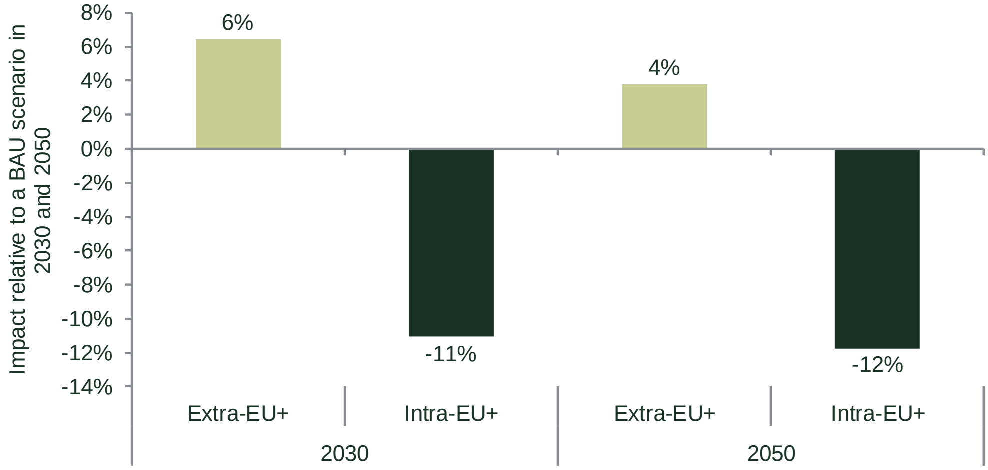
Source: Oxera analysis.

As a result, demand on intra-EU+ routes will be more affected—see Figure 5.3 below. Compared to the BAU scenario, the proposals reduce demand by 11% and 12% respectively in 2030 and 2050.[60] In contrast, demand on extra-EU+ routes rises by 6% in 2030 and 4% in 2050 compared to the BAU scenario. Even though there is a rise in fares on these routes which leads to demand loss, passengers divert from intra-EU+ to extra-EU+ routes, offsetting the impact of the fare increase on these routes.

While demand on extra-EU+ routes increases on average, the effects differ by route. The passengers diverting from intra-EU+ routes tend to travel to North Africa, the Middle East or Balkan destinations. Therefore, the demand increase on extra-EU+ routes is focused on routes to these regions. There is less diversion to other regions (e.g. North America, Asia-Pacific), so demand between the EU+ and these regions declines relative to a BAU scenario.

[60] Despite these demand impacts, demand on intra-EU+ routes would still grow by 10% and 78% in 2030 and 2050 relative to 2019 levels, even with the Fit for 55 proposals.

Figure 5.3 Impact of the Fit for 55 policies on demand, by region



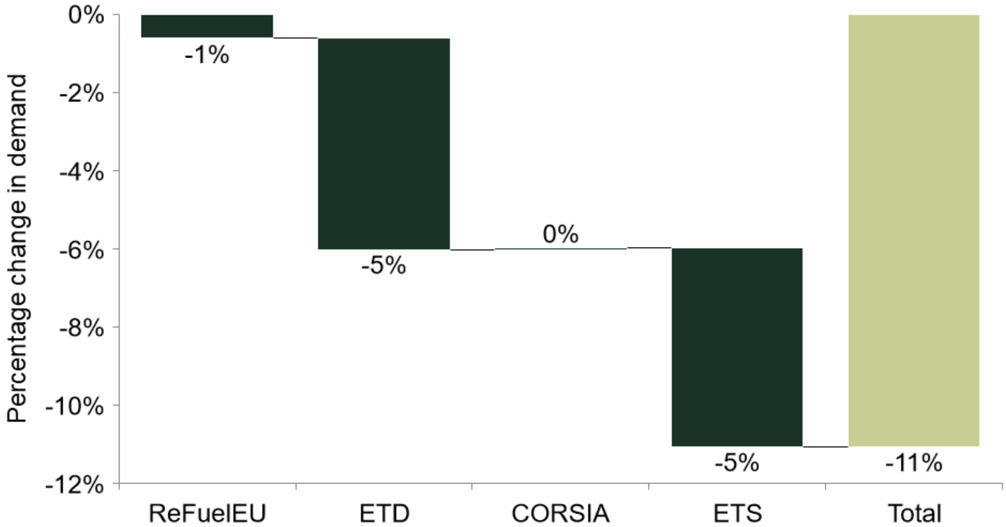
Note: The figures above represent percentage changes relative to the BAU scenario in 2030 and 2050, rather than relative to 2019 levels.

Source: Oxera analysis.

Impact of each Fit for 55 proposal

The impact of the Fit for 55 policies on fares and demand differ between 2030 and 2050. For intra-EU+ flights, the ETD and ETS are the main drivers of the demand reduction in 2030, while ReFuelEU explains most of the demand reduction in 2050—see Figure 5.4 and Figure 5.5 below.

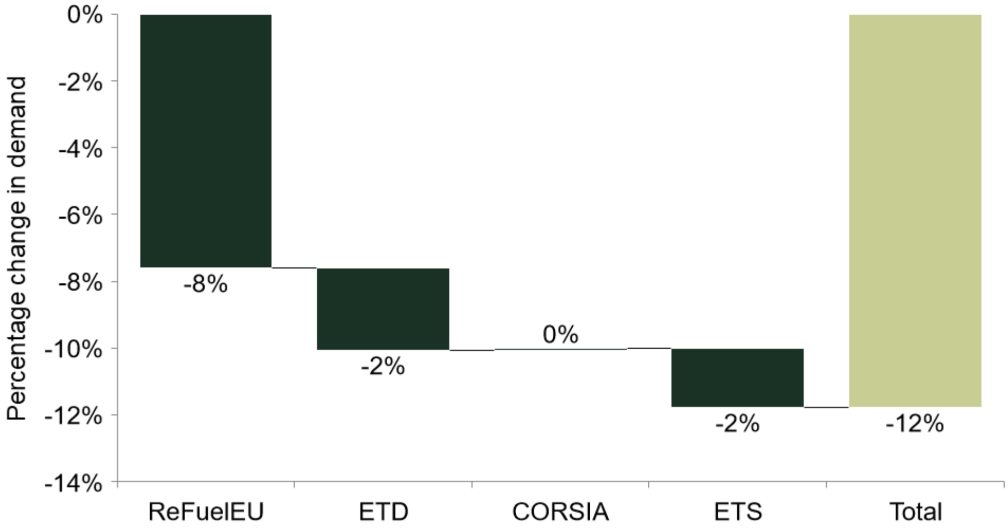
Figure 5.4 Impact on demand on intra-EU+ flights, by policy in 2030



Note: The 'Total' 11% figure here is comparable the numbers presented in Figure 5.3.

Source: Oxera analysis.

Figure 5.5 Impact on demand on intra-EU flights, by policy in 2050



Note: The 'Total' 12% figure here is comparable the numbers presented in Figure 5.3.

Source: Oxera analysis.

Impacts on direct traffic across airports

The Fit for 55 proposals will also have different effects across airports, with two types of airports being most potentially affected in terms of the loss of demand and connectivity.

Firstly, the above analysis shows that airports with a higher proportion of intra-EU traffic (e.g. regional EU airports) are likely to experience larger demand impacts for direct traffic than airports with a higher proportion of extra-EU traffic (e.g. large EU hubs).

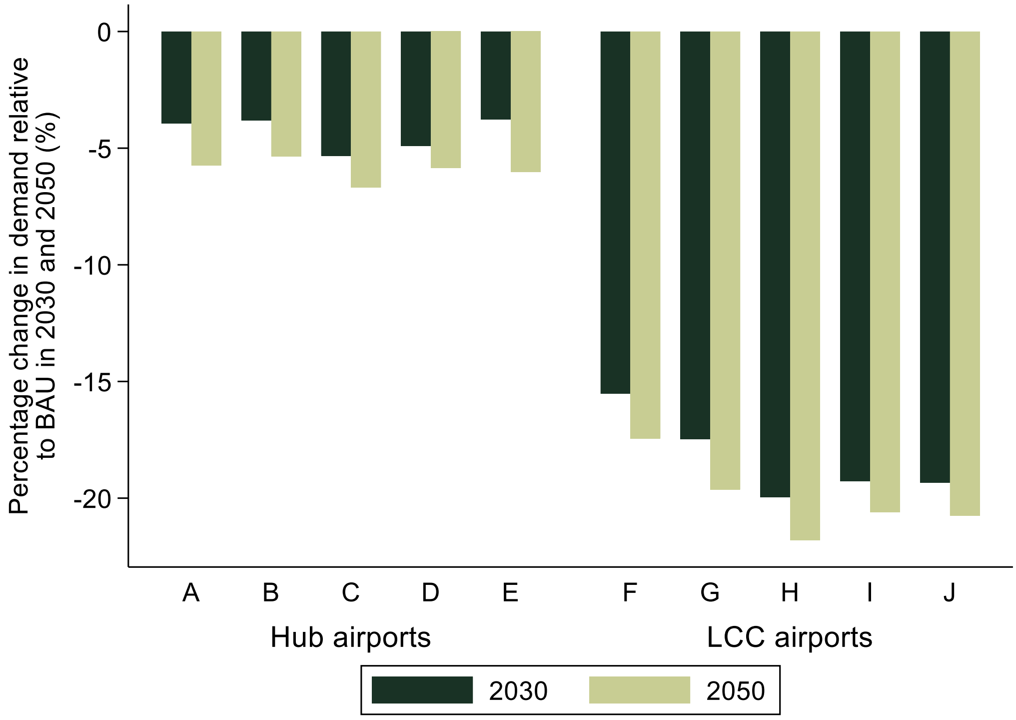
Secondly, airports that focus on low-cost traffic are likely to experience a greater increase in fares across the routes offered (as the cost of the policies will be a larger proportion of the fare), leading to greater demand impacts.

Figure 5.6 shows the overall demand effects of the proposals on direct routes for five large hub airports and five airports with a high proportion of low-cost and intra-EU traffic. We estimate airports that focus on low-cost and intra-EU traffic are likely to experience a greater reduction in direct traffic (around 17% in 2050 for the five airports considered below) compared to large hub airports (around 4% in 2050).[61]

Figure 5.6 below only accounts for direct traffic. However, there will also be an impact on connecting traffic, which varies across different types of connecting itineraries. This means that while the hub airports may be less impacted in terms of direct traffic loss, they will also experience losses on particular connecting route markets. At hub airports, there may also be an effect of losing direct routes on the financial viability of connecting routes. These results are discussed in section 5.3.

[61] Our analysis assumes a single load factor for all airlines (see section 3.2). One factor that may mitigate the difference in demand impacts between the two types of airlines is that low-cost carriers tend to have a higher load factor than hub carriers. This means that low-cost carriers may be able to better spread out the cost of the proposals across its passengers on a given flight.

Figure 5.6 Impact of the Fit for 55 proposals on direct traffic by airport type, 2030 and 2050



Note: The figures above only consider demand impacts for direct traffic. They represent percentage changes relative to the BAU scenario in 2030 and 2050, rather than relative to 2019 levels.

Source: Oxera.

5.2.2 Carbon leakage and carbon savings

The impact of the Fit for 55 proposals on carbon emissions come from a few different sources.

- **Demand CO_2 savings**. All other things being equal, when fares increase on a given route, demand on that route falls. Demand CO_2 savings measure the reduction in emissions associated with the reduction in demand. In effect, this measures the potential carbon savings if all of the carbon emitted by these passengers is abated. However, in practice, passengers may choose to divert from intra-EU+ routes to extra-EU+ routes, which will offset these carbon savings (see '**CO_2 from diverted passengers**' below).
- **SAF CO_2 savings**. The use of SAF leads to carbon savings for the passengers who continue to travel.
- **CO_2 from diverted passengers**. This measures the carbon emissions from passengers who divert to extra-EU+ routes.

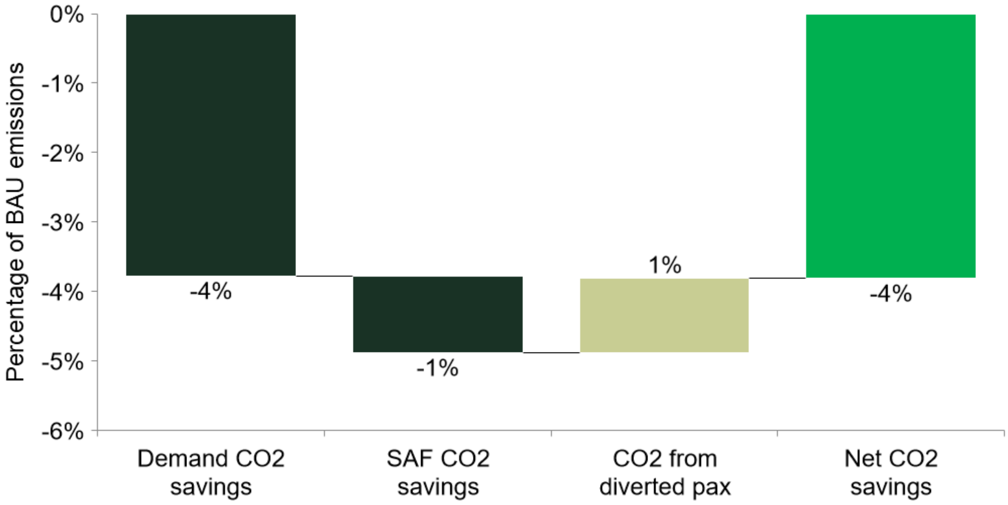
The net carbon savings is the sum of the demand and SAF CO_2 savings minus the CO_2 from diverted passengers.

Figure 5.7 and Figure 5.8 below illustrate the impacts of the Fit for 55 policies on carbon emissions in 2030 and 2050. Each of the impacts is calculated as a proportion of BAU carbon emissions, which includes all flights departing from or arriving in the EU+ (see section 4.1 for a more detailed description of how we have defined carbon leakage).[62]

As shown in Figure 5.7, 4% of all BAU carbon emissions will be abated through fewer people travelling (demand carbon savings) in 2030. Another important element of carbon savings is reducing the amount of emissions per passenger. This is driven by the use of SAF—the greater the use of SAF, the greater the savings in carbon emissions per passenger. In 2030 SAF carbon savings are small, representing only 1% of all BAU carbon emissions. This is because the ReFuelEU mandate requires airlines to uplift only a small proportion of their fuel (5%) as SAF when departing from an EU airport in 2030.

The emissions reductions due to demand and SAF CO_2 savings are offset to a small extent by carbon emissions from diverted passengers, accounting for 1% of emissions. Overall, however, there are net CO_2 savings of 4% for direct flights in 2030.

Figure 5.7 Effect of Fit for 55 proposals on carbon emissions on direct flights, 2030



Note: Each bar is calculated as a proportion of BAU emissions, covering all flights departing from or arriving in the EU+. Therefore, net CO_2 savings of 4% means that 4% of all BAU emissions on flights departing or arriving in the EU+ would be abated due to the Fit for 55 proposals. The aggregate figures have been calculated using a weighted average, with weights according to 2019 passenger demand.

Source: Oxera analysis.

In 2030, carbon leakage—according to the IPCC definition (see section 4.1)—is approximately 22%. This means that for every 100tCO_2 that is saved due to the use of SAF and reductions in demand, 22t will be emitted by passengers who divert from intra-EU+ to extra-EU+ flights.

In the context of overall emissions, the Fit for 55 proposals do not significantly reduce carbon emissions in 2030—only 5% of BAU carbon emissions will be saved through reductions in demand and the use of SAF. Therefore, the carbon leakage figure of 22% represents 1% of total BAU emissions. In other words, for every 100t of carbon under the BAU scenario, only 5t of carbon will be saved due to the use of SAF and reductions in demand, and around 1t of carbon will be leaked. It is important to understand the carbon leakage figure of

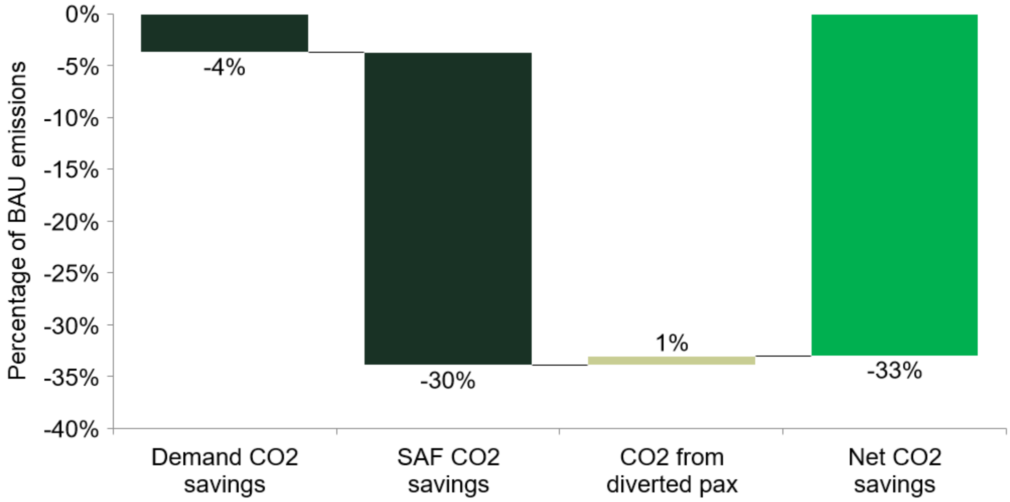
[62] As we express carbon impacts as a proportion of all emissions departing from or arriving in the EU+, the denominator also includes emissions on flights from non-EU+ to EU+.

22% in the context of total emissions—carbon leakage in 2030 does not significantly contribute to an increase in emissions.

In 2050, the use of SAF leads to much larger reductions in carbon emissions at around 30% of BAU emissions, as shown in Figure 5.8. This is because the ReFuelEU proposal requires airlines to uplift a much more significant proportion of their fuel as SAF (63%). Furthermore, CO_2 emissions from diverted passengers remains relatively small (1% of BAU emissions). This is driven, in part, by the fact that emissions from diverted passengers will also be lower as a higher proportion of SAF will need to be uplifted on extra-EU+ flights, albeit only the departing leg from the EU+.

After accounting for demand CO_2 savings (4%) and the CO_2 emissions from diverted passengers (1%), the net impact is that 33% of all BAU emissions will be abated. Adopting the IPCC definition of carbon leakage as described above, carbon leakage in 2050 is only around 3%.

Figure 5.8 Effect of Fit for 55 proposals on carbon emissions on direct flights, 2050



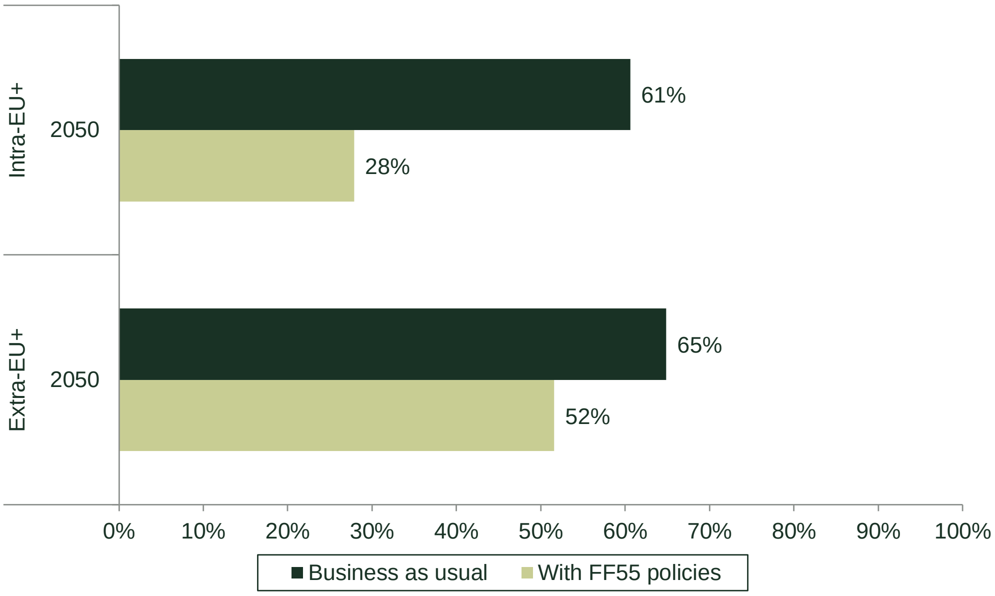
Note: Each bar is calculated as a proportion of BAU emissions, covering all flights departing from or arriving in the EU+. Therefore, net CO_2 savings of 33% mean that 33% of all BAU emissions on flights departing or arriving in the EU+ would be abated due to the FF55 proposals. The aggregate figures have been calculated using a weighted average, with weights according to 2019 passenger demand.

Source: Oxera analysis.

Figure 5.9 compares the carbon emissions per passenger on intra-EU+ flights and extra-EU+ flights in 2050 to 2019 levels. On both intra- and extra-EU+ flights, emissions per passenger in the BAU scenario are around 60–65% of their 2019 levels. This is due to anticipated fuel efficiency improvements and the use of a small volume of SAF in a BAU scenario.

As a result of the Fit for 55 proposals, intra-EU+ emissions per passenger are reduced to only 28% of their 2019 levels while extra-EU+ emissions per passenger remain at 52% of 2019 levels. This means that while intra-EU+ passengers will be disproportionately affected by fare increases compared to extra-EU+ passengers, they will also generate the most significant carbon savings as a proportion of BAU emissions.

Figure 5.9 Carbon emissions per passenger on direct flights, as a proportion of 2019



Source: Oxera analysis.

As the proposals affect demand and carbon emissions much more on flights between two policy area airports, airports and countries are affected more or less strongly depending on the type of traffic served.

Countries with a higher share of intra-EU+ flights suffer greater losses in demand, but also achieve the highest share of carbon reductions (see, for instance, Slovakia in the heatmap below). In absolute terms, the countries with the greatest number of passengers contribute the greatest amount in terms of carbon savings (see, for instance, the UK in the heatmap below).

Figure 5.10 Carbon emissions by country

Note: The darker the colour of the bubble, the larger the relative carbon savings. The larger the size of the bubble, the larger the absolute carbon savings. The list of countries is sorted in descending manner by the relative carbon savings.

Source: Oxera analysis.

5.3 Impact of proposals on connecting traffic

We have also assessed the impact of the Fit for 55 proposals on fares, demand and carbon emissions for ten example connecting routes (see Table 4.2). The results have been aggregated across the routes, with weights applied according to passenger numbers. Results for individual routes are shown in Appendix A7.

5.3.3 Airline fares and demand

Overall impact

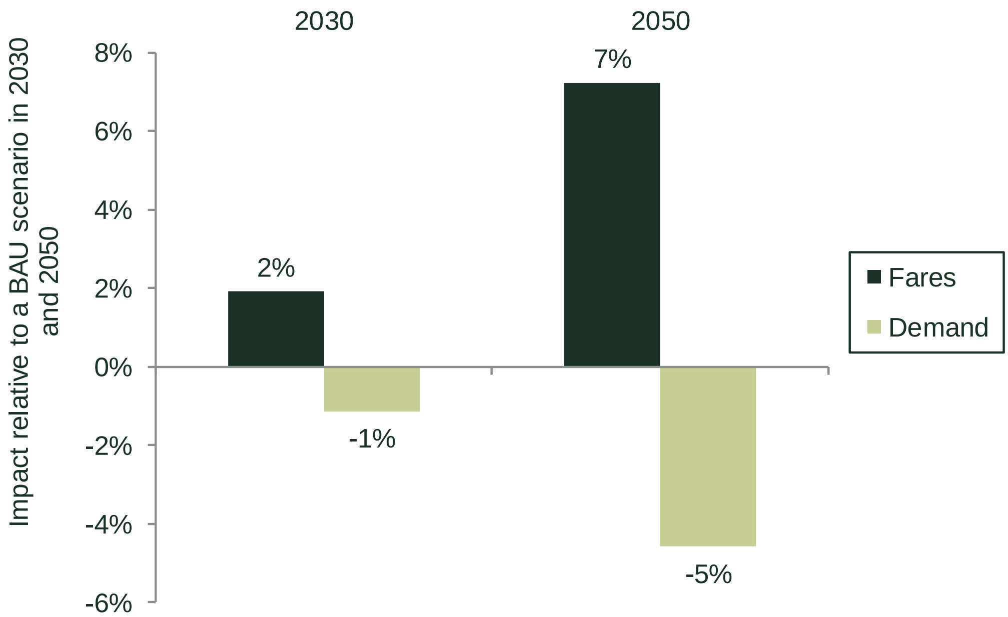
Figure 5.11 shows that on average,[63] across the ten connecting routes examined, the Fit for 55 proposals lead to an increase in fares of 2% and 7% in 2030 and 2050 respectively, relative to a 'business-as-usual' (BAU) scenario where the Fit for 55 policies are not implemented. This reduces demand by 1% and 5% in 2030 and 2050. This is an average across EU and non-EU hubs.

However, there are different impacts on hub airports within and outside the EU+. Connecting passengers can often choose between different hub airports to travel between a given origin and destination, and can therefore substitute an EU+ hub for a non-EU+ hub. This is important, as carbon leakage on direct flights requires a passenger to change the destination airport from an EU+ to a non-EU+ airport. In contrast, hub switching on connecting routes does not impact the passenger's origin or destination. As a result, there is a greater risk of carbon leakage on connecting routes than on direct ones.

[63] All the averages in this section are weighted averages, where the weights are the number of passengers.

While the proposals have an impact on demand compared to a BAU scenario, there is still expected to be strong demand growth relative to 2019. Even if the Fit for 55 proposals are implemented, demand is expected to rise by 70% and 186% in 2030 and 2050 respectively compared to 2019. These high growth rates are driven by above-average growth of itineraries outside of Europe—especially those including Asia.

Figure 5.11 Impact of Fit for 55 policies on demand on connecting flights, average of EU and non-EU hubs

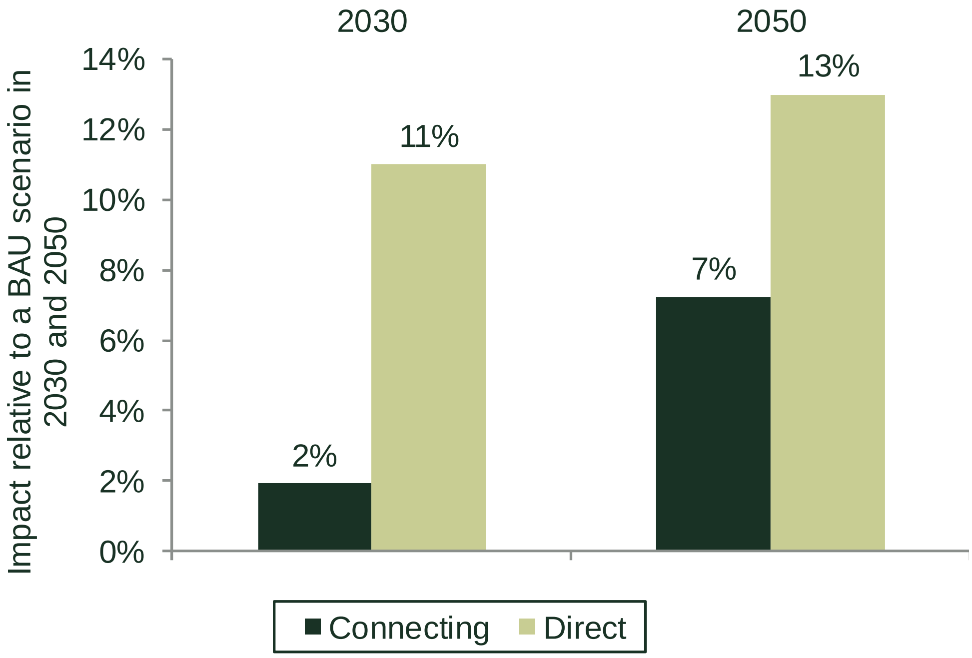


Note: The figures above represent percentage changes relative to the BAU scenario in 2030 and 2050.

Source: Oxera analysis.

Figure 5.12 below compares the aggregate impact of the Fit for 55 policies on fares for direct passengers and connecting passengers, and shows that the impact for connecting passengers is smaller than that for direct passengers. This is because: (i) fares for connecting flights are typically higher as they are long-haul flights, so any cost increase is a smaller proportion of the overall fare; and (ii) flights between two airports outside of the policy area will not be affected by the Fit for 55 policies. Given the lower impact on fares, the impact on demand for connecting flights on the selected routes is also smaller than for direct flights.

Figure 5.12 Impact of Fit for 55 policies on fares of connecting and direct routes, 2030 and 2050



Note: The aggregate figures have been calculated using a weighted average, with weights according to 2019 passenger demand.

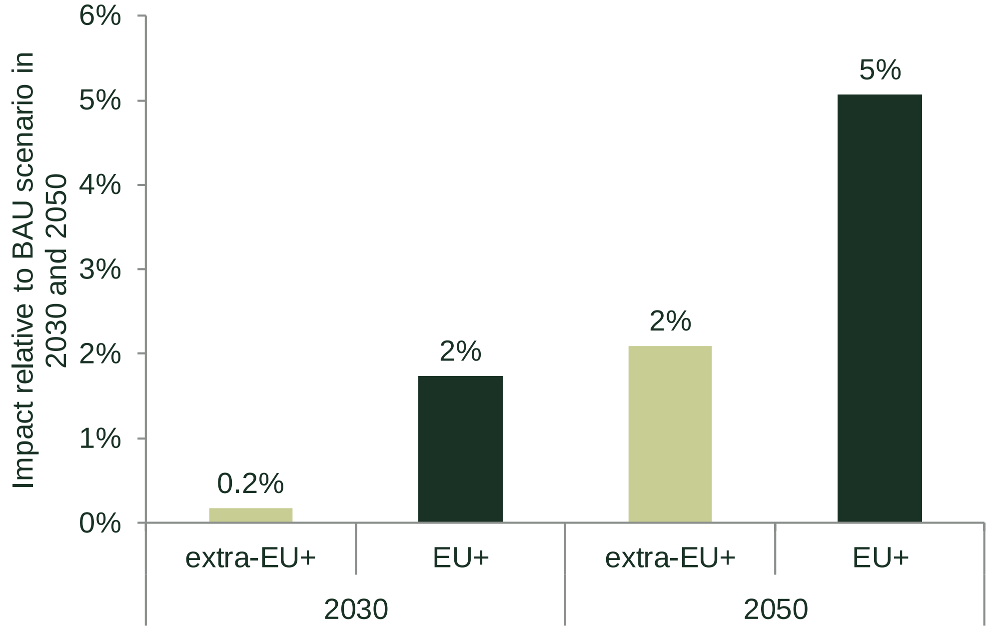
Source: Oxera analysis.

Impact on EU+ and non-EU+ hubs

The Fit for 55 proposals will affect EU+ hubs more than hubs outside of the EU+. Flights that hub inside the EU+ are subject to the ETS, ETD and the SAF mandate on at least at one leg of the itinerary, while extra-EU+ hubs are only affected by CORSIA (and the SAF mandate on one leg of the itinerary if the flight is from the EU). Fares of connecting itineraries that hub at EU+ airports will therefore increase by a larger amount than fares of connecting itineraries that hub at airports outside of the EU+.

Figure 5.13 below shows the increase in fares for extra-EU+ hubs and intra-EU+ hubs. While the fares at EU+ hubs increase by 2% in 2030 and 5% in 2050, the average increase in fares for hubs outside of the EU+ region is only 0.2% in 2030 and 2% in 2050.

Figure 5.13 Impact of the Fit for 55 policies on fares for connecting flights, by hub location

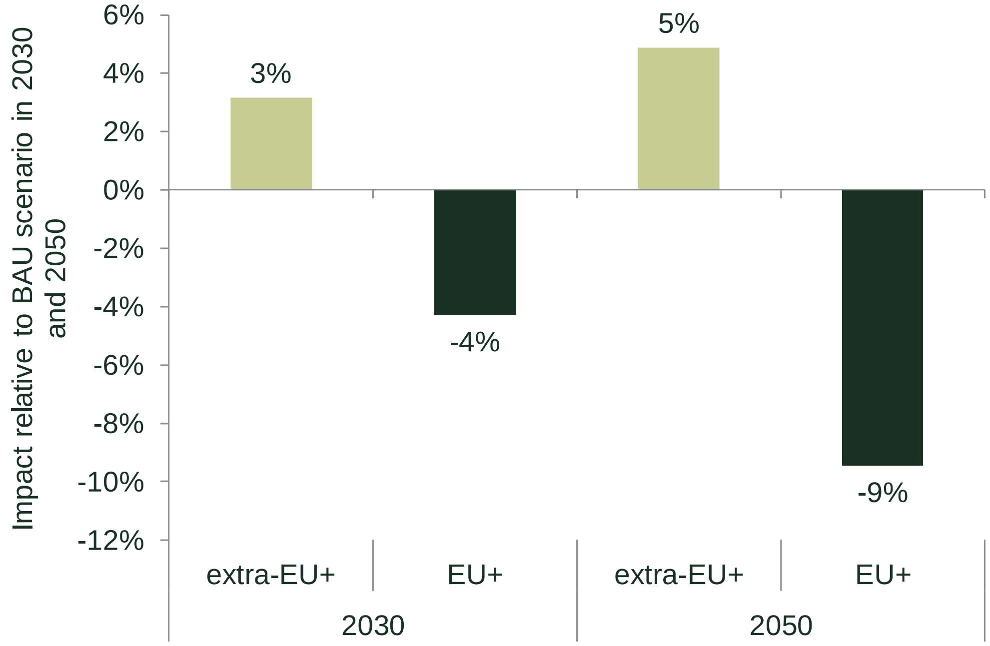


Note: The aggregate figures have been calculated using a weighted average, with weights according to 2019 passenger demand.

Source: Oxera analysis.

Due to the greater increase in fares on itineraries that hub through EU+ airports, passengers may choose to shift from hubs within the EU+ to hubs outside of the EU+. Figure 5.14 below shows that EU+ hubs face demand losses, while hubs outside of the policy area experience an increase in demand due to passenger diversion. The proposals lead to a reduction in passengers at EU+ hubs by 4% and 9% respectively in 2030 and 2050. In contrast, we estimate that passenger demand at extra-EU+ hubs would increase by 3% and 5% in 2030 and 2050 compared to the BAU scenario.

Figure 5.14 Impact of the Fit for 55 policies on demand for connecting flights, by hub location



Note: The figures have been indexed to 2019 demand and calculated using a weighted average, with weights according to passenger demand.

Source: Oxera analysis.

Despite these demand impacts, connecting traffic at EU+ hubs would still grow by 67% and 181% in 2030 and 2050 relative to 2019 levels, even if the Fit for 55 proposals are implemented.

While Figure 5.14 shows the aggregate results across the connecting routes considered, the impacts differ by route. Box 5.1 sets out the results for one of the routes analysed in more detail, while the impacts on the other connecting routes are included in Appendix A7.

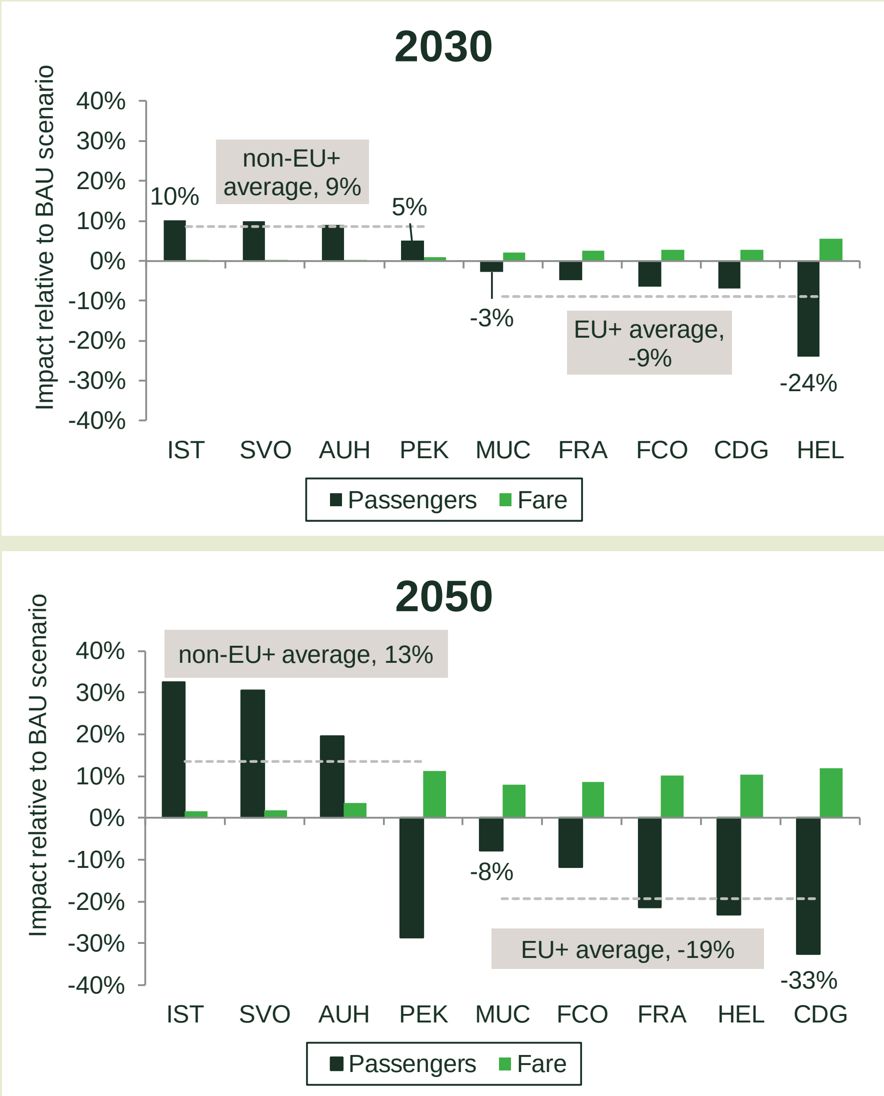
Box 5.1 Case study: impact in 2035 on a selected connecting route (Milan Malpensa–Seoul)

On the Milan Malpensa–Seoul Incheon route, the Fit for 55 proposals lead to a reduction in passengers travelling via EU+ hubs. By 2030, connecting passenger traffic via Munich decreases by 3%, while Helsinki experiences a much greater reduction in passengers at approximately 24%. The extent of the loss in passengers is related to the size of the cost increase: the larger the cost increase, the larger the reduction in demand. Extra-EU+ hubs such as Istanbul (IST), Moscow (SVO), Abu Dhabi (AUH) and Beijing (PEK) experience an increase in connecting passenger traffic on this route by between 5% and 10% due to comparatively lower price increases as a result of the Fit for 55 proposals.

By 2050, there is much greater diversion of passengers from EU+ to non-EU+ hubs due to more significant cost increases. Traffic via Munich reduces by 3% and traffic at Paris reduces by about 33%, while connecting passengers via Istanbul (IST) and Moscow (SVO) increase by over 30%. Beijing International Airport will be negatively affected by the Fit for 55 policies in 2050 as SAF mandates put a significant cost burden on hubs far away from the EU+ region, due to the long journey from the EU+ airport to the extra-EU+ hub.

Overall in 2030, the reduction in traffic across EU+ airports is 9%, while non-EU+ airports experience an increase in traffic by 9%, with impacts of -19% and 13% respectively in 2050.

Figure 5.15 Impact on fares and passenger demand for 2030 and 2050 for different hubs on the route Milan Malpensa–Seoul Incheon



Note: The figures above represent percentage changes relative to the BAU scenario in 2030 and 2050.

Source: Oxera analysis.

5.3.4 Carbon leakage and carbon savings

As noted in section 5.2.2, carbon emissions are affected by the Fit for 55 proposals in a number of ways. CO_2 is saved as fewer passengers travel by air (**demand CO_2 savings**) and airlines use SAF to fuel their planes (**SAF CO_2 savings**), but more CO_2 is produced when passengers divert to extra-EU+ routes (**CO_2 from diverted passengers**). The net carbon savings is the sum of the demand and SAF CO_2 savings minus the CO_2 from diverted passengers.

Table 5.1 shows the carbon savings, the carbon emissions increase from passenger diversion, and the net carbon savings in 2030 and 2050 aggregated across the ten example connecting routes. Each of the impacts is calculated as a proportion of BAU carbon emissions.[64] While there is a limited amount of carbon leakage, net carbon savings are positive in 2030 and 2050. This implies that the Fit for 55 policies lead to a reduction of CO_2 emissions for the connecting flights considered.[65]

The figures below include carbon emission savings across all itineraries analysed. Because European airports are more affected by the policies, carbon emission reductions at EU+ airports will tend to be larger than the average figures cited here.

Table 5.1 Carbon savings and carbon leakage for connecting traffic, 2030 and 2050

	Carbon savings (demand + SAF)	CO_2 from diverted passengers	Net carbon savings
2030	6%	-4%	2%
2050	32%	-4%	27%
Total	**38%**	**-8%**	**30%**

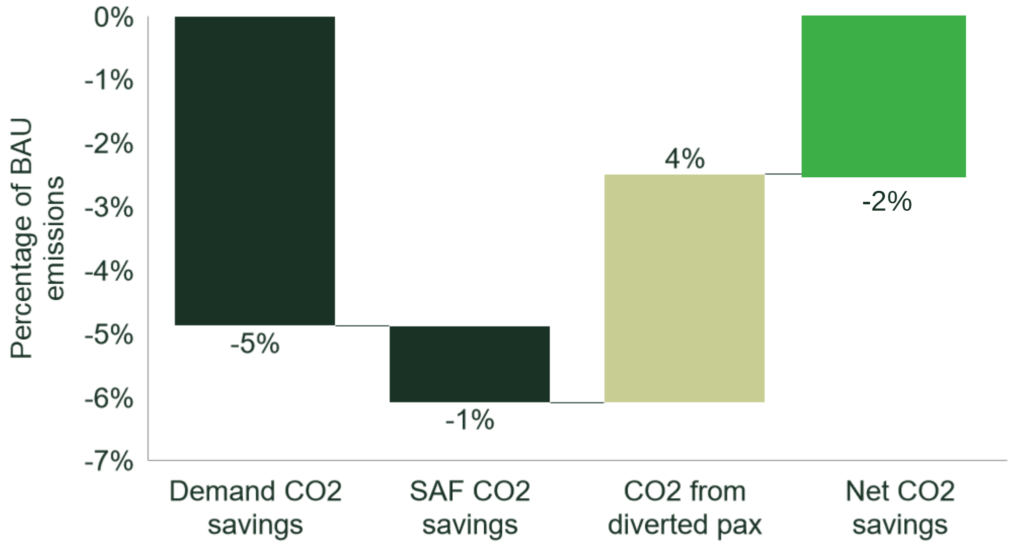
Note: The aggregate figures have been calculated using a weighted average, with weights according to 2019 passenger demand. Percentages have been calculated as share of total business-as-usual carbon emissions on itineraries that involve at least one EU+ airport.

Source: Oxera analysis.

Figure 5.16 and Figure 5.17 illustrate how the Fit for 55 proposals affect carbon emissions in 2030 and 2050 on connecting flights. As shown in Figure 5.16, 5% of all BAU carbon emissions will be abated through fewer people travelling (demand carbon savings). At the same time, the Fit for 55 policies will reduce the amount of emissions per passenger due to increased SAF usage. In 2030 SAF carbon savings are small, representing only 1% of all BAU carbon emissions. This is because the ReFuelEU mandate requires airlines to uplift only a small proportion of their fuel (5%) as SAF when departing from an EU airport. These emissions reductions are partially offset by carbon emissions from diverted passengers, accounting for 4% of emissions. Overall, however, there are net CO_2 savings of 2% for connecting traffic in 2030.

[64] We express carbon impacts as a proportion of all emissions on the selected example routes where a connecting itinerary involves an EU+ airport.
[65] This section accounts for all carbon emitted on both legs of the selected example routes. If our analysis of carbon savings and diversion took into account only the emissions from the legs departing from the EU+, the estimated effectiveness of policy proposals would be higher.

Figure 5.16 Effect of Fit for 55 proposals on carbon emissions for connecting traffic, 2030

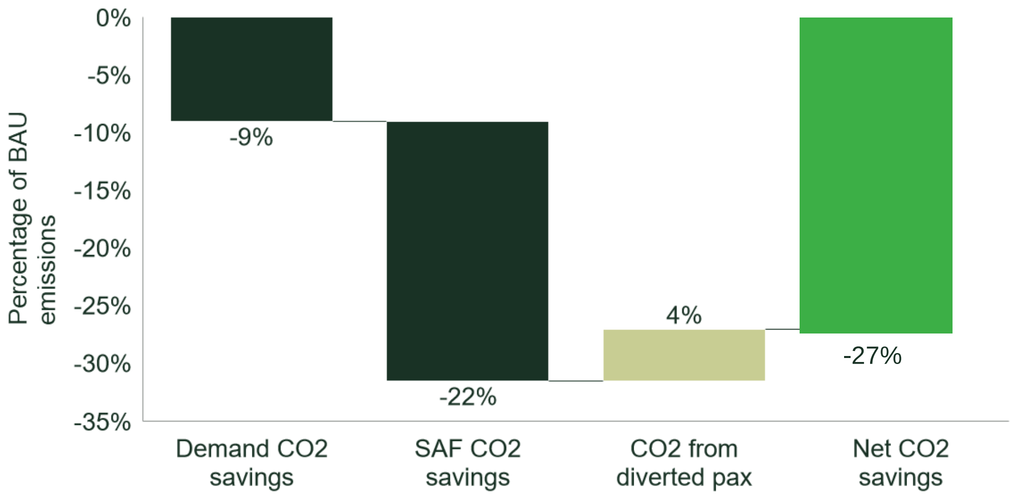


Note: 'Demand CO_2 savings' refers to carbon reductions as a result of decreased passenger demand for air travel. 'SAF CO_2 savings' refers to carbon reductions as a result of lower per-passenger emissions. 'CO_2 from diverted pax' refers to an increase in CO_2 on the ten example routes via non-EU hubs. Each bar is calculated as a proportion of BAU emissions, covering all then example routes. The aggregate figures have been calculated using a weighted average, with weights according to 2019 passenger demand. Percentages have been calculated as share of total business-as-usual carbon emissions.

Source: Oxera analysis.

In 2050, the net carbon savings resulting from the Fit for 55 policies are approximately 12 times larger than in 2030. This is mainly driven by the increase in carbon savings from increased SAF usage. Importantly, carbon emissions from passenger diversion remains fairly similar at 4% in 2050.

Figure 5.17 Effect of Fit for 55 proposals on carbon emissions for connecting traffic, 2050



Note: 'Demand CO_2 savings' refers to carbon reductions as a result of decreased passenger demand for air travel. 'SAF CO_2 savings' refers to carbon reductions as a result of lower per passenger emissions. 'CO_2 from diverted pax' refers to an increase in CO_2 on the ten example routes via non-EU hubs. Each bar is calculated as a proportion of BAU emissions, covering all then example routes. The aggregate figures have been calculated using a weighted average, with weights according to 2019 passenger demand. Percentages have been calculated as share of total business-as-usual carbon emissions.

Source: Oxera analysis.

In 2030, carbon leakage—according to the IPCC definition (see section 4.1)—is around 67%. This means that for every 100tCO_2 that is *saved* due to the use of SAF and reductions in demand, 67t will be emitted by passengers who divert from intra-EU+ to extra-EU+ hubs.

In the context of overall emissions, in 2030 only 6% of BAU carbon emissions will be saved through reductions in demand and the use of SAF. Therefore, the carbon leakage figure of 67% actually only represents 4% of total BAU emissions. In other words, for every 100t of carbon under the BAU scenario, only 6t of carbon will be saved due to the use of SAF and reductions in demand, and around 4t of carbon will be leaked.

In 2050, CO_2 savings from reductions in demand and the use of SAF are 32% of BAU emissions, and CO_2 from diverted passengers account for 4% of BAU emissions. Therefore, under the IPCC definition of carbon leakage, carbon leakage is 13%.

While results differ by route, net carbon savings are positive on each route analysed. In general, carbon savings are positively correlated with the share of total distance that is flown between two EU+ airports—i.e. the greater the share of a connecting flight that is between two EU+ airports, the greater the reduction in carbon emissions.

As an example, for the route Rome–San Francisco, a passenger could fly through a number of hubs within or outside the policy area. The itineraries that have a larger proportion of the flight inside the policy area—i.e. those that hub in London, Lisbon or Paris—have the largest carbon savings. The itineraries that hub outside of the policy area, such as in New York, are subject to an increase in carbon emissions because of passenger diversion from EU+ hubs and lower use of SAF. Appendix A7 provides analysis of the results for each route.

6 Sensitivity analysis: a techno-optimist and policy-pessimist view

6.1 Introduction

We have undertaken sensitivity analysis to consider how the impact of the policies depends on assumptions about technological progress and the extent to which certain targets are achieved. In addition to the baseline analysis, we consider a techno-optimist sensitivity—which includes greater uptake of SAF and fuel efficiency improvements—as well as a policy pessimist sensitivity—which captures a world in which the policy proposals become less stringent during the legislative process and in which less ambitious goals are set. In this way, the techno-optimist sensitivity shows the impact of the policies if technological progress makes them less costly to achieve, while the policy pessimist sensitivity assumes that the policies adopted are less stringent.

6.2 Description of techno-optimist and policy-pessimist assumptions

The key differences between the assumptions in the baseline, techno-optimist and policy-pessimist analysis are outlined in Table 6.1 below.

The techno-optimist sensitivity includes greater improvements in fuel efficiency over the entire period modelled. It also assumes that SAF prices decline more quickly than anticipated, and reach price parity[66] with kerosene by 2050. As the cost of SAF declines, SAF uptake is higher than in the baseline. Additionally, the types of SAF that are used vary between the two scenarios: the techno-optimist scenario includes more power-to-liquid fuels and fewer hydroprocessed esters and fatty acids (HEFA). As the former have a smaller carbon footprint, the emissions savings from SAF usage are higher, and taxes paid under the ETD are lower than in the baseline.

The policy pessimist sensitivity models less ambitious Fit for 55 policies. In particular, this is reflected in lower SAF targets and no tax on kerosene. Additionally, it assumes that a slower phasing out of free allowances and a reduction of emission allowances supply reduces the price of the EU ETS. As such, the policies have less of a financial impact on airlines, leading to less of an incentive to reduce carbon emissions from aviation.

[66] Price parity after taxes.

Table 6.1 Assumptions that differ between baseline, techno-optimist and policy-pessimist analysis

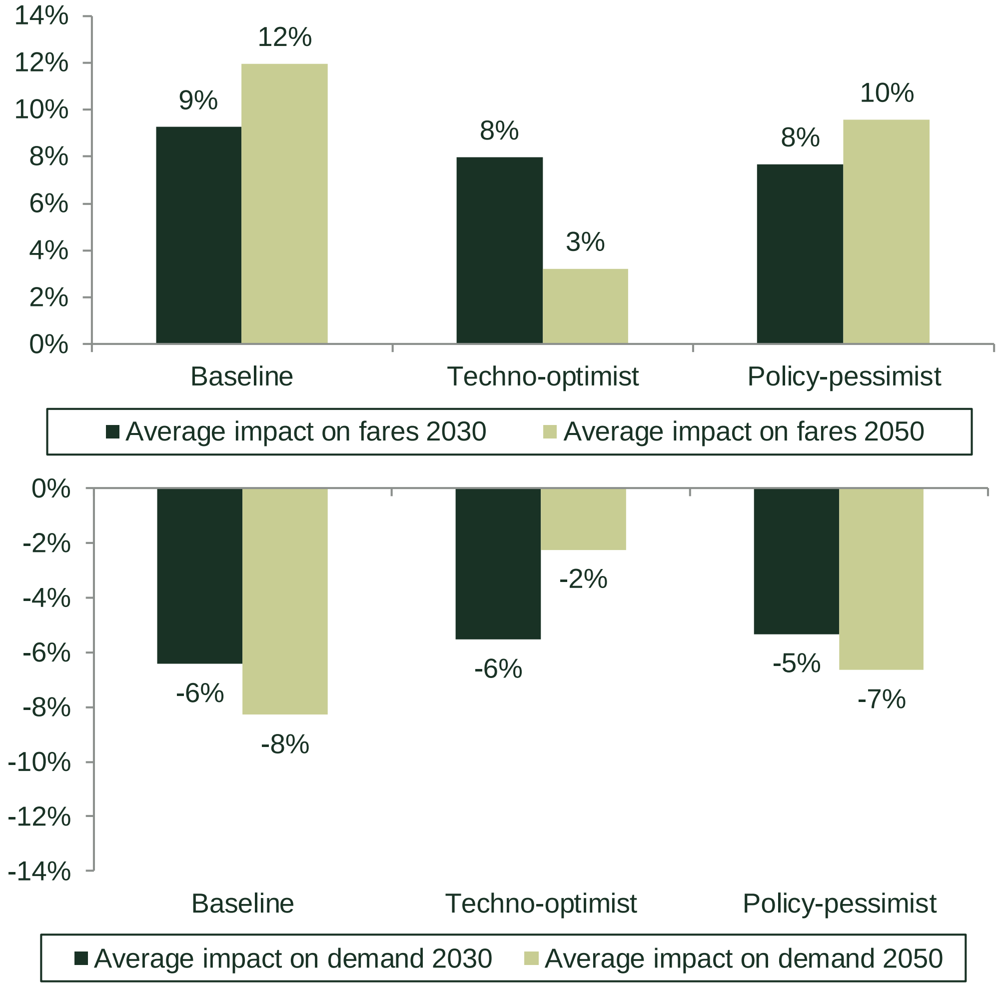
	Baseline	Techno-optimist	Policy-pessimist	Comment
Fuel efficiency improvement (2030/2050)	1.3%/1.3%	2.0%/2.0%	Same as baseline	Techno-optimist: due to technological progress, fuel efficiency savings could be closer to the historical peak of 2.5%
SAF uptake (2030/2050)	5%/63%	15%/80%	3%/43%	Techno-optimist: due to technological progress, SAF becomes cheaper and take-up is faster. Policy-pessimist: SAF mandates are not met by industry, or mandates are changed during the legislative process.
SAF unit costs before tax (2030/2050)	1,960 EUR/ 1,968 EUR	1,191 EUR/ 1,130 EUR	Same as baseline	Techno-optimist: due to technological progress, costs for SAF decline more rapidly than expected. By 2050, price parity (after taxes) with conventional jet fuel is reached.
ETD (2030/2050)	No taxation on SAF in 2030; SAF taxed at €6.45 per tonne in 2050. Kerosene taxed at €323.58 in 2030 and €462.25 in 2050.	Same as baseline	No ETD implemented; tax rates on all fuels are 0.	The ETD is implemented with the same parameters in the baseline and the techno-optimist scenarios. No ETD is implemented in the policy pessimist sensitivity.
EU ETS effective prices (2030/2050)	129 EUR/ 212 EUR	Same as baseline	98 EUR/ 136 EUR	Policy-pessimist: a less stringent implementation of the EU ETS means that demand for emissions allowances does not increase as quickly and supply does not reduce as quickly. Consequently, the price for the ETS increases by less.

Source: Oxera analysis.

6.3 Results

Figure 6.1 illustrates the impact of the Fit for 55 policies on fares and demand with the baseline, techno-optimist and policy-pessimist assumptions. The results for 2030 do not vary greatly between the three scenarios, though there is more variation between the sensitivities in 2050. In particular, the impact on fares and demand will be much smaller in a techno-optimist world with greatly reduced SAF prices. In the policy pessimist scenario, where the quantity of SAF used is lower, the impact on demand is only around 5%. The ReFuelEU mandate, with its requirements on SAF uptake, is the policy with the largest impact on fares in all three scenarios in 2050.

Figure 6.1 Impact of the different policy scenarios on fares and demand, 2030 and 2050



Note: 'Extra-EU+ flights' refers to any flights between two non-EU airports, or a flight from an EU+ airport to a non-EU+ airport.

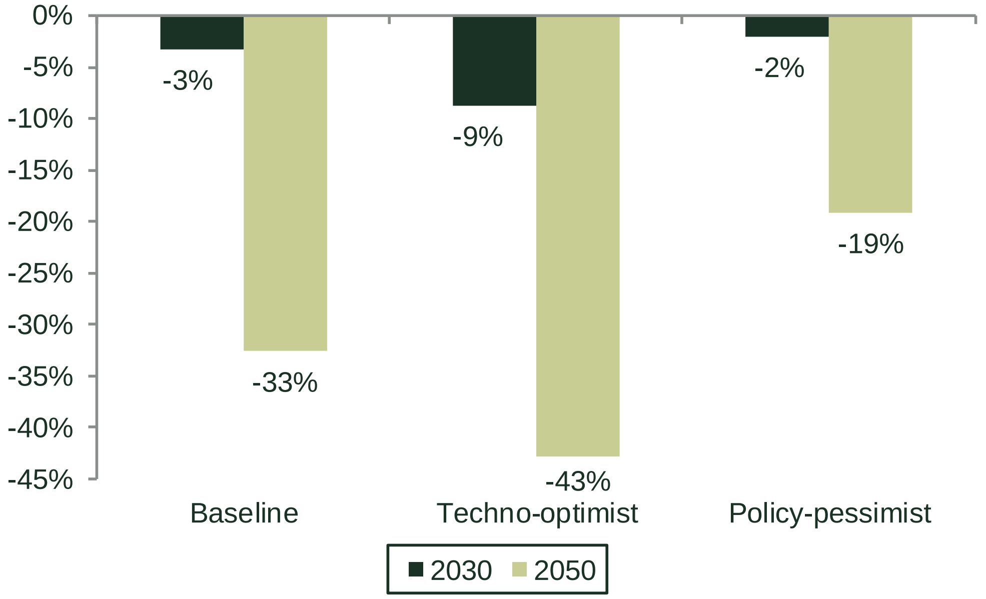
Source: Oxera analysis.

The impacts of the policies on fares and demand must be viewed in the context of the effect on carbon emissions. Figure 6.2 displays the carbon savings in each year under the different sensitivities. These savings are calculated compared to the business-as-usual scenario in which no policies are implemented.

Our modelling shows that carbon emissions vary significantly depending on the assumptions. In particular, if technological progress on SAF is quick and its uptake surpasses the minimum thresholds set by ReFuelEU, as assumed in the techno-optimist scenario, carbon savings could be more than twice as large as the baseline in 2030 and around 30% higher than the baseline in 2050.

In contrast, if the Fit for 55 policies become less stringent during the legislative process, as modelled in the policy pessimist scenario, carbon savings could be half of those achieved with full implementation of the policies, even though demand losses are similar.

Figure 6.2 Proposed net carbon savings from the Fit for 55 policies in different sensitivities



Note: The percentage reduction is the difference in total aviation emissions between the counterfactual and policy scenarios, once savings from demand reductions and use of SAFs, as well as carbon leakage, are taken into account.

Source: Oxera analysis.

This sensitivity analysis highlights that: (i) the impact of the Fit for 55 policies on demand and carbon emissions could be significantly more favourable than the baseline scenario if technological progress is quick and the uptake of SAF is high; (ii) the impact of the policies on carbon emissions could be considerably lower, though with similar demand impacts, if they are applied less stringently. Importantly, the ReFuelEU initiative remains the most impactful policy in all scenarios. This means that if policymakers are serious about reducing carbon emissions in the EU+, SAF mandates should be first priority.

7 Conclusion

The European Commission has put forward the Fit for 55 proposals to achieve a 55% reduction in emissions by 2030 relative to 1990 levels, and to meet net zero targets by 2050. In particular, to address the aviation sector's impact on the environment, the European Commission has proposed mandating the use of sustainable aviation fuels, requiring the supply of electricity to stationary aircraft, and placing an effective price on CO_2 emissions and jet fuel. This report estimates the impacts of the European Commission's Fit for 55 proposals on airports. Our key conclusions are set out below.

The AFIR leads to additional costs that will need to be borne by airports. The effects of the AFIR will differ by airport and depend on a range of factors—e.g. whether the airport serves narrow- and/or wide-body aircraft, and whether airports provide fixed electricity supply or use electrical ground power units.

The ETS, ETD, ReFuelEU and CORSIA will lead to additional costs for airlines, which will be partly passed through to passengers in the form of higher fares, leading to a demand response. While we find that the proposals lead to a reduction in demand relative to a business-as-usual scenario, there will still be growth in air travel relative to 2019 levels.

There will be a reduction in demand on intra-EU+ direct flights as a result of the Fit for 55 policies. In particular, the ETD and ETS will have significant effects in 2030, while ReFuelEU drives the demand reduction in 2050. We estimate that fares will increase by 16% and 17% on intra-EU+ flights in 2030 and 2050 relative to a business-as-usual scenario. This results in a reduction in demand of 11% and 12% in 2030 and 2050. Furthermore, airports that focus on low-cost traffic are likely to be significantly affected by the proposals, partly due to their focus on intra-EU+ flights, but also because the proposals would lead to a greater proportional increase in their fares. These reductions in demand may lead to losses in connectivity at a number of these airports.

In contrast, demand on extra-EU+ direct flights will rise by 6% and 4% in 2030 and 2050 respectively compared to the business-as-usual scenario. Even though there is an increase in fares on these routes (0.4% in 2030 and 5% in 2050) that leads to demand loss, passengers divert from intra-EU+ to extra-EU+ routes, offsetting the impact of the fare increase. However, impacts differ by route—the diverting passengers tend to travel to North Africa, the Middle East or Balkan destinations. Therefore, the demand increase on extra-EU+ routes is focused on routes to these regions. There is less diversion to other regions (e.g. North America, Asia-Pacific), so demand between the EU+ and these regions declines relative to a BAU scenario.

The Fit for 55 proposals will increase costs on itineraries connecting via EU+ hubs more than itineraries connecting via non-EU+ hubs, leading to diversion in connecting traffic from EU+ to non-EU+ hubs. We estimate that connecting traffic at EU+ hubs will reduce by 4% and 9% in 2030 and 2050 respectively relative to a BAU scenario. Some of these passengers will divert to extra-EU+ hubs, resulting in an increase in demand of 3% in 2030 and 5% in 2050.

The impact of the Fit for 55 proposals vary by connecting itinerary. For example, connecting itineraries with a long intra-EU+ leg will be more affected by the ETS and the ETD, while itineraries with a long leg between an EU+ and non-EU+ airport will be more affected by the ReFuelEU proposal.

The Fit for 55 proposals will result in carbon leakage, potentially limiting the environmental effectiveness of the proposals. In particular, we consider direct passengers who may switch from intra-EU+ to extra-EU+ flights, and connecting passengers who may switch from EU+ hubs to non-EU+ hubs. Therefore, while we find that the Fit for 55 proposals lead to a net reduction in carbon emissions, these will also lead to carbon leakage arising from passenger diversion.

A1 Economic impacts of the Fit for 55 policies

A1.1 Introduction

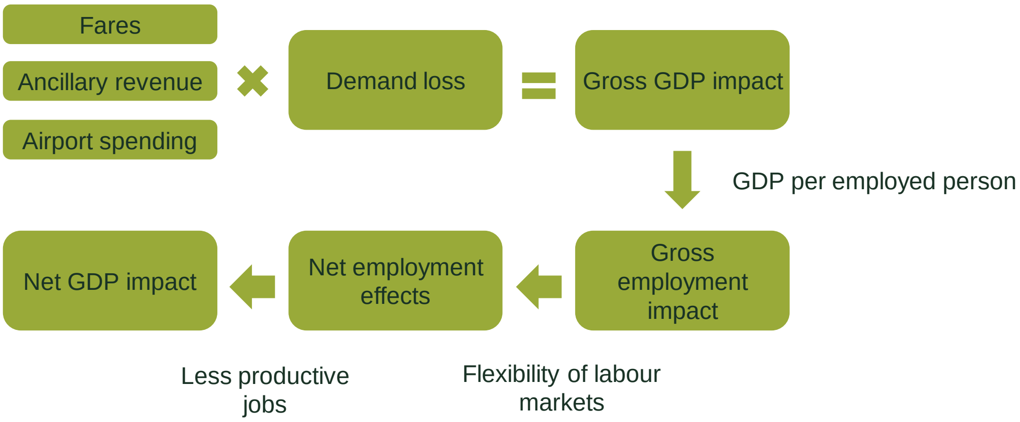
The reduction in aviation demand due to the Fit for 55 proposals could lead to reductions in gross domestic product (GDP)[67] and employment in Europe. Section A1.2 sets out our methodology for quantifying these effects while Section A1.3 provides the results.

A1.2 Methodology

GDP and employment impacts can be categorised into gross and net impacts. Gross impacts, also known as the 'economic footprint', measure the GDP and jobs that are supported by the aviation sector. These are therefore the GDP and job losses that could occur due to the Fit for 55 proposals without accounting for substitution effects—i.e. without accounting for the fact that people who lose their jobs may be able to find jobs elsewhere. Net impacts adjust the gross impacts for substitution effects.

Our methodology for estimating GDP and employment impacts of the Fit for 55 proposals is summarised in Figure A1.1 below.

Figure A1.1 Overview of methodology for calculating economic impacts



Source: Oxera.

Methodology for estimating gross impacts ('economic footprint')

Under the expenditure approach, GDP is calculated as the sum of consumption, investment, government spending and net exports. A key mechanism by which the Fit for 55 proposals will affect GDP is through a reduction in consumption by passengers.[68] This will lead to a reduction in the number of people directly employed in the aviation sector (direct employment impacts), but also a reduction in jobs in industries that support the aviation

[67] Gross domestic product (GDP) is a measure of economic activity. It is defined as the value of all goods and services produced minus the value of any goods or services used in their creation. See Eurostat (2021), 'GDP per capita in PPS', https://bit.ly/3KkZA1S.
[68] There are other secondary mechanisms by which the Fit for 55 proposals may affect GDP. A reduction in aviation demand may reduce the amount of investment in the aviation industry. Alternatively the additional tax revenue from the proposals may enable more government spending. However, these effects are difficult to robustly quantify. For instance, a reduction in investment in the aviation industry may free up funds to be used elsewhere in the economy, or government spending may crowd out resources from the private sector. A quantification of these other mechanisms is outside the scope of this report.

sector (supply chain employment impacts), such as aircraft maintenance. We quantify both the direct and indirect employment effects.[69]

We calculate the gross GDP impact by estimating the loss in passenger spending on air tickets, which is the demand loss set out in section 5 multiplied by fares from the Google Flights dataset.[70] We include other sources of passenger spending associated with flights, including spending at airports and ancillary revenues.[71] Table A1.1 below sets out the ancillary and airport revenue per passenger that we have used in our calculations. Adding the loss in passenger spending on air tickets, in airports and on ancillary services provides an estimate of the gross GDP impact.[72] We carry out these calculations for each country in the policy area.

Table A1.1 Ancillary and airport spending per passenger

Spend area	Spend per passenger
Ancillary revenue per passenger	€19.26[1]
Spending per passenger at airports	€20[2]

Source: [1] Sorensen, J. (2021), 'The 2021 CarTrawler Yearbook of Ancillary Revenue', 14 September, https://bit.ly/3sMw3Ix. [2] Based on information from ACI.

To derive the gross impact on employment, we would ideally divide the gross GDP impact by the GDP per employed person in the aviation sector. However, these estimates are not publicly available. Therefore, we estimate the GDP per employed person in the aviation sector using the following methodology. We obtain the GDP per employed person across the EU+.[73] We account for the potential that the aviation sector may be a more productive sector than the average sector, and scale up the GDP per employed person using the EU KLEMS dataset.[74] We forecast these figures to 2030 and 2050 based on GDP per-capita growth rates.[75] We then divide the gross GDP impact by our estimate of the GDP per employed person to obtain the gross impact on employment.

[69] Another type of impact is induced effects. The initial loss in spending by passengers leads to lower income for others in the economy, which leads to even less spending. However, these multiplier effects are difficult to quantify robustly. For example, passengers may substitute their spending away from the aviation sector towards other sectors in the economy, leading to an increase in demand and more jobs in those sectors. Given the difficulty of robustly quantifying these impacts, we do not consider them further in our report.
[70] As we have taken a case study approach to connecting flights, we have not calculated the overall impact of the proposals on connecting flights. For the purposes of obtaining a high level estimate of the economic impacts of the proposals, we include the impact of connecting flights by modelling each of the legs as direct flights. While this does not take into account the level of fares on connecting itineraries and the nature of competition on these routes, it allows us to provide an estimate of the demand impact on connecting itineraries beyond the case studies we have considered.
[71] Ancillary revenues are revenues from non-ticket sources, such as baggage handling and on-board food and services.
[72] As this gross GDP impact is calculated using the price of final products, it captures the value add of all the sectors involved in producing the final product. Our GDP and employment estimates, which are calculated using the GDP impacts, capture both the direct and supply chain effects of the Fit for 55 proposals.
[73] Calculated by taking the GDP at market prices in 2019 in the EU28 divided by the total number of full and part-time employees in the EU28. Eurostat (2022), 'Gross domestic product at market prices', https://bit.ly/3MuKxEv; Statista (2022), 'Number of part-time employees in the European Union (EU28) from 2002 to 2019', https://bit.ly/3tALQZU; Statista (2022), 'Number of full-time employees in the European Union (EU28) from 2002 to 2020', https://bit.ly/3MpSuei.
[74] The EU KLEMS dataset provides value added and total employment by industry in the EU. As the EU KLEMS dataset is not sufficiently disaggregated to provide the value added at the aviation sector level, we use the 'transport and storage' and 'transport and equipment' sectors as comparators to the aviation sector. We average the value added per employee of these two sectors, and find that it is 1.3 times larger than the average across all EU industries. We multiply our GDP per employed person figure with this figure to approximate the GDP per employed person in the EU aviation sector.
[75] European Commission (2021), 'The 2021 Ageing Report. Economic & budgetary projections for the EU Member States (2019-2070)', May, https://bit.ly/35YfmRu.

Methodology for estimating net impacts

Net impacts adjust the gross impacts for substitution effects. In order to calculate net impacts in the short-run, we would need to account for a wide range of knock-on impacts following the initial impact of the proposals. Therefore, given the complexity and the large number of assumptions needed to quantify the short-run net impacts, we focus on the medium- to longer-term effects on the economy. In particular, we consider the effects of the proposals on the supply side—how would the policies affect labour markets?

Some individuals who lose their jobs due to the reduction in demand associated with the Fit for 55 proposals may be able to quickly find work in other sectors. Others may take longer to find work—i.e. become long-term unemployed—which refers to people who have been unemployed for 12 months or more. This will depend on the flexibility of labour markets in each country—countries with better support for people who have lost their jobs will likely have lower long-term unemployment effects. We estimate the number of people who may become long-term unemployed by multiplying the job losses by the long-term unemployment rate in each country. This represents the medium-term (i.e. lasting more than a year) net job impacts of the policy as other people would have been able to find work in other sectors.

To calculate the net medium-term impact on GDP, we note that those who are able to find work relatively quickly (i.e. not the long-term unemployed) will be contributing to GDP. However, evidence from economic literature suggests that displaced workers (i.e. those with established work histories who have lost their jobs due to economic reasons unrelated to job performance) tend to accept lower earnings to find work again, suggesting that they work in less productive jobs. Therefore, based on lower bound values from the economic literature, we assume that the jobs they find will be 5% less productive than jobs they previously held.[76]

Over the longer term, most people should be able to find some form of employment again.[77] Therefore, the longer-term job impacts of the proposals are not likely to be significant. However, individuals may have to accept a cut in pay relative to their previous jobs, or work fewer hours than they would like. We assume that the long-term unemployed who manage to find work again will be in jobs that are 20% less productive, based on upper-bound values from the economic literature.[78]

A1.3 Results

Table A1.2 below shows the gross economic impacts on annual GDP and employment. These estimates do not account for substitution effects—i.e. that the displaced workers will be able to find work again. On this basis, we estimate that the Fit for 55 proposals will lead to a gross annual GDP reduction of €28bn and €63bn per year in 2030 and 2050 respectively. There will also be a loss of 248,000 and 371,000 jobs in 2030 and 2050 respectively, either directly in the aviation sector or in supporting industries.

[76] For a summary of the literature in the USA and Europe, see Appelqvist, J. (2007), 'Wage and earnings losses of displaced workers in Finland', *Vatt discussion papers.*
[77] For example, see Ruhm, C.J. (1991), 'Are workers permanently scarred by job displacements?', *American Economic Review*, **81**:1, pp. 319–24.
[78] For a summary of the literature in the USA and Europe, see Appelqvist, J. (2007), op. cit.

Table A1.2 Gross economic impacts

Economic impacts	2030	2050
GDP per year (€bn)	-28	-63
Employment (jobs)	-248,000	-371,000

Source: Oxera.

Table A1.3 below shows the net economic impacts on annual GDP and employment, accounting for substitution effects. Over the medium term—i.e. a year or more—the annual reduction in GDP is €11bn and €24bn respectively in 2030 and 2050, with net job losses of 88,000 and 130,000 in 2030 and 2050.

These job losses represent a relatively small proportion of total employment, so the medium-term net job loss figures would be less than 0.1% of total employment in 2030 and 2050. Nevertheless, in absolute terms, the number of jobs lost is still quite large—88,000 and 130,000 more people would be out of work for more than a year in 2030 and 2050 respectively relative to a BAU scenario.

Over the longer term, assuming that the long-term unemployed are eventually able to find work again, albeit at lower productivity than their previous jobs, the annual GDP impacts are estimated to be €3bn in 2030 and €7bn in 2050.

Table A1.3 Net economic impacts

Time frame	Economic impacts	2030	2050
Medium term: a year or more	GDP per year (€bn)	-11	-24
	Employment (jobs)	-88,000	-130,000
Long term	GDP per year (€bn)	-3	-7
	Employment (jobs)	Not significant	Not significant

Source: Oxera.

A2 High-level estimates of the potential costs of the AFIR

This appendix sets out the potential costs of AFIR, as described in section 2.3.1. It provides indicative high-level costs based on the minimum, average and maximum number of gates and stands for each group of airports. The average numbers in this table are the same as those in section 2.

Table A2.1 Minimum, average and maximum number of stands and gates by airport size

			All narrow-bodied aircraft		With 50% of gates/stands for wide-bodied aircraft	
Group	Group traffic band (mppa)	Stands and gates	No existing electricity supply	With existing electricity supply	No existing electricity supply	With existing electricity supply
Group 1	>25	Max	24.8	49.6	37.2	74.4
		Average	10.0	20.0	15.0	30.0
		Min	3.9	7.8	5.9	11.7
Group 2	15–25	Max	13.9	27.8	20.9	41.7
		Average	7.2	14.4	10.8	21.6
		Min	3.1	6.1	4.6	9.2
Group 3	5–15	Max	12.8	25.6	19.2	38.4
		Average	4.4	8.8	6.6	13.2
		Min	1.3	2.6	2.0	4.0
Group 4	1–5	Max	4.1	8.2	6.2	12.3
		Average	1.8	3.6	2.7	5.4
		Min	0.5	1.1	0.8	1.6
Group 5	<1 mppa	Max	2.4	4.8	3.6	7.2
		Average	0.4	0.8	0.6	1.2
		Min	0.1	0.2	0.2	0.4

Source: Oxera.

A3 Description of data

In this appendix, we provide further details on how we have gathered the Google Flights data.

We obtain data on carbon emissions per passenger,[79] and airline fares for return flights from Google Flights, based on data from April 2021 to February 2022.[80] We gather data from Google Flights on all routes with at least a weekly frequency.[81] For each route, we obtain prices and carbon emissions on a daily basis.[82]

As preferences differ across passengers—for instance, business passengers may book much closer to the departure date than leisure passengers—we use prices based on different combinations of departure dates and trip durations. Specifically, we gather prices for flights 14, 60 and 240 days in advance of the departure date, and for trip durations of three and seven days. We calculate route-level average prices and carbon emissions per passenger by taking an average of the prices and carbon emissions collected for each route. We remove routes with only a small number of observations to ensure that the data used in the analysis is robust. The routes included in our analysis account for over 90% of capacity in the 2019 OAG dataset.

Google Flights includes both CO_2 and non-CO_2 effects, such as nitrogen oxide emissions and contrails, in its carbon emissions estimates. However, the EU ETS only covers CO_2 emissions.[83] Therefore, to estimate the impact of the ETS, we remove non-CO_2 effects from Google Flights' carbon emission estimates. We compare the CO_2 emissions from our dataset to verified CO_2 emissions volumes in the EU ETS, and find that they are broadly aligned.[84]

[79] Google Flights estimates carbon emissions per passenger using the European Environmental Agency (EEA) methodology. This takes into account factors including origin, destination, aircraft type, and the fuel efficiency of aircraft. For further details on how Google Flights estimates carbon emissions, see Google (N.D.), 'Check carbon emissions on Google Flights', https://support.google.com/travel/answer/9671620?hl=en-GB.

[80] The data from Google Flights was gathered over a period when the aviation industry was affected by COVID-19, which may affect the fares data. However, we understand from ACI that yields in 2021 were actually around 1% higher than in 2019. In addition, data from Eurostat shows that the price of air travel in 2020 and 2021 was only about 5% lower than in 2019. The ECB noted that during the initial lockdowns in the second quarter of 2020, firms may have preferred to delay price changes until restrictions were lifted to avoid additional menu costs. See Eurostat (2022), 'HICP – annual data (average index and rate of change). [prc_hicp_aind]', https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=prc_hicp_aind&lang=en; Lis, E. and Nordeman, J. (2021), 'Prices for travel during the COVID-19 pandemic: is there commonality across countries and items?', https://www.ecb.europa.eu/pub/economic-bulletin/focus/2021/html/ecb.ebbox202101_06~bcb28cb255.en.html.

[81] At least a weekly frequency in at least one IATA season from 2017 to 2019, based on the OAG dataset.

[82] For connecting flights, prices for the selected routes have been collected on 11 to 14 February 2022 for a seven-day trip between 25 February 2022 and 4 March 2022 (i.e. 14 days ahead).

[83] European Commission (2020), 'Report from the Commission to the European Parliament and the Council. Updated analysis of the non-CO2 climate impacts of aviation and potential policy measures pursuant to EU Emissions Trading System Directive Article 30(4)', 23 November, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2020:747:FIN.

[84] Verified CO_2 emissions for aviation under the EU ETS were 68Mt of CO_2 in 2019. We multiply the carbon emissions per passenger estimates in the Google Flights database with the number of seats on each route (this implicitly assumes a 100% load factor) in the OAG dataset to obtain the total emissions per route. If we add up the emissions across all the routes within the scope of the EU ETS, 60Mt of CO_2 would be emitted under our estimates. While our estimates are slightly lower than the verified emissions under the EU ETS, this could be due to a number of factors. For example, we only have carbon emissions data for 90% of passengers.

A4 Forecasting demand

A4.1 Overview of approach

We base our demand forecasts on the ACI World Airport Traffic Forecasts (WATF). The WATF provides growth rates for different regions of the world from 2019 until 2040. This is shown in Table A4.1 below.

In order to produce forecasts up to 2050, we assume that growth rates between 2040 and 2050 will be similar to growth rates between 2030 and 2040.

Table A4.1 Growth rates of international passengers, 2019–50

Region	2019–30	2030–40
Africa	51%	39%
Asia-Pacific	77%	64%
Latin America-Caribbean	66%	62%
Middle East	81%	71%
North America	59%	51%
Europe[1]	42%	28%

Note: the growth rate for Europe includes all intra-EU+ flights.

Source: ACI World Air Traffic Forecasts.

However, the WATF does not provide passenger growth rates between different regions—for instance, from Europe to Asia-Pacific. To estimate this, we assume that if the growth rate of the Asia-Pacific region is, for example, twice that of Africa, then the growth rate of traffic between Europe and Asia-Pacific will also be twice that of the growth rate between Europe and Africa. This captures the fact that growth rates from Europe to some regions may be higher than others.

We then calibrate these growth rates to be consistent with the overall EU+ growth rate, as shown in Table A4.1 above. In particular, we ensure that the weighted average of growth rates between Europe and each region is equal to the overall European growth rate, where the weights are the share of overall European traffic for each region (the mathematical details are provided at the bottom of this section). The resulting growth rates are shown in Table A4.2 below.

Table A4.2 Estimated growth rates between Europe and each region of the world

Route	2019–30	2019–50
Europe to Africa	4.1%	2.4%
Europe to Asia-Pacific	5.6%	3.8%
Europe to Latin America-Caribbean	5.0%	3.6%
Europe to Middle East	5.8%	4.1%
Europe to North America	4.6%	3.0%
Intra-EU+[1]	2.5%	2.5%

Note: the intra-EU+ growth rate is taken from the ICAO long-term traffic forecasts.

Source: Oxera.

For our analysis of connecting traffic, we require growth rates between two non-EU+ regions—for instance, between North America and Asia-Pacific.

As we do not have sufficient data to apply the methodology above, we rely on ICAO long-term traffic forecasts.[85]

A4.2 Mathematical derivation

The number of passengers in Europe is the sum of passengers between Europe and each region of the world. This is written in mathematical notation in the equation below, where $P^{t}_{Europe,j}$ is the number of passengers travelling between Europe and region j (where j are the regions listed in Table A4.2 above) in year t, and P^{t}_{Europe} is the total number passengers departing from or arriving in Europe:

$$\sum P^{t}_{Europe,j} = P^{t}_{Europe}$$

We can then show that the overall growth rate of European traffic is a weighted average of growth rates between Europe and each region:

$$\sum (P^{t}_{Europe,j} - P^{2019}_{Europe,j}) = P^{t}_{Europe} - P^{2019}_{Europe}$$

$$\sum \frac{P^{t}_{Europe,j} - P^{2019}_{Europe,j}}{P^{2019}_{Europe}} * \frac{P^{2019}_{Europe,j}}{P^{2019}_{Europe,j}} = \frac{P^{t}_{Europe} - P^{2019}_{Europe}}{P^{2019}_{Europe}}$$

$$\sum \frac{P^{t}_{Europe,j} - P^{2019}_{Europe,j}}{P^{t}_{Europe,j}} * \frac{P^{2019}_{Europe,j}}{P^{2019}_{Europe}} = \frac{P^{t}_{Europe} - P^{2019}_{Europe}}{P^{2019}_{Europe}}$$

We can rewrite this equation as:

$$\sum \Delta^{t}_{Europe,j} w_{Europe,j} = \Delta^{t}_{Europe} ----(1)$$

where

$$\Delta^{t}_{Europe,j} = \frac{P^{t}_{Europe,j} - P^{2019}_{Europe,j}}{P^{2019}_{Europe,j}}$$

which is the percentage change in international passengers between year t and 2019 between Europe and region j (the quantity we are interested in estimating);

$$w_{i,j} = \frac{P^{2019}_{Europe,j}}{P^{2019}_{Europe}}$$

which is the share of European traffic to region j; and

$$\Delta^{t}_{Europe} = \frac{P^{t}_{Europe} - P^{2019}_{Europe}}{P^{2019}_{Europe}}$$

which is the overall growth rate of European traffic.

We calculate Δ^{t}_{Europe} using the ACI world traffic forecasts, and $w_{Europe,j}$ using OAG data in 2019.

[85] ICAO (2016), 'ICAO long-term traffic forecasts. Passenger and cargo', July 2016, p. 21.

In order to estimate $\Delta^t_{Europe,j}$, the growth rate between Europe and each region we assume that:

$$\Delta^t_{Europe,j} = \frac{\Delta^t_j}{\sum \Delta^t_k w_{Europe,k}} \Delta^t_{Europe} ----(2)$$

We can see that (2) obeys the identity in (1), meaning that estimating the growth rates from Europe to each region using this equation will be consistent with the overall European growth rate.

A5 Demand elasticities

There are a number of studies that quantify the price elasticity of demand in the aviation industry. However, these tend to focus on the effect of fare changes on individual routes, rather than fare changes across a large number of routes. As a result, passengers may be able to switch to alternative routes where prices have not increased. For example, a leisure passenger departing from Milan Bergamo Airport flying to Palma de Mallorca may consider travelling to another beach holiday destination instead if prices of flying to Palma de Mallorca increase. Price elasticities of demand from studies that only consider fare changes on individual routes are therefore likely to be higher given the number of alternative routes.

However, the Fit for 55 policies will apply to a large number of routes. Using the previous example, if the passenger flying from Milan Bergamo Airport now finds that fares to other beach destinations are also higher, there is less of an incentive to switch away from their original flight. Therefore, the demand response as a result of the Fit for 55 policies may be more inelastic.

Ideally we would use elasticities from studies that consider the effect of EU-wide cost shocks on demand. However, there are very few studies on the demand effects of EU-wide cost shocks. There are some studies that examine the impact of the EU ETS on the aviation sector, though these generally find that the ETS does not have significant effects on air passenger demand.[86] Nonetheless, the past effects of the ETS, with a significant number of free allowances and low ETS prices, may not be a good indicator of the future effects of the ETS under the Fit for 55 proposals.

Therefore, we use demand elasticities based on studies of air passenger taxes. These taxes are typically levied on all flights departing from a country, and therefore cover a wide geographical scope. These studies are summarised in Table A5.1 below.[87] The average elasticity of these studies is -0.63. This estimate suggests that if average fares on a given route rise by 10%, then passenger demand on that route would fall by 6.3%.

[86] For example, see Oesingmann (2022), 'The effect of the European Emissions Trading System (EU ETS) on aviation demand: An empirical comparison with the impact of ticket taxes', *Energy Policy*, **160**:112657; Anger, A. and Köhler, J. (2010), 'Including aviation emissions in the EU ETS: Much ado about nothing? A review', *Transport Policy*, **17**:1, pp. 38–46.

[87] There are other studies that consider the impact of the air passenger taxes on demand. However, we do not consider that they are representative of the effects of the Fit for 55 policies, or use methodologies which are sufficiently robust. For example, Markham et al. (2018) studied the effect of Australian carbon taxes, and failed to find an effect on the aviation industry due to the small size of the tax. Another study by Seetaram (2018) based its estimates on stated preference rather than empirical evidence. Falk and Hagsten (2018) studied the impact of the Austrian and German air passenger tax; their findings implied a very high elasticity estimate -1.84. See Markham, F., Young, M., Reis, A. and Higham, J. (2018), 'Does carbon pricing reduce air travel? Evidence from the Australian "Clean Energy Future" policy, July 2012 to June 2014', *Journal of Transport Geography*, **70**, pp. 206–14; Oesingmann, K. (2022), 'The effect of the European Emissions Trading System (EU ETS) on aviation demand: An empirical comparison with the impact of ticket taxes', *Energy Policy*, **160**:112657; Seetaram, N., Song, H., Ye, S. and Page, S. (2018), 'Estimating willingness to pay air passenger duty', *Annals of Tourism Research*, **72**, pp. 85–97; Falk, M. and Hagsten, E. (2019), 'Short-run impact of the flight departure tax on air travel', *International Journal of Tourism Research*, **21**:1, pp. 37–44.

Table A5.1 Price elasticities of demand: selected studies based on air passenger taxes

Study	Elasticity	Description
Seetaram (2014)[88]	-0.32	Studies the effects of UK air passenger taxes on tourism
Gurr and Moser (2017)[89]	-0.61	Studies the effects of German air passenger taxes
Strale (2021)[90]	-0.76	Studies the effects of Swedish air passenger taxes
Oesingmann (2022)[91]	-0.84	Studies the effects of the Austrian and German air passenger taxes.
Average elasticity	**-0.63**	

Note: [1] The studies typically present their estimates as the observed percentage change in demand in response to the implementation of the taxes. We have calibrated these estimates so that they are price elasticities of demand (i.e. the percentage change in demand in response to a percentage change in prices due to the tax) in order to average the different estimates and apply them in the model.

Source: Oxera analysis.

[88] Seetaram, N., Song, H. and Page, S.J. (2014), 'Air passenger duty and outbound tourism demand from the United Kingdom', *Journal of Travel Research*, **53**:4, pp. 476–87.
[89] Gurr, P. and Moser, M. (2017), 'Beeinflusst die Luftverkehrssteuer Passagieraufkommen? Ergebnisse einer Paneldatenanalyse', *Zeitschrift fuer Verkehrswissenschaft*, **88**:3.
[90] Stråle, J. (2021), 'The Effects of the Swedish Aviation Tax on the Demand and Price of International Air Travel'.
[91] Oesingmann, K. (2022), 'The effect of the European Emissions Trading System (EU ETS) on aviation demand: An empirical comparison with the impact of ticket taxes', *Energy Policy*, **160**:112657.

A6 Representative routes for connecting traffic

We analyse a number of connecting routes between different regions of the world in order to identify the effects of the Fit for 55 policies. We focus on connecting routes where there is a high risk of diversion between EU+ and non-EU+ hubs.

- **Step 1**. We consider airports in six broad regions: North America, Asia-Pacific, Latin America, Africa, the Middle East and Europe.
- **Step 2**. We then consider the types of routes on which there is the highest risk of diversion from EU+ to non-EU+ hubs. We split these routes into two categories: continental–intercontinental routes and intercontinental–intercontinental routes.[92]

Continental–intercontinental routes

These are routes from Europe to an intercontinental destination via either an EU+ or non-EU+ hub. Based on information we received from ACI, this accounts for the majority of connecting traffic in the EU. However, not all of these routes are equally at risk of diversion to non-EU+ hubs, as set out in Table A6.1 below.

Table A6.1 Types of continental–intercontinental routes

#	Type of route	Assessment
1	Smaller EU+ airport to large EU+ airport to Intercontinental destination (e.g. Dusseldorf–Amsterdam Schiphol–Singapore)	In order for such routes to be at risk of diversion from EU+ hubs to non-EU+ hubs, this would require there to be a connection between the smaller EU+ airport and the non-EU+ hub. While this is possible in principle, we consider that it is unlikely to drive significant diversion between EU+ and non-EU+ hubs in practice.[93]
2	Large EU+ airport to Large EU+ airport to Intercontinental destination (e.g. Amsterdam–Madrid–Lima)	These are routes between a large EU+ airport and an intercontinental destination via an EU+ airport. For example, passengers in Amsterdam wishing to travel to Lima may transfer via a European airport—e.g. Madrid. However, passengers in Amsterdam may also be able to transfer outside the EU+ (e.g. in North America). We consider that there is a risk of diversion from EU+ to non-EU+ hubs in these cases.

Source: Oxera.

Based on the above, we focus on the second type of routes when considering continental–intercontinental travel.

Intercontinental–intercontinental routes

These are routes between two non-EU+ airports that may hub in the EU+. These account for a relatively small proportion of connecting traffic at many EU+ hubs (c. 5%), and only up to 20% of connecting traffic at the largest hubs.

Some routes are at a higher risk of diversion between EU+ and non-EU+ airports than others. For example, passengers on routes between North America and Asia-Pacific may view an EU+ hub and a non-EU+ hub (e.g. in

[92] Continental–continental itineraries are connecting flights that begin and end in the EU, and therefore are unlikely to hub outside the EU.
[93] For example, even if there are some links between the smaller EU airport and the non-EU hub, making it possible for passengers to choose between hubbing in the EU vs outside the EU, it is likely that the EU links have much higher frequencies compared to non-EU links, meaning that most of the choices available to passengers will be via EU links.

the Middle East) as substitutable. However, passengers between the Middle East and Africa will likely not route through the EU+.

There are other routes where there could be some connecting traffic via Europe—for instance, between Asia-Pacific and Latin America. However, given that intercontinental–intercontinental routes account for a relatively small proportion of EU+ traffic, we do not explicitly consider these routes in our analysis.

Based on the above, we identify intercontinental–intercontinental routes where there may be significant risk of diversion between EU+ and non-EU+ routes.

- North America–Middle East;
- North America–Africa;
- Asia–South America;

Step 3. We identify the airports with the most international connectivity in each region of the world based on OAG data.[94] This is shown in Table A6.2 below.

Table A6.2 Airports by region

Region	Airports
North America	Chicago O'Hare International Airport (ORD) Hartsfield-Jackson Atlanta International Airport (ATL) John F. Kennedy International Airport (JFK) San Francisco International Airport (SFO)
Asia Pacific	Singapore Changi Airport (SIN) Indira Gandhi International Airport (DEL) [1] Tokyo International Airport Haneda (HND) Incheon International Airport (ICN)
Latin America	São Paulo/Guarulhos International Airport (GRU) Jorge Chávez International Airport (LIM)
Middle East	Dubai International Airport (DXB) Hamad International Airport (DOH)
Africa	O.R. Tambo International Airport (JNB) Cairo International Airport (CAI) Jomo Kenyatta International Airport (NBO)
Europe	Madrid-Barajas Airport (MAD) Vienna International Airport (VIE) Munich International Airport (MUC) Amsterdam Airport Schiphol (AMS)

Note: [1] While this airport is not currently within the OAG's list of top ten most connected airports in the Asia-Pacific region, we have included it as it is a major airport in the South Asian region.

Source: Oxera, based on OAG (2019), 'Megahubs index 2019', https://www.oag.com/oag-megahubs-2019.

Based on this list, we select example routes to analyse the impact of the Fit for 55 policies on connecting traffic. Our selection of example routes is presented in section 4.3.

[94] See OAG (2019), 'Megahubs index 2019', https://www.oag.com/oag-megahubs-2019.

A7 Fares, demand and carbon savings by connecting route

Table A7.1 to A7.4 below show the fares, demand and carbon impact of the Fit for 55 policies for each of the connecting routes analysed. While these tables show the total impact of the policies for the specified routes, the impact on individual hubs will differ within an overall route. For more information on how individual hubs are affected, see Figures A7.1 to A7.10.

Fares and demand by route

Table A7.1 Impact on passenger demand and fare in 2030

Route	Average fare increase	Average change in demand
Rome (FCO)–San Francisco (SFO)	3%	-4%
Madrid (MAD)–Delhi (DEL)	1%	0%
Munich (MUC)–Lima (LIM)	2%	-1%
Amsterdam (AMS)–Cairo (CAI)	3%	-2%
Hamburg (HAM)–Bangkok (BKK)	3%	-1%
Milan Malpensa (MXP)–Seoul (ICN)	2%	-1%
Lyon (LYS)–Bangkok (BKK)	1%	2%
Atlanta (ATL)–Dubai (DXB)	0%	-1%
Chicago (ORD)–Johannesburg (JNB)	0%	0%
Singapore (SIN)–São Paolo (GRU)	0%	0%

Note: Includes EU+ and non-EU+ airports.

Source: Oxera analysis.

Table A7.2 Impact on passenger demand and fare in 2050

Route	Average fare increase	Average change in demand
Rome (FCO)–San Francisco (SFO)	11%	-10%
Madrid (MAD)–Delhi (DEL)	5%	-3%
Munich (MUC)–Lima (LIM)	9%	-5%
Amsterdam (AMS)–Cairo (CAI)	7%	-3%
Hamburg (HAM)–Bangkok (BKK)	12%	-7%
Milan Malpensa (MXP)–Seoul (ICN)	8%	-5%
Lyon (LYS)–Bangkok (BKK)	8%	3%
Atlanta (ATL)–Dubai (DXB)	5%	-9%
Chicago (ORD)–Johannesburg (JNB)	5%	3%
Singapore (SIN)–São Paolo (GRU)	1%	2%

Note: Includes EU+ and non-EU+ airports.

Source: Oxera analysis.

Carbon savings by route

Table A7.3 Carbon savings by connecting route, 2030

Route	Carbon savings (demand + SAF)	CO_2 from diverted passengers	Net carbon savings
Rome (FCO)–San Francisco (SFO)	8%	-3%	5%
Madrid (MAD)–Delhi (DEL)	2%	-2%	1%
Munich (MUC)–Lima (LIM)	4%	-1%	3%
Amsterdam (AMS)–Cairo (CAI)	9%	-7%	2%
Hamburg (HAM)–Bangkok (BKK)	8%	-5%	3%
Milan Malpensa (MXP)–Seoul (ICN)	6%	-4%	2%
Lyon (LYS)–Bangkok (BKK)	4%	-4%	0%
Atlanta (ATL)–Dubai (DXB)	2%	0%	2%
Chicago (ORD)–Johannesburg (JNB)	2%	-1%	0%
Singapore (SIN)–São Paolo (GRU)	1%	0%	0%

Note: The aggregate figures have been calculated using a weighted average, with weights according to 2019 passenger demand. Percentages have been calculated as share of total business-as-usual carbon emissions. Net carbon savings may differ due to rounding.

Source: Oxera analysis.

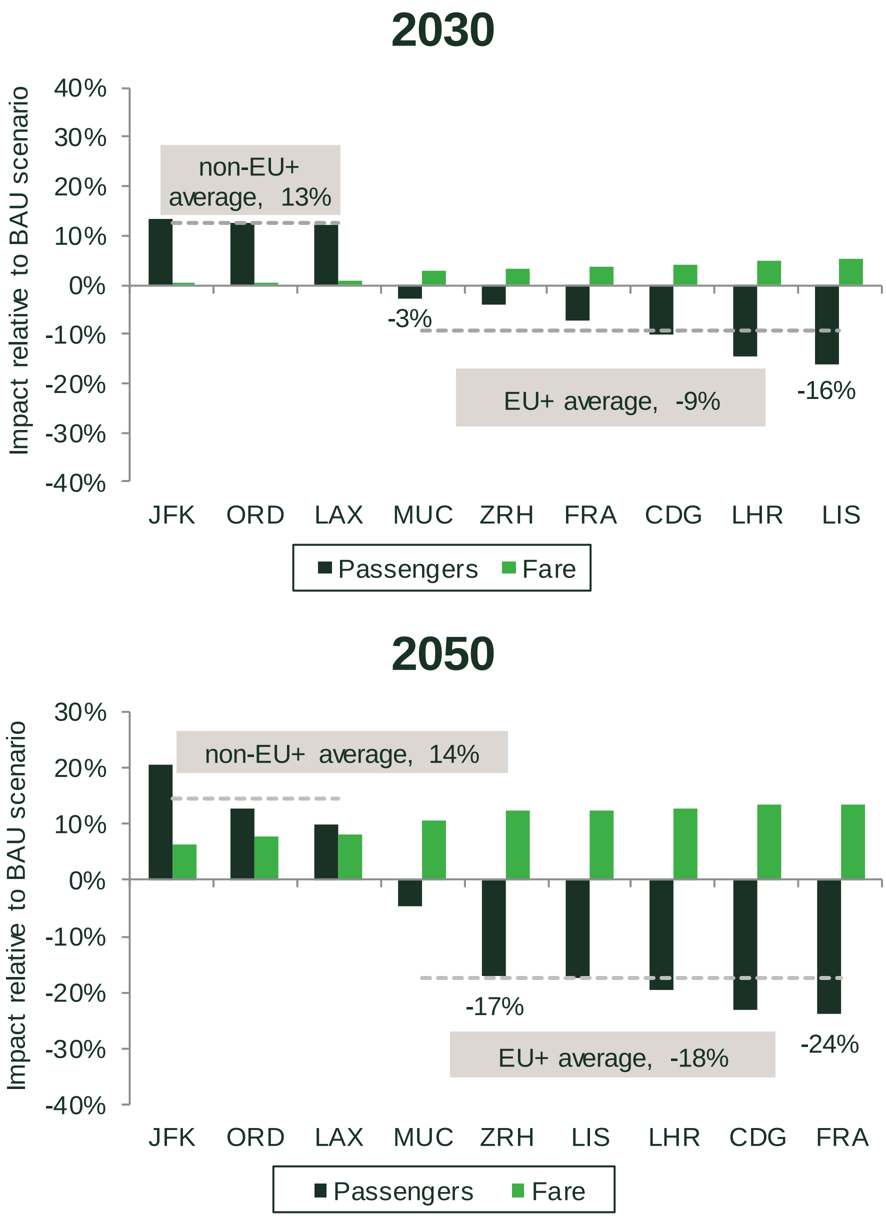
Table A7.4 Carbon savings by connecting route, 2050

Route	Carbon savings (demand + SAF)	CO_2 from diverted passengers	Net carbon savings
Rome (FCO)–San Francisco (SFO)	33%	-3%	30%
Madrid (MAD)–Delhi (DEL)	21%	-1%	20%
Munich (MUC)–Lima (LIM)	33%	0%	33%
Amsterdam (AMS)–Cairo (CAI)	32%	-5%	28%
Hamburg (HAM)–Bangkok (BKK)	35%	-6%	28%
Milan Malpensa (MXP)–Seoul (ICN)	33%	-7%	26%
Lyon (LYS)–Bangkok (BKK)	27%	-9%	19%
Atlanta (ATL)–Dubai (DXB)	24%	-5%	20%
Chicago (ORD)–Johannesburg (JNB)	16%	-15%	1%
Singapore (SIN)–São Paolo (GRU)	6%	-6%	0%

Note: The aggregate figures have been calculated using a weighted average, with weights according to 2019 passenger demand. Percentages have been calculated as share of total business-as-usual carbon emissions. Net carbon savings may differ due to rounding.

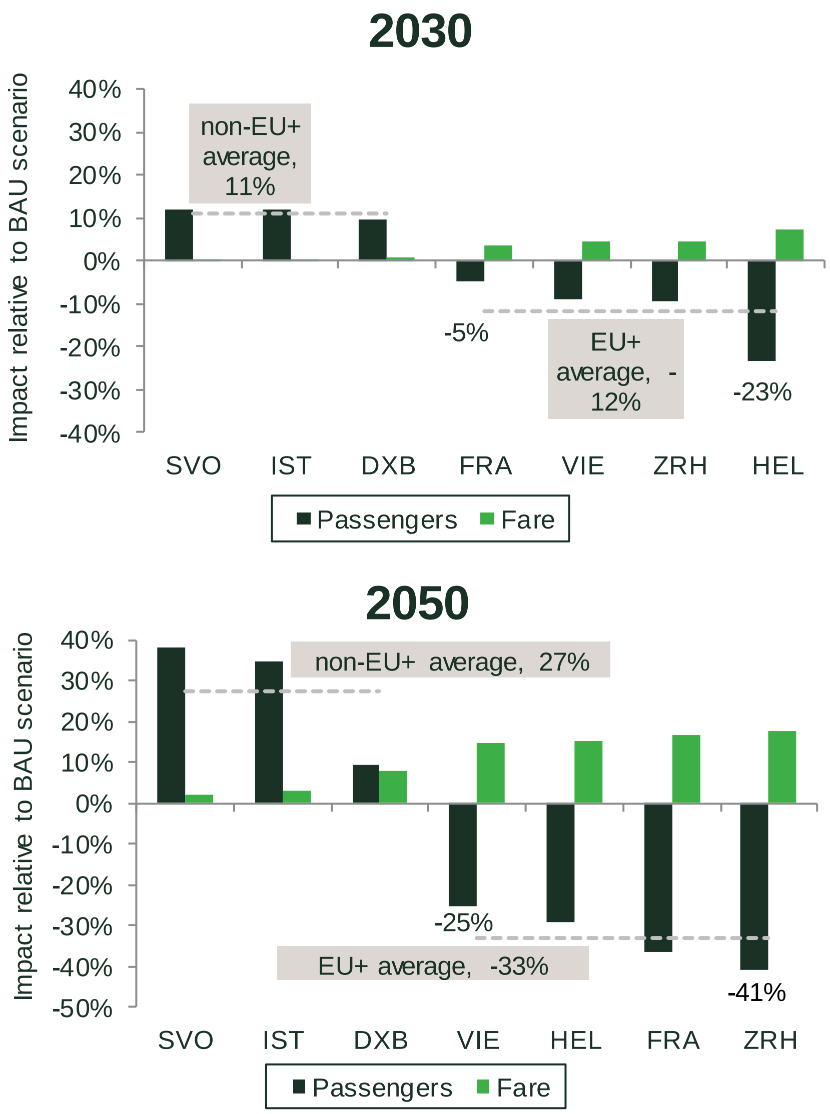
Source: Oxera analysis.

Figure A7.1 Changes to passenger numbers and fares for routes via largest hubs between Rome Fiumicino (FCO) and San Francisco (SFO)



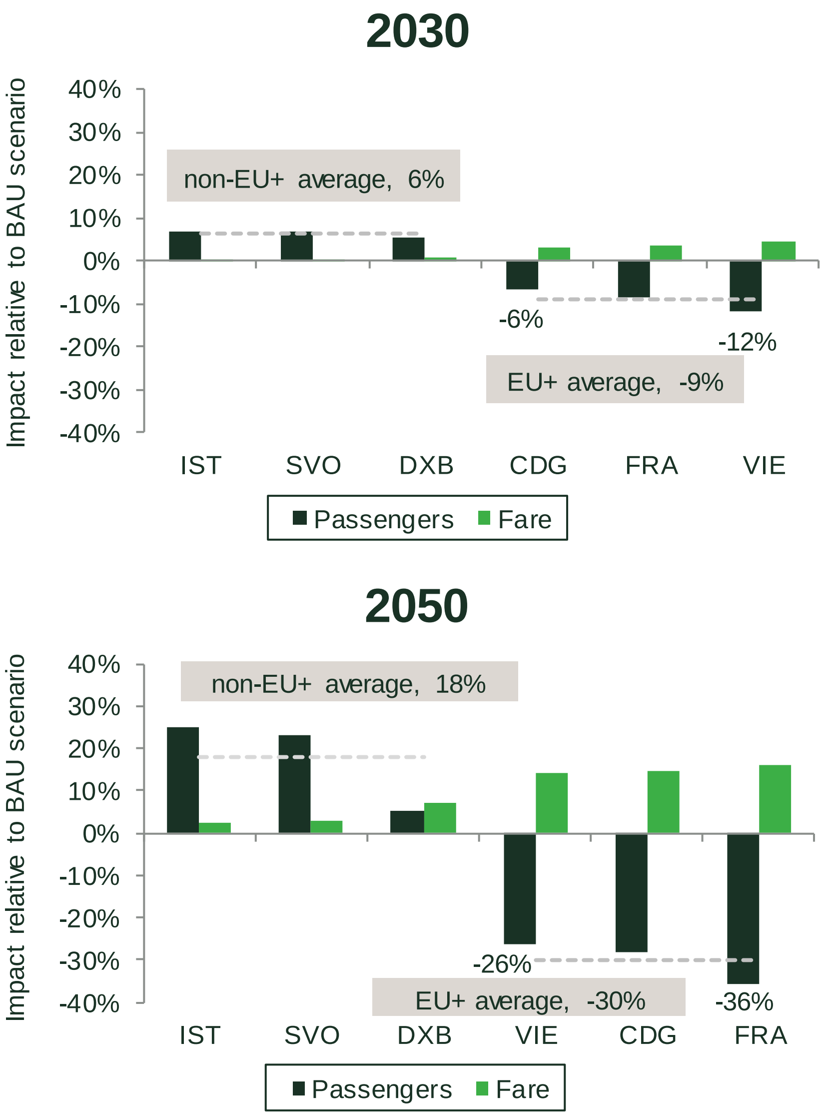
Source: Oxera analysis.

Figure A7.2 Changes to passenger numbers and fares for routes via largest hubs between Hamburg (HAM) and Bangkok (BKK)



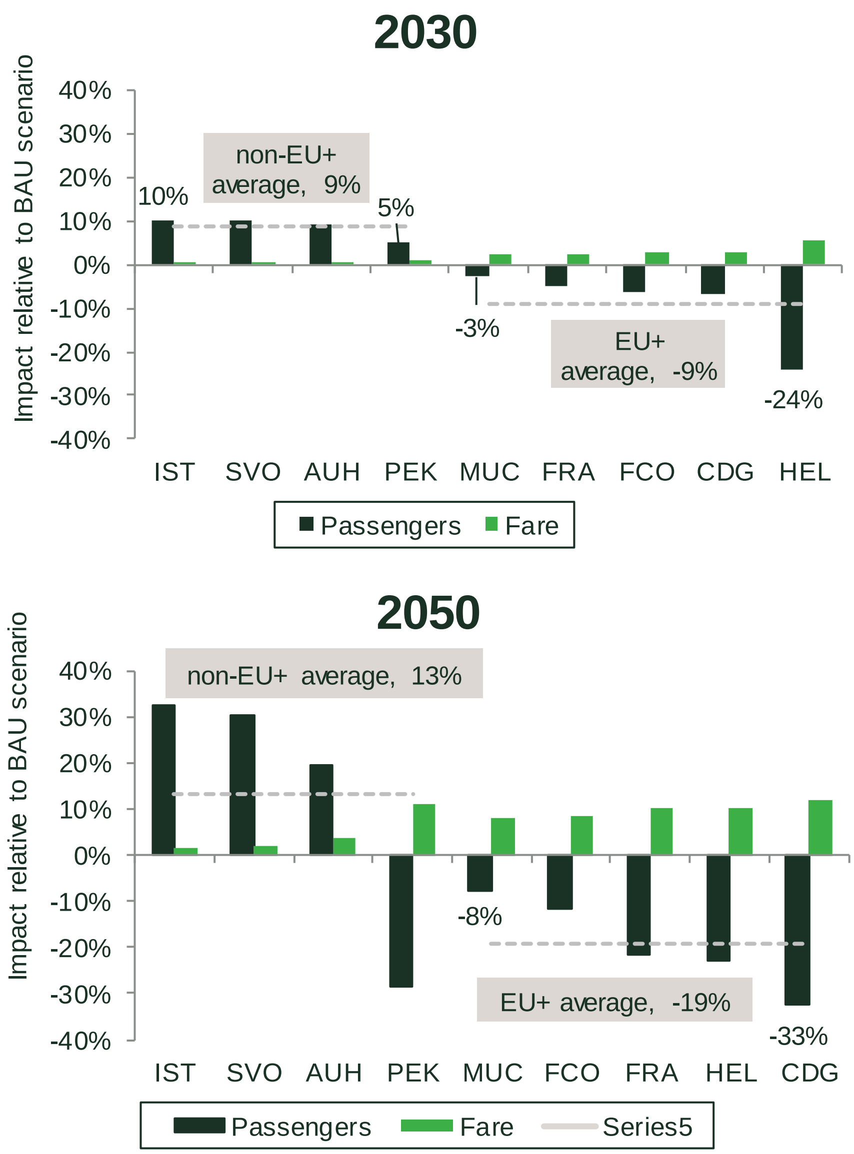
Source: Oxera analysis.

Figure A7.2 Changes to passenger numbers and fares for routes via largest hubs between Lyon (LYS) and Bangkok (BKK)



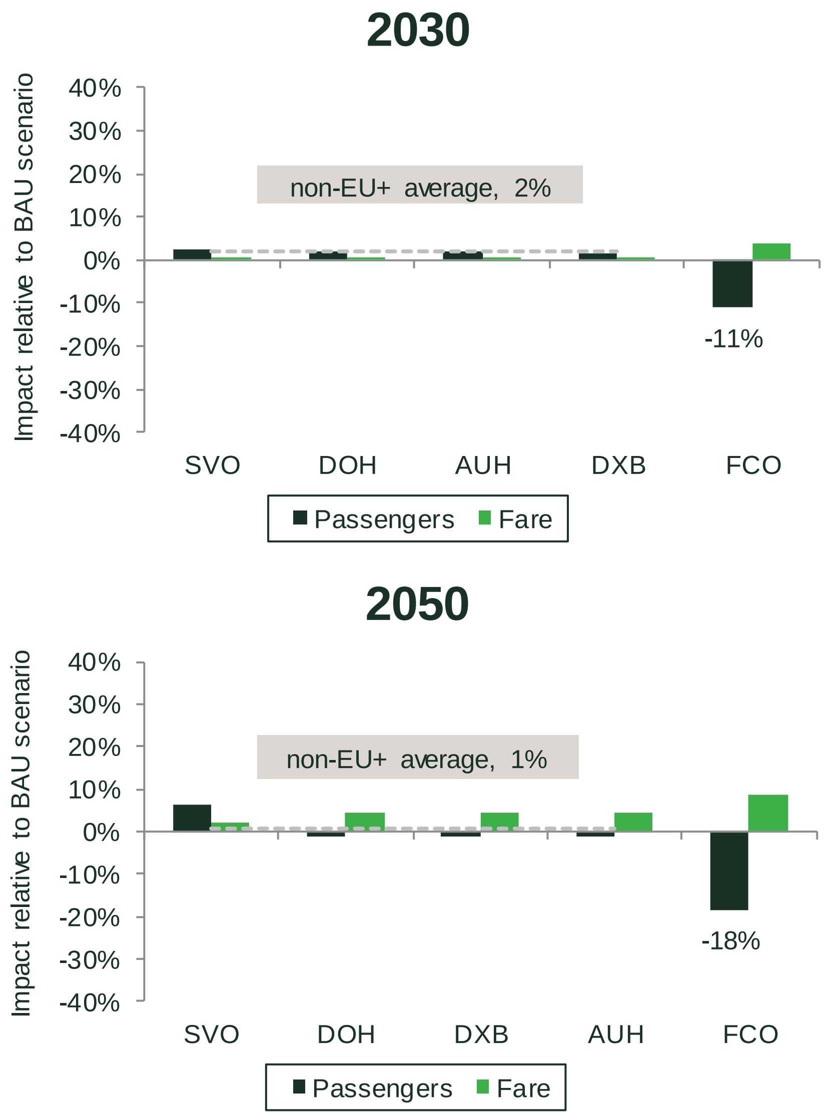
Source: Oxera analysis.

Figure A7.3 Changes to passenger numbers and fares for routes via largest hubs between Milan Malpensa (MXP) and Seoul Incheon (ICN)



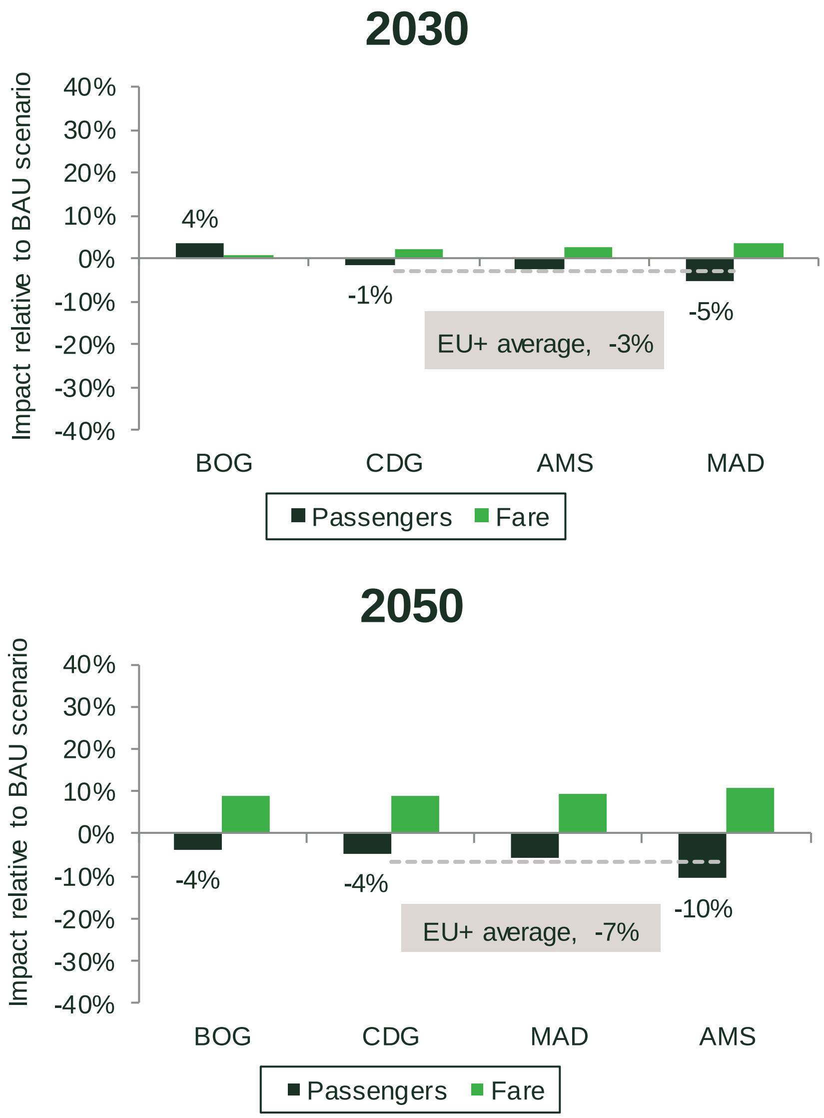
Source: Oxera analysis.

Figure A7.4 Changes to passenger numbers and fares for routes via largest hubs between Madrid (MAD) and Delhi (DEL)



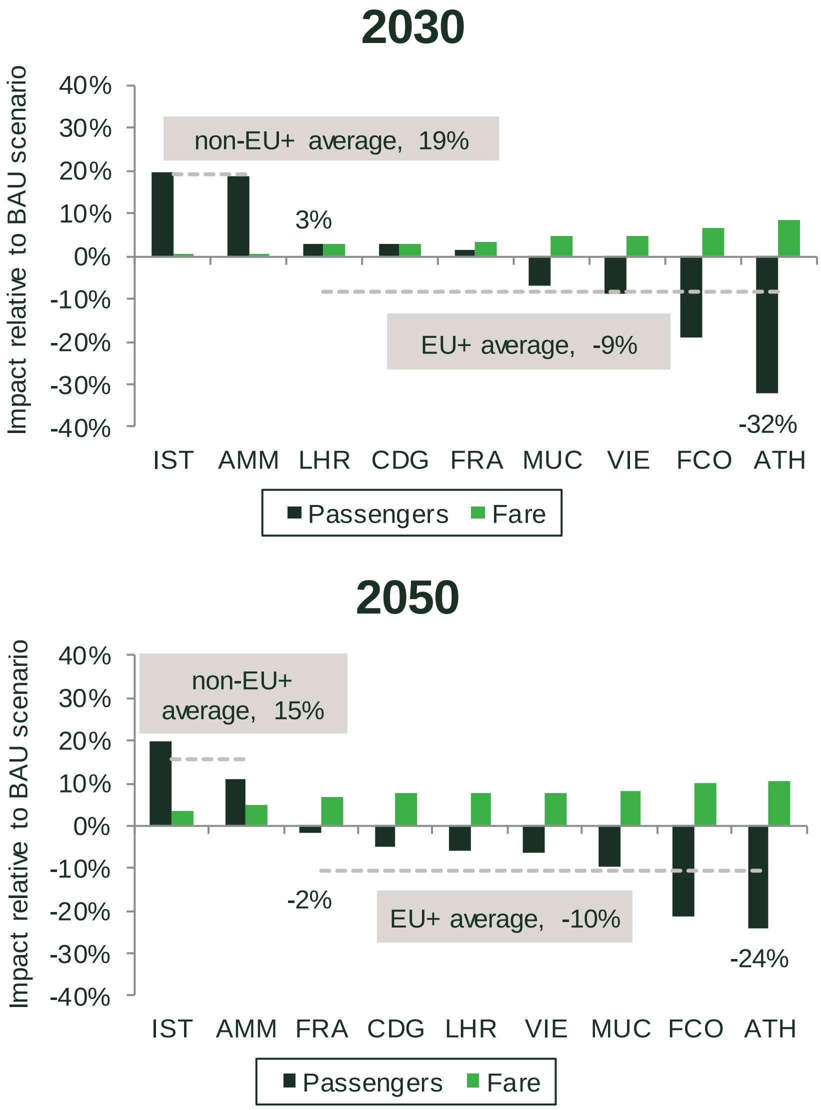
Source: Oxera analysis.

Figure A7.5 Changes to passenger numbers and fares for routes via largest hubs between Munich (MUC) and Lima (LIM)



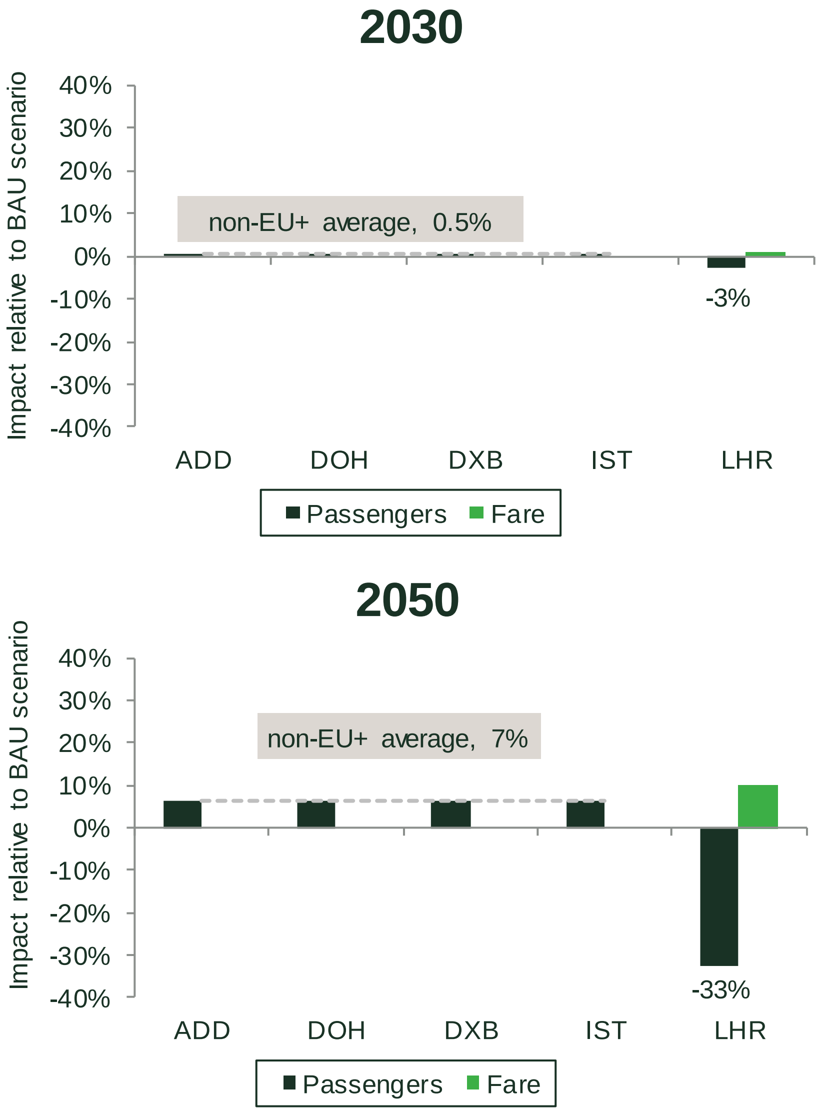
Source: Oxera analysis.

Figure A7.6 Changes to passenger numbers and fares for routes via largest hubs between Amsterdam (AMS) and Cairo (CAI)



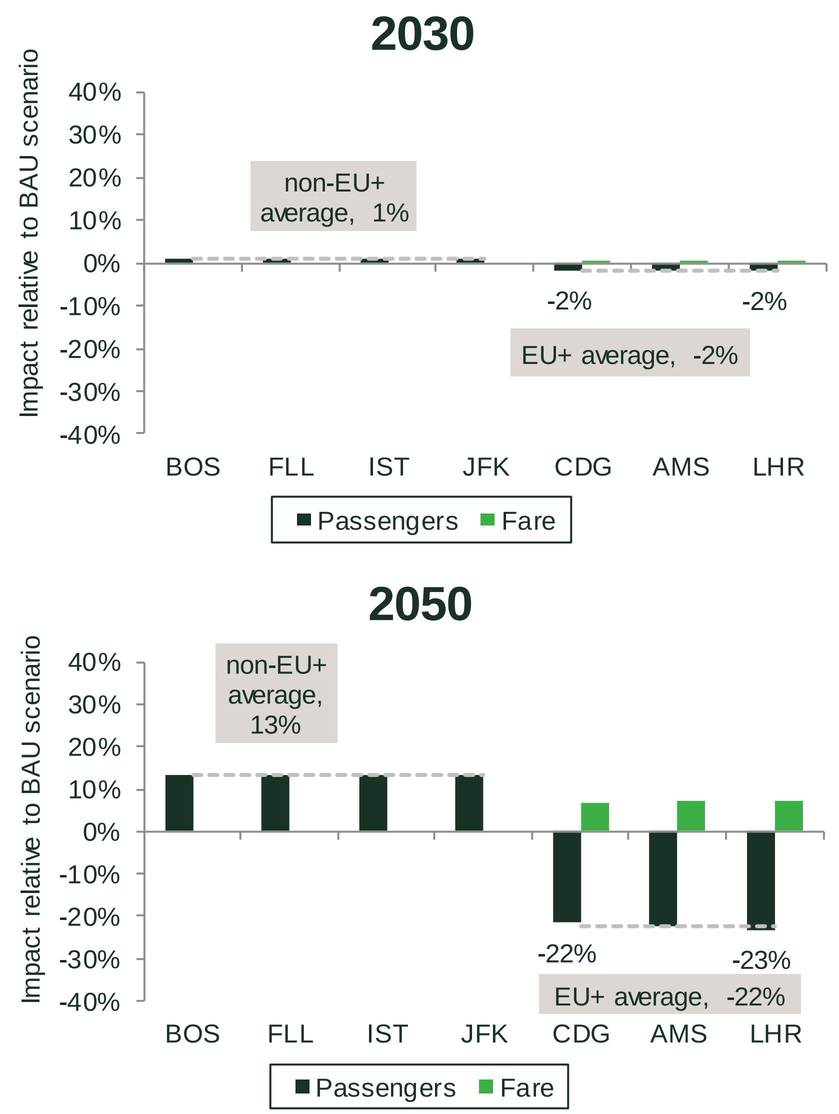
Source: Oxera analysis.

Figure A7.7 Changes to passenger numbers and fares for routes via largest hubs between Singapore (SIN) and São Paulo (GRU)



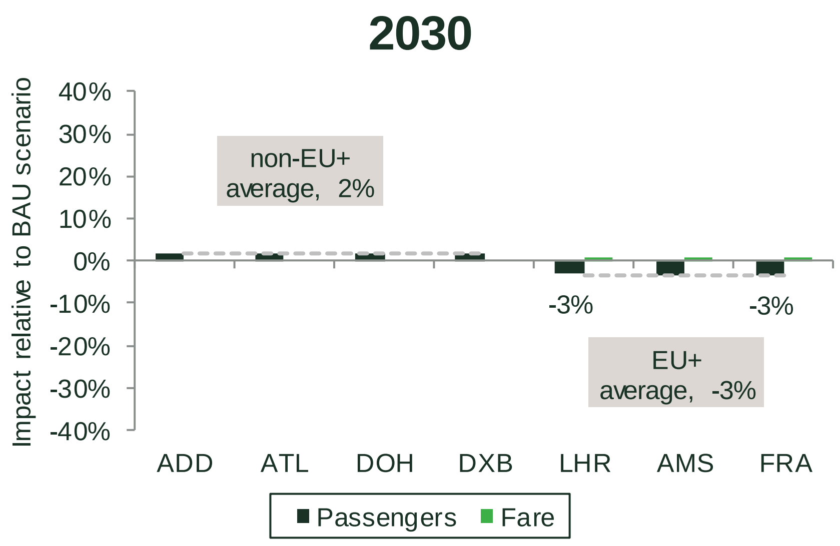
Source: Oxera analysis.

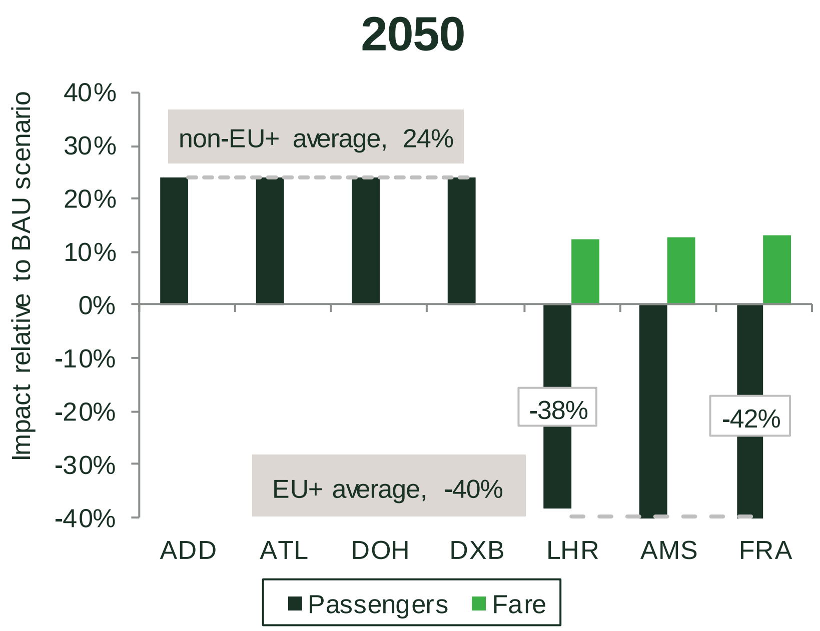
Figure A7.8 Changes to passenger numbers and fares for routes via largest hubs between Atlanta (ATL) and Dubai (DXB)



Source: Oxera analysis.

Figure A7.9 Changes to passenger numbers and fares for routes via largest hubs between Chicago O'Hare (ORD) and Johannesburg (JNB)





Source: Oxera analysis.

A8 Economic model for estimating pass-through rates and volume effects

This annex sets out the model used for estimating pass-through rates and volume effects of cost changes in a market where n firms compete by setting their quantity (or capacity) levels.

Inverse demand for firm i is given by

$$p_i = a_i - bQ \tag{1}$$

for $i = 1, \dots, n$, where p_i is the price of firm i as a decreasing linear function (with slope $-b$) of the aggregate quantity $Q = \sum_j q_j$, where q_j is the quantity of firm j for $j = 1, \dots, n$, and a_i is a firm-specific constant that will be higher for firms with higher quality or brand value, allowing such firms to charge higher prices compared to firms with lower quality or brand value.

The profit of firm i is given by

$$\pi_i = (p_i - c_i)q_i \tag{2}$$

where c_i is the marginal cost of firm i.

There are thus two asymmetries between firms: their quality levels, given by a_i, and their cost levels, given by c_i.

Differentiating profit with respect to q_i gives the following first-order condition of profit maximisation:

$$\frac{\partial \pi_i}{\partial q_i} = p_i - c_i - bq_i = a_i - bQ - c_i - bq_i = 0 \tag{3}$$

Summing up over all n firms gives:

$$n\overline{a} - nbQ - n\overline{c} - bQ = 0 \tag{4}$$

where $\overline{a}$ and $\overline{c}$ are the simple averages of a_i and c_i over the n firms.

Solving this for the equilibrium aggregate quantity gives:

$$Q = \frac{n}{n+1}\frac{\overline{a} - \overline{c}}{b} \tag{5}$$

Plugging this into (1) gives the equilibrium price of firm i:

$$p_i = a_i - \frac{n}{n+1}(\overline{a} - \overline{c}) \tag{6}$$

Differentiating this with respect to $\overline{c}$ gives the pass-through rate of industry-wide cost changes:

$$\frac{\partial p_i}{\partial \overline{c}} = \frac{n}{n+1} \tag{7}$$

Instead, differentiating (6) with respect to c_i gives the pass-through rate of firm-specific cost changes:

$$\frac{\partial p_i}{\partial c_i} = \frac{\partial p_i}{\partial \overline{c}} \frac{\partial \overline{c}}{\partial c_i} = \frac{n}{n+1} \cdot \frac{1}{n} = \frac{1}{n+1} \tag{8}$$

Solving (3) for q_i and plugging in the equilibrium aggregate quantity from (5) gives the equilibrium quantity of firm i:

$$q_i = \frac{1}{b}\left(a_i - c_i - \frac{n}{n+1}(\overline{a} - \overline{c})\right) \tag{9}$$

Note that this is a linear function of c_i and $\overline{c}$. The volume effects can thus be calculated as:

$$\Delta q_i = \frac{\partial q_i}{\partial c_i}\Delta c_i + \frac{\partial q_i}{\partial \overline{c}}\Delta \overline{c} = \frac{1}{b}\left(-\Delta c_i + \frac{n}{n+1}\Delta \overline{c}\right) \tag{10}$$

where Δc_i and $\Delta \overline{c}$ are the firm i and market-average cost changes respectively. Let the market-wide elasticity be given by $\varepsilon = -\frac{\partial Q}{\partial p_i}\frac{\overline{p}}{Q}$, where $\overline{p}$ is the simple average of p_i over the n firms. It follows from (1) that $-\frac{\partial Q}{\partial p_i} = \frac{1}{b}$. Plugging this into the definition of the elasticity gives $\frac{1}{b} = \varepsilon \frac{Q}{\overline{p}}$. In turn plugging this into (10) gives:

$$\Delta q_i = \varepsilon \frac{Q}{\overline{p}}\left(-\Delta c_i + \frac{n}{n+1}\Delta \overline{c}\right) \tag{11}$$

Finally, dividing by q_i gives the volume effect in percentage terms:

$$\frac{\Delta q_i}{q_i} = \varepsilon\left(-\Delta c_i + \frac{n}{n+1}\Delta \overline{c}\right)\frac{1}{\overline{p}}\frac{1}{s_i} \tag{12}$$

where $s_i = q_i/Q$ is the market share of firm i.

A9 Fuel details

Table A9.1 Prices and proportions of different SAF feedstocks in 2030 and 2050

Fuel type	Price per tonne in 2030 (€)	Price per tonne in 2050 (€)	Emissions saving per tonne vs kerosene	Fuel use as percentage of total in 2030	Fuel use as percentage of total in 2050
HEFA	1,100	1,250	78%	2%	4.6%
Power-to-liquid	2,900	1,557	99%	0.8%	29%
Alcohol-to-Jet	2,000	2,100	89%	2.2%	15%
Gas and Fischer-Tropsch	1,900	2,100	89%	0%	15%

Note: Emissions saving is for total lifetime emissions. The remaining percentage of fuel use in both 2030 and 2050 is made up of kerosene.

Source: Oxera; World Economic Forum (2020), 'Clean Skies for Tomorrow: Sustainable Aviation Fuels as a Pathway to Net-Zero Aviation', November.

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