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Down to earth

Why European aviation needs to urgently address its growth problem

T&E

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Author: Juliette Egal, Jo Dardenne
Modelling: Juliette Egal
Expert group: Diane Vitry, Camille Mutrelle, Alexander Kunkel, Simon Suzan, Valentin Simon

Editeur responsable: William Todts, Executive Director

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Further information
Jo Dardenne
T&E
jo.dardenne@transportenvironment.org
www.transportenvironment.org | @transenv | fb: Transport & Environment

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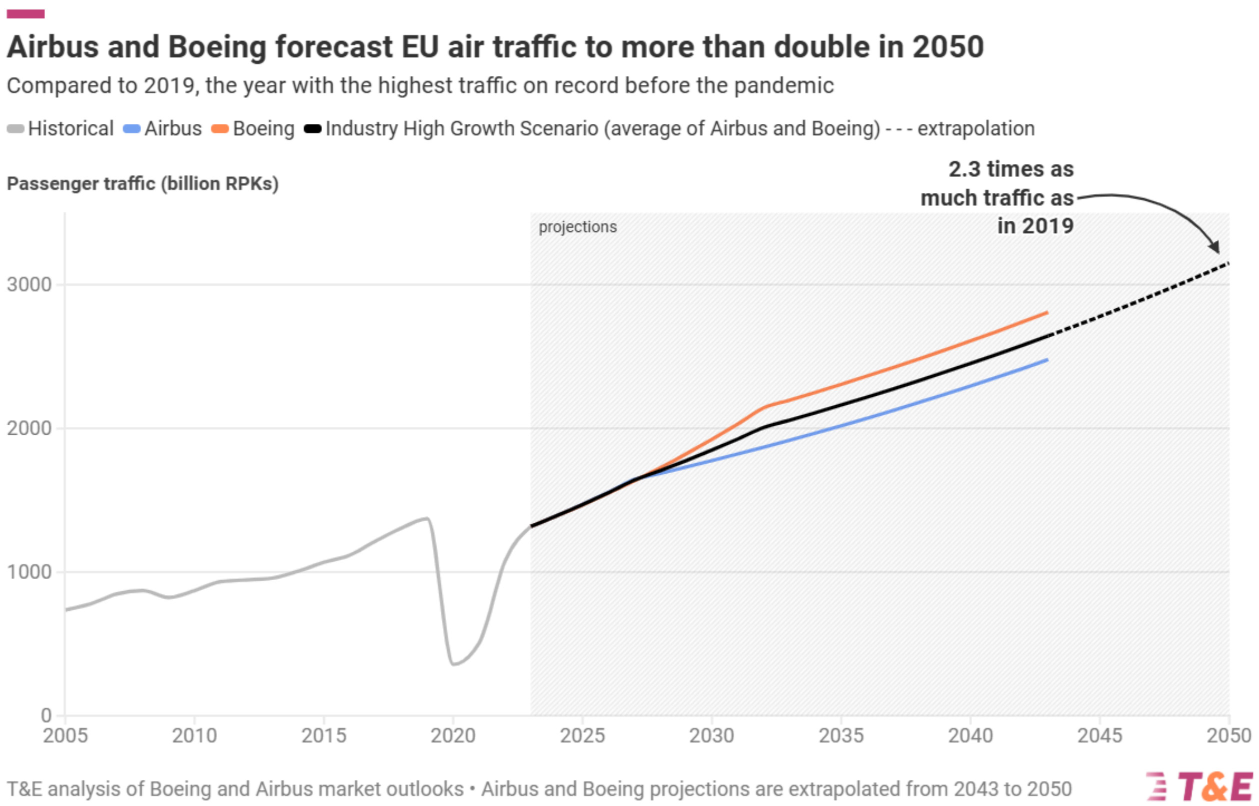
Summary

Current air traffic growth projections by the aviation industry will counteract most of the efforts from the sector to reduce its emissions.

The aviation sector plans to double its passenger traffic between 2019 and 2050. Such rapid growth in traffic raises serious concerns about the aviation sector's escalating energy demands and its climate impact.

Despite efficiency improvements, aircraft departing from EU airports will burn 59% more fuel in 2050 than in 2019 to cater for an increase in traffic.



- Even though the sector will use a lot of sustainable aviation fuels - enough to fulfill the EU's SAF mandate called ReFuelEU **- in 2049, the sector could be burning as much fossil kerosene as in 2023.**

- **Emissions of European aviation will decrease by less than 3% by 2049 compared to 2019 due to an explosion of growth.**
- **European aviation's 1.5°C carbon budget will be depleted as soon as 2026.**

Truly sustainable feedstocks for sustainable aviation fuels will not be available in sufficient quantities to cater for growth in demand. The aviation industry plans to rely heavily on biofuels as an alternative to fossil kerosene - most of which do not come from sustainable feedstocks. As a result, as of 2035, more aviation biofuels will be consumed that can be sustainably produced:

- **By 2050, four out of every five litres of SAFs could derive from unsustainable feedstocks.**

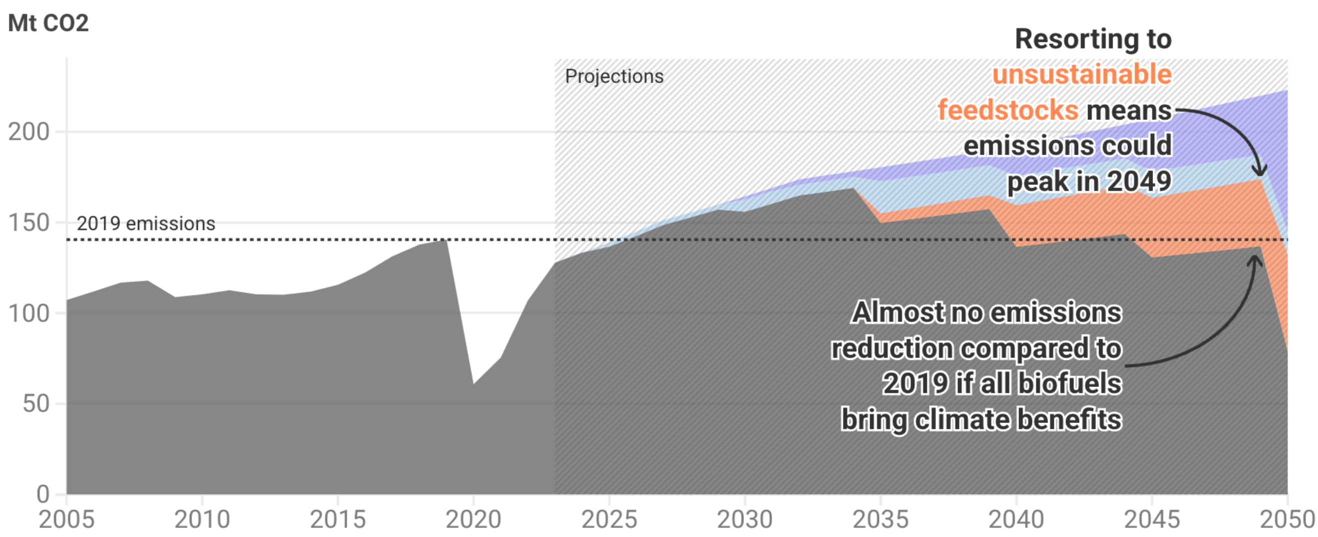
Another, more sustainable alternative to fossil kerosene, is e-kerosene. The main problem of this type of fuel is that it is very demanding in energy. **In 2050, 585 TWh of renewable electricity** will be required to produce enough e-fuels to cover 35% of the fuel mix, as mandated by RefuelEU.

- **This is more than the yearly electricity demand of Germany (506 TWh in 2023).**

Increase in air travel weakens the savings from SAF: almost no emissions reduction in 2049 compared to 2019 while meeting SAF requirements

If unsustainable biofuels bring no actual reduction, emissions will peak in 2049

CO2 emissions · Potential emissions savings from unstainable biofuels · Emissions savings from sustainable biofuels · Emissions savings from e-fuels



Source: T&E modelling based on Airbus and Boeing market outlooks

As part of its modelling for the 90% target for the EU in 2040, the European Commission projects traffic annual growth to be 60% lower than the Airbus and Boeing projections.

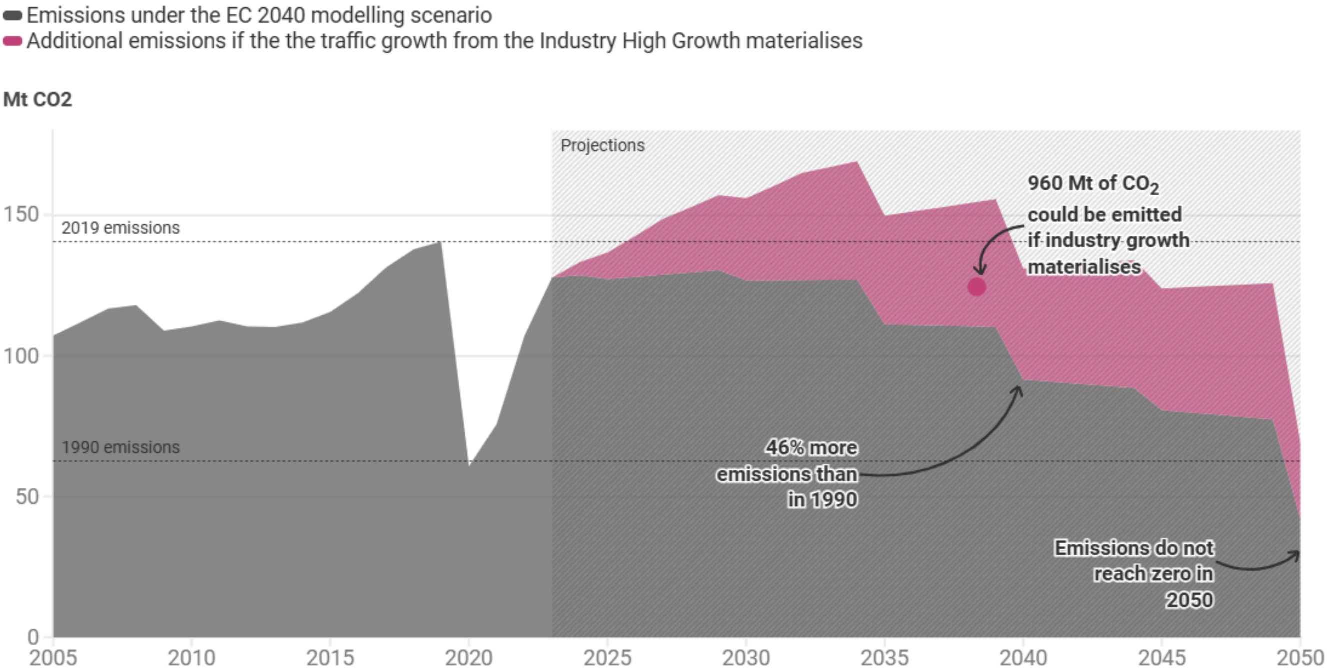
Despite slightly higher uptake of alternative fuels and zero-emission aviation, and the lower air traffic growth rate, this would still result in a **46% emissions increase by 2040 compared to 1990** - when the economy is meant to reduce its net emissions by 90%.

The European Commission's modelled growth rates could fail to materialise if it is not accompanied by serious policy measures to limit growth in high-polluting sectors like aviation.

- **If no concrete policies to address growth are introduced and if Airbus and Boeing projections materialise, 960 more million tonnes of CO_2 than planned in the European Commission's 2040 modelling scenario could be emitted**.

European Commission's 2040 scenario is still not up to the decarbonisation challenge

And 960 additional million tonnes of CO_2 could be emitted if traffic growth is left unchecked



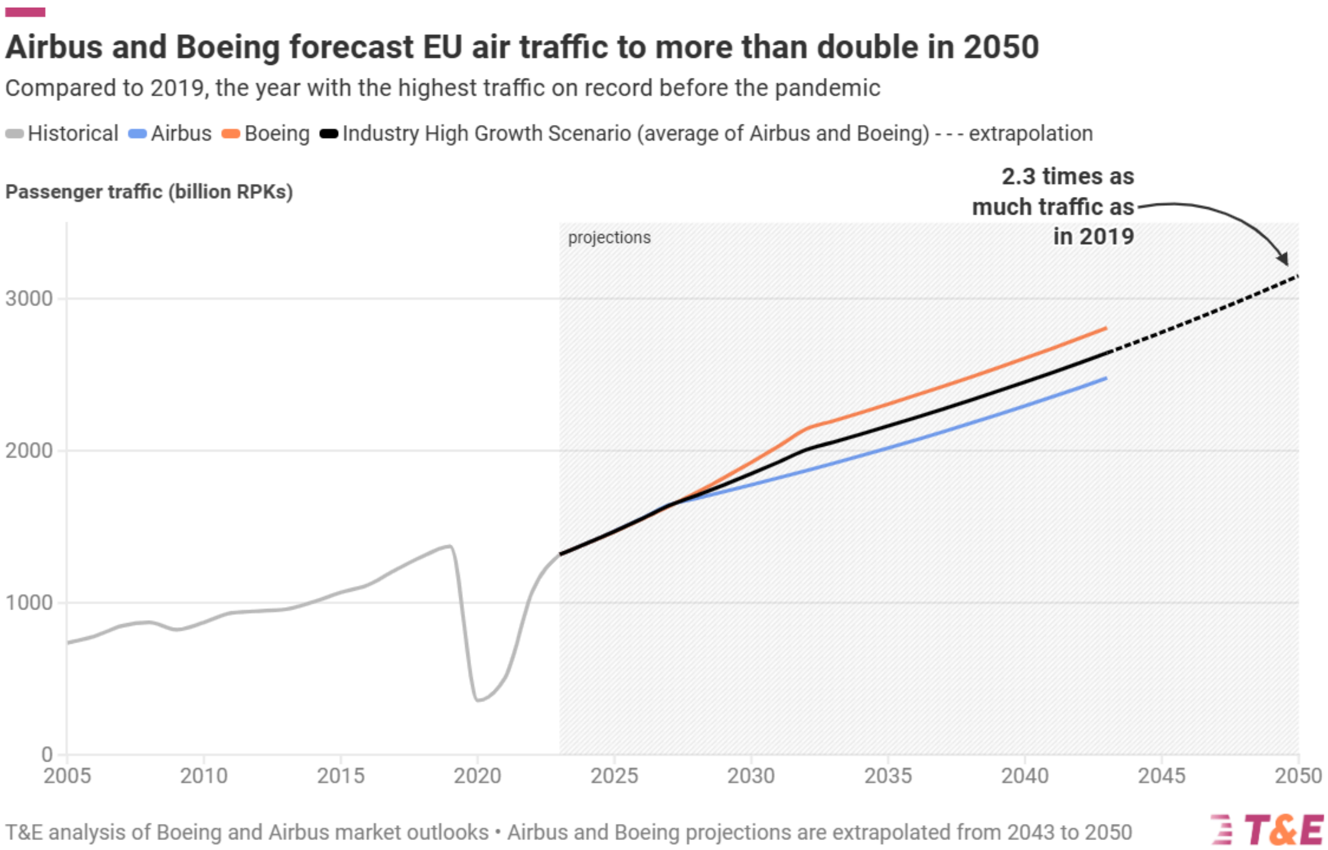
Source: T&E modelling based on the European Commission 2040 Impact assessment and Airbus and Boeing market outlooks

T&E urges the European Commission and member states to introduce the following measures:

1	**Stop fueling growth of traffic by ending infrastructure expansion** Allowing a fossil dependent sector to continue expanding, by building new airport terminals and increasing capacity is incompatible with the EU's climate objectives.
2	**Remove unfair fossil fuel subsidies** The EU and member states should continue to remove unfair subsidies to the aviation sector, by fully pricing emissions and taxing fuel on flights departing from EU territory.
3	**Focus on scaling truly sustainable technologies** The EU should use part of the revenues to support the scale up of truly sustainable fuels like e-kerosene.
4	**Maximise European rail climate potential** Unlocking competition, improving ticketing and ensuring a proper implementation of the Trans-European Transport Network will enhance rail services, helping trains to better compete with planes in Europe.

1. Airbus and Boeing project passenger traffic to double between 2019 and 2050

Passenger air traffic departing from EU airports will more than double in 2050 compared to 2019, if Airbus and Boeing growth projections materialise.



We base our projections for passenger traffic from EU airports on growth estimates from Airbus and Boeing's market outlooks[1,2]. According to their respective forecasts, EU passenger traffic is expected to grow at an annual rate of approximately 5.7% and 5.6% in the initial years (up to 2027 for Airbus and 2033 for Boeing), followed by a more moderate long-term growth rate of 2.6% and 2.5% through 2043.

For the purpose of this study's modelling, we average both Airbus and Boeing's estimations, hereon named the *Industry High Growth Scenario* in black on the graph above, extrapolating them until 2050 — the year the EU has pledged to achieve net-zero greenhouse gas emissions. This air traffic growth scenario paints a concerning, yet plausible, future depicted by the aviation industry, where EU passenger traffic grows on average by 3.3% annually from 2023 to 2050.

Our estimations show that **passenger traffic is expected to more than double by 2050 compared to 2019,** which remains the year with the highest recorded traffic volume in the EU at the time of writing.

The following sections assess how such unchecked growth could derail aviation's climate targets and raises serious concerns about the sector's escalating energy demands and its climate impact.

2. Despite efficiency improvements, aircraft will burn 59% more fuel in 2050 than in 2019 to meet increasing energy needs

Assuming a yearly energy intensity reduction of 1.25% until 2040, and 1.0% thereafter (Annex 2), we calculated the amount of fuel that will be burnt to accommodate the growing number of passengers in the *Industry High Growth Scenario*. **The results show that improvements in energy efficiency will largely be outweighed by the surge in traffic**.

Despite more efficient engines, better designed aircraft and operational optimisation, fuel uptake from European airports will still increase by 59% in 2050, compared to 2019, to meet the growing demand in air travel depicted by the *Industry High Growth Scenario*.

As a result, fuel consumption will continue to rise by an average of 2.1% annually between 2023 and 2050, making it increasingly difficult to deploy green technologies that can reduce the sector's emissions.

Infobox 1: Two very different futures for European aviation: Airbus and Boeing vs. European Commission 2040 traffic projections

2040 scenario: What does the European Commission say about aviation growth?

Although assessing the likelihood of future traffic projection is beyond the scope of this report, the *Industry High Growth Scenario* depicts a concerning, yet plausible future for European aviation if no policy measures are introduced to address the sector's growth. But in 2024, the European Commission brought in some new ideas for an alternative future for European aviation.

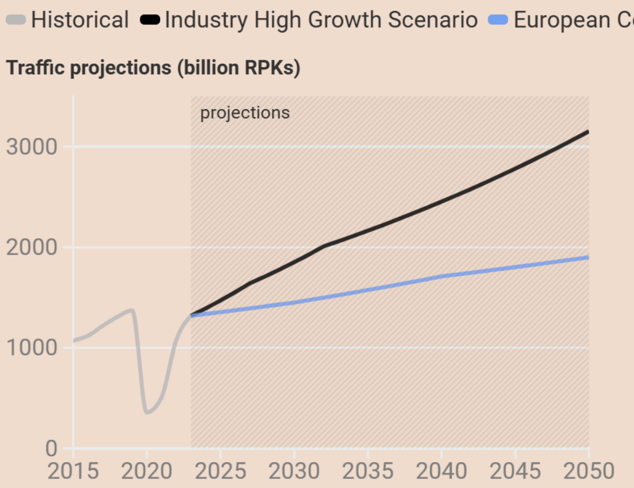
Indeed, in its impact assessment on Europe's 2040 climate target[3], the European Commission modelled sectoral reductions to reach a net emissions reduction of 90% in 2040 compared to 1990. It should be noted that only intra-EU aviation is included in the 90% reduction target. By excluding extra-EU aviation, the Commission leaves out more than half of aviation emissions. The scenarios modelled however include traffic growth assumption for extra-EU aviation - which we use in this report. Hereafter, we name the European Commission's model of both intra-EU aviation and extra-EU aviation the *EC 2040 modelling scenario.*

For EU aviation, the *EC 2040 modelling scenario* relies on growth assumptions that are very different from the *Industry High Growth Scenario*:

- An average yearly activity growth of 1.4% between 2023 and 2050, or 60% lower than the *Industry High Growth Scenario* (at 3.3%).

- A stable fuel consumption as of 2030, and below 2019 levels - whereas the *Industry High Growth Scenario* leads to an increase in fuel consumption of 37% in 2040 and 59% in 2050 relative to 2019.

Two very different futures for European aviation



T&E analysis of Boeing and Airbus market outlooks, and the EC 2040 target Impact Assessment

The difference in traffic growth — assuming equal efficiency improvements in both scenarios — results in a divergence of 440 Mtoe in fuel consumption over the period of 2024 to 2050.

Although the publication of a 90% emissions reduction target by 2040 is a positive step forward, the lower traffic projections underpinning the *EC 2040 modelling aviation scenario* will only materialise if additional measures are introduced to address the high traffic growth of the sector. T&E puts forward recommendations for such measures later on in this report.

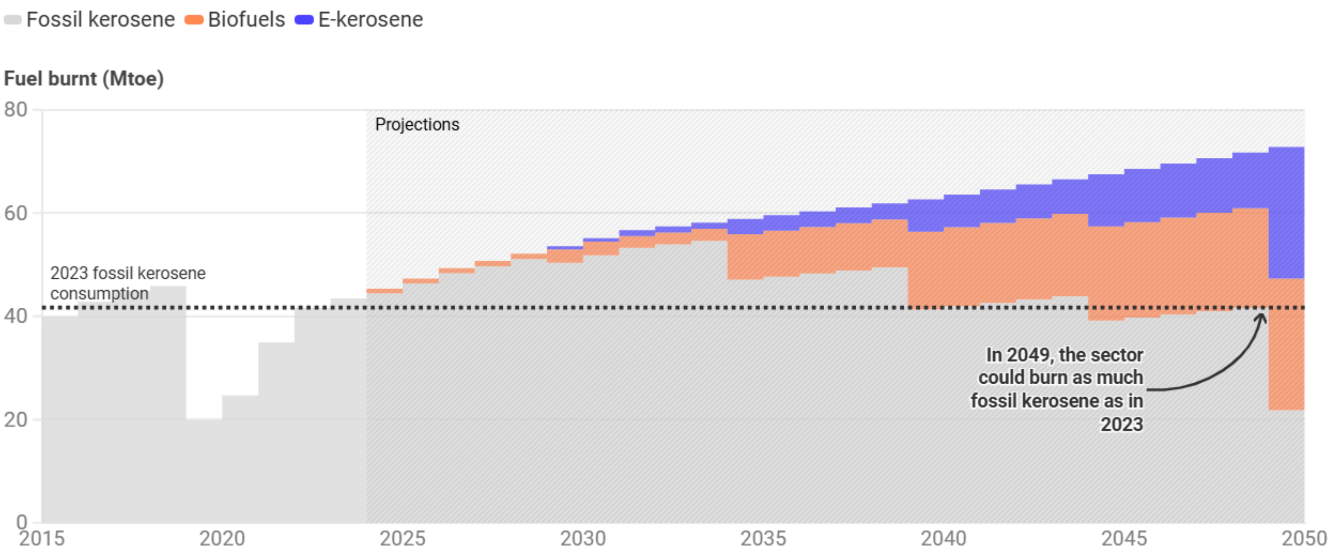
3. In 2049, the sector could be burning as much fossil kerosene as in 2023, even when using sustainable aviation fuels

Sustainable Aviation Fuels (SAFs) are seen as the most promising technology to decarbonise the aviation sector. In the EU, the ReFuelEU regulation[4] mandates jet fuel suppliers to blend an increasing share of SAFs in planes as an alternative to fossil kerosene. However, if fuel consumption grows by 2.1% every year as projected in the *Industry High Growth Scenario*, we find that:

- In the first 15 years of the EU mandate, SAFs will barely cover for the surge in energy demand compared to 2019, and will start replacing fossil fuel durably only from 2040 onwards.
- In 2049, the sector could be burning as much fossil kerosene as it did 2023, even when using 42% of SAF, as required by the RefuelEU regulation.
- In 2050, planes taking-off from EU airports will still burn 21.8 Mtoe (21.1 Mt) of fossil kerosene, which is almost half of what was consumed in 2019. This level of consumption would require the yearly extraction of 1.9 billion barrels of crude oil - based on EU refineries' average yield of 9% in 2022[5].

The EU's sustainable aviation fuel mandate will only barely cancel out the growth in energy demand

In 2049, the sector could be burning as much fossil kerosene as in 2023, while complying with sustainable aviation fuel mandates



Source: T&E modelling based on Airbus and Boeing market outlooks

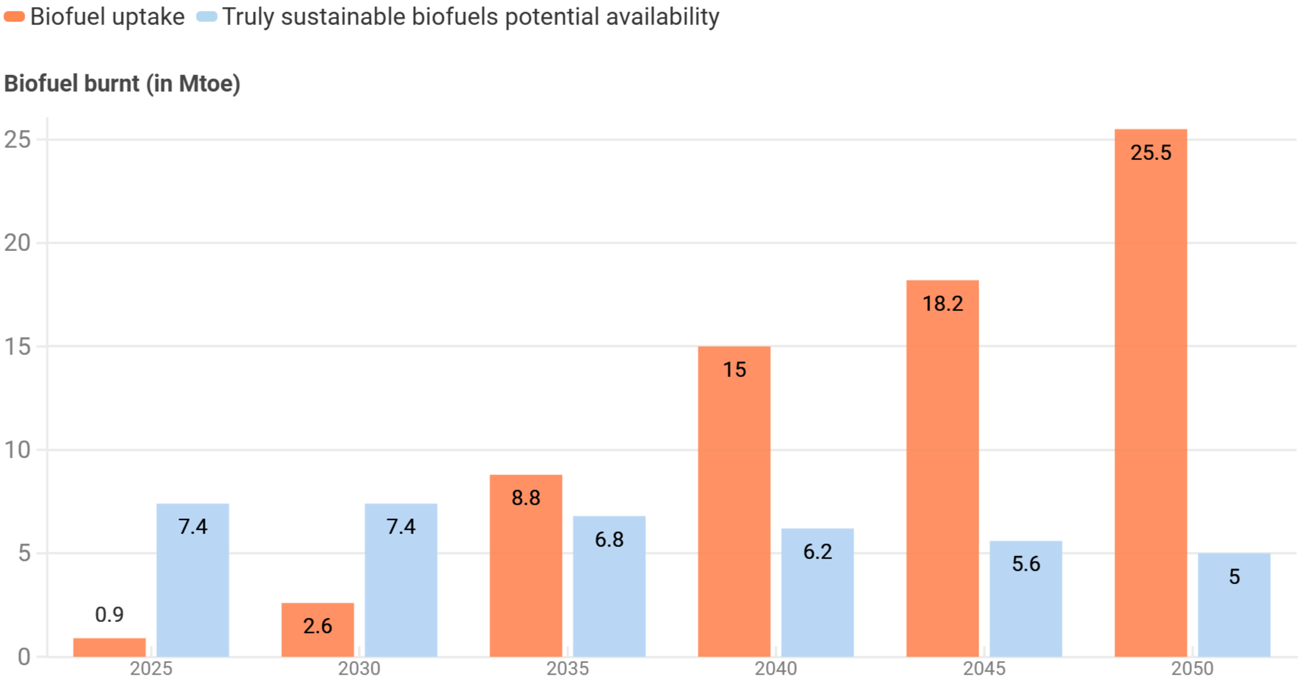
SAFs are a "sustainable" alternative to fossil kerosene. They can be derived from biomass, or synthesized from renewable hydrogen and captured CO_2 (so-called e-fuels). Their sustainability varies greatly depending on which raw materials they are produced from. In general, biofuels face important scalability constraints, which makes them less sustainable in the long term.

4. Overreliance on biofuels will drive the use of unsustainable feedstocks

Given the limited scalability and potential for truly sustainable biofuels, the rapid growth in traffic and energy demand will push biofuel consumption to levels that will inevitably lead to the use of unsustainable ones - undermining ReFuelEU's contribution to the sector's decarbonisation. Using the *Industry High Growth Scenario*, we find that:

- Starting in 2035, there will not be enough sustainable feedstock to meet the EU's biofuel mandate in aviation (Infobox 2) - according to T&E's assessment of what counts as a truly sustainable feedstock[6]. This will therefore mean that the mandate will have to be met with unsustainable biofuels.
- By 2050, a 35% biofuel blend in the *Industry High Growth scenario* results in the use of 25.5 Mtoe (24.2 Mt) of bio-kerosene. This is more than the 16.4 Mtoe of biofuels burnt[7] in the 252 million European cars on the road in 2022[8], mostly crop-based biofuels, known to be a cure worse than its fossil counterpart.
- By 2050, four out of every five litres of biofuel supplied could derive from feedstocks that are not truly sustainable according to T&E's assessment (Infobox 2).
- This raises significant concerns, as up to 385 Mt of CO_2 savings from biofuels between 2025 and 2050 could be at risk due to the uncertain climate benefits of these unsustainable feedstocks.

Biofuel demand to largely exceed the sustainable available potential



T&E modelling based on Airbus and Boeing traffic projections, T&E (2024), The advanced and waste biofuels paradox: Availability and sustainability of advanced and waste biofuels

Infobox 2: ReFuelEU's over reliance on biofuels will drive the use of unsustainable feedstocks

The climate benefits of biofuels are dependent on the feedstock used. The ReFuelEU regulation allows a restricted list of bio-based feedstocks to be used to produce SAF, based on the Renewable Energy Directive's list of advanced and waste materials. According to T&E, only some of these biofuels feedstocks[6] - with limited competing uses and proven emissions savings compared to fossil fuels - can be considered as fully sustainable.

These feedstocks include used cooking oil collected domestically, so-called animal fats of category 1 and 2, the biomass fraction of waste and sewage sludge. Agricultural residues could also play a role, but only if strong sustainability criteria are implemented, such as limiting residue harvests to ensure soil health is maintained. Availability for bio-kerosene coming from truly sustainable feedstocks as defined by T&E is thus estimated at 7.4 Mtoe in 2030 and 5 Mtoe in 2050. The ICCT's analysis shows similar conclusions: sustainable biomass feedstocks will not be sufficient to meet the mid- to long-term aviation fuel demand[9].

Despite being increasingly advertised as climate-friendly solutions, the benefits of using advanced and waste materials as aviation fuels is often very uncertain. When competing with existing and future uses, biofuels can indeed lead to displacement effects and indirect emissions, if less sustainable alternatives are replacing initial intended uses. Furthermore, the increased reliance on imported materials can raise suspicions over non sustainable feedstocks being mislabelled as advanced or waste, cancelling the promised environmental benefits.

> To account for the uncertainty regarding the climate benefits of biofuels derived from unsustainable feedstocks, we model a range of emissions reductions for biofuels exceeding the sustainable potential. This range varies from an 85% reduction compared to fossil kerosene (the same as biofuels produced from sustainable feedstocks) to no reduction at all.

In Section 6, we estimate that between 2025 and 2030, 385 $MtCO_2$ of potential savings are at risk if unsustainable feedstocks do not bring any environmental benefit at all.

5. E-fuels are green and scalable, but not to the point of decarbonising an increasingly growing sector

E-kerosene is produced from green hydrogen and carbon. Green hydrogen is made by electrolyzing water with renewable electricity, while CO_2 is sourced either from the air (direct air capture) or biogenic sources like biomass combustion. Since e-kerosene emits only previously captured CO_2 when burned, it qualifies as carbon-neutral. Unlike biofuels, which have limited availability, e-fuels can be scaled to meet growing demand by expanding electrolysis and CO_2 capture—but this will require significant amounts of additional renewable electricity.

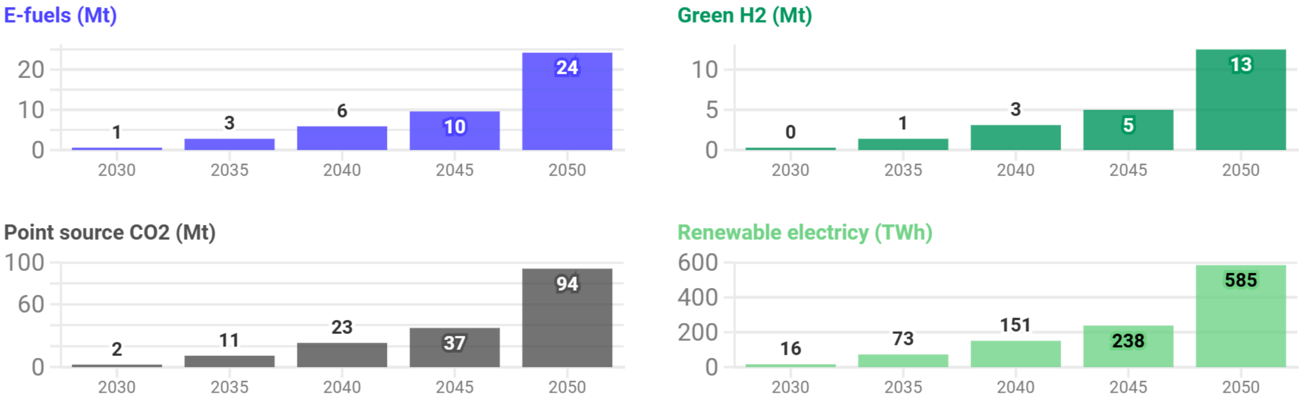
Exponential increases in air traffic could therefore lead to a significant amount of energy being used to power planes through e-kerosene. The EU's SAF mandate requires a 35% blend of e-fuels in the EU's aviation fuel system by 2050. In a future where the aviation sector burns 59% more fuel in 2050 than in 2019 (Section 2), this would translate to 25.5 Mtoe (24.2 Mt) of e-kerosene - requiring 585 TWh of renewable electricity. To put this into perspective:

- This is more than Germany's total electricity demand in 2023 (505.8 TWh[10]).
- It is enough electricity to power 160 million heat pumps for a year, or almost twice as much as the number of heat pumps that would be needed to replace the 86 million gas and oil boilers still in use in EU residential buildings[11] (Annex 5.3).
- It would account for about 10% of the total wind and solar electricity expected to be produced in the EU by 2050, according to the Distributed Energy Scenario of the Ten-Year Network development Plans 2024 projections [12].

Already in five years time, in 2030, the renewable electricity required to produce e-fuels up to the RefuelEU mandate (1.2%, Annex 4.1) will be 16.2 TWh. This is comparable to Denmark's current electricity production from wind farms (19.4 TWh[13]), one of the countries where most e-fuel projects are likely to be located (Infobox 3).

Unchecked passenger growth means that e-fuel production will require 585 TWh of renewable electricity in 2050

And this only covers 35% of the total aviation fuel consumption, as mandated by law.



Source: T&E modelling, based on Airbus and Boeing growth projections • We assume that e-fuels are made from point source CO_2.

Infobox 3: Competing use for renewable electricity and CO_2

Producing one kilogram of e-kerosene using point-source CO_2 requires approximately 25 kWh of renewable electricity (Annex 5.1). Meeting the *Industry High Growth Scenario* for European aviation would demand around 585 TWh of renewable electricity.

In order to prevent e-fuels from diverting renewable energy from other uses, the electricity used to produce them is supposed to be "additional" according to the rules set by the Delegated Acts on RFNBOs[28,29]. In practice, this means that the renewable electricity used for RFNBO production must come from new installations that were commissioned less than 36 months before the RFNBO production facility starts operating. However, this rule doesn't apply in bidding zones where more than 90% of the annual electricity mix comes from renewable sources. Moreover, low-carbon grids (where the average carbon intensity of the electricity mix is below 18 gCO_2e/MJ) are also exempt from additionality rules. These exceptions make it easier and more cost-effective to produce RFNBOs in regions like the Nordic countries or France and Denmark. Therefore, it is possible that most of the European e-kerosene production will take place in these countries, where many projects are already located[14].

Concerns also arise over the availability of point-source biogenic CO_2. The consultancy Ricardo estimates that the sustainable supply will fall short of meeting both e-fuel demand and competing needs from sectors like chemicals, plastics, construction, and permanent carbon storage. While Direct Air Capture (DAC) offers an alternative, it is costlier and currently absent from European e-kerosene projects under development[14].

6. Almost no emissions reduction in 2049 compared to 2019 due to explosion of growth

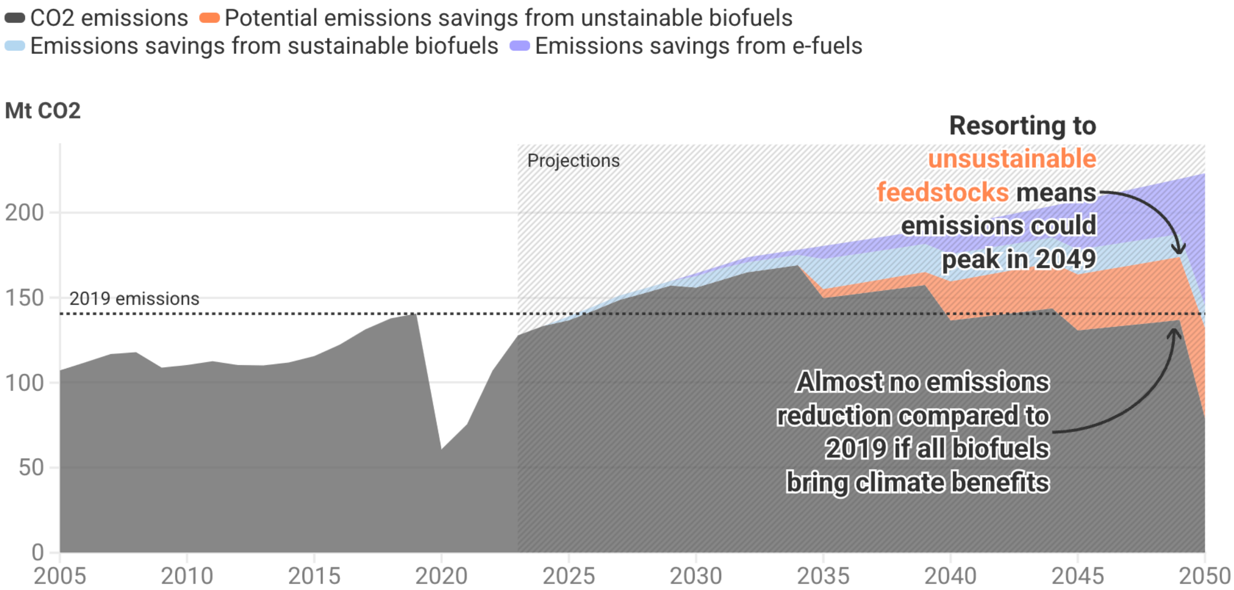
The adoption of Sustainable Aviation Fuels (SAFs) will progress too slowly to offset the significant rise in passenger numbers. Indeed, the surge in air travel pictured in the *Industry High Growth Scenario* nearly cancels out the emission reductions achieved by SAF.

Concerns also arise from the actual climate benefits from some types of biofuels, since starting in 2035, biofuel consumption will be pushed to levels that inevitably lead to the use of unsustainable ones. Taking into account the uncertainty surrounding their actual climate benefits (Infobox 2), the future depicted by the *Industry High Growth Scenario* means that:

- By 2040, European aviation will emit between 3% less and 14% more CO_2 than in 2019, despite a 34% SAF mandate. This is 118% to 155% more emissions than in 1990, the year used as a baseline to define the European Commission 2040 target of a 90% economy wide net reduction.
- By 2049, despite a 42% SAF mandate, European aviation could emit between 3% less and 24% more CO_2 than in 2019 - which means emissions could peak in 2049.
- By 2050, when the EU pledged to have reached net zero GHG emissions, despite a 70% SAF mandate, European aviation will still emit 79 to 132 million tonnes of CO_2, a decrease of 6% to 44% compared to 2019.
- Between 2025 and 2050, the uncertainty around the actual climate benefits from unsustainable biofuels amounts to 385 Mt of CO_2 (in orange in the figure below).

Increase in air travel weakens the savings from SAF: almost no emissions reduction in 2049 compared to 2019 while meeting SAF requirements

If unsustainable biofuels bring no actual reduction, emissions will peak in 2049



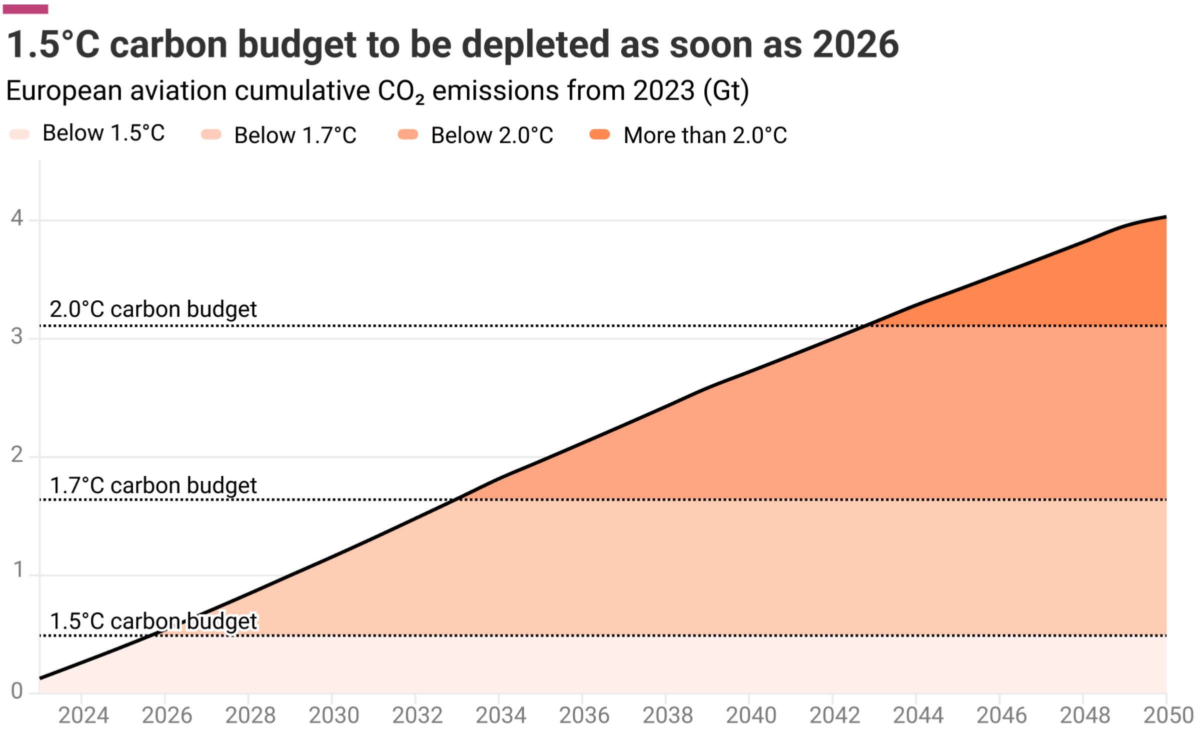
Source: T&E modelling based on Airbus and Boeing market outlooks

7. Unchecked traffic growth means that European aviation will deplete its Paris agreement compatible carbon budget as soon as 2026

Between 2023 and 2050, European aviation is projected to emit a cumulative 4 to 4.4 $GtCO_2$ depending on the actual climate benefits from unsustainable biofuels (Infobox 2) - an average of 144 Mt to 158 Mt of CO_2 per year. The 'grandfathering' approach consists in allocating the share of the remaining carbon budget to a sector according to its historical contributions. Based on this approach, and with a 67% chance of remaining below a certain temperature increase level, European passenger aviation will deplete its carbon budget:

- As soon as 2026, to remain below 1.5°C global warming.
- As soon as 2033, to remain below 1.7°C global warming.
- As soon as 2043, to remain below 2.0°C global warming.

To limit global warming to 1.5°C, 1.7°C and 2.0°C respectively with a 67% probability, the updated estimates of the global remaining carbon budget as of early 2023 are 150 $GtCO_2$, 500 $GtCO_2$ and 950 $GtCO_2$[15]. In 2019, global aviation (tank-to-wing) contributed 2.4% of all CO_2 emissions emitted that year[16]. As European passenger aviation emissions were 14% of global aviation emissions in 2019, the grandfathering approach results in European aviation receiving 0.33% of the remaining global carbon budget.



T&E modelling based on Airbus and Boeing market outlook. Global carbon budget with a 67% likelihood of limiting global warming under a given temperature. We use the grandfathering approach to calculate European aviation share among the global remaining budgets.

If biofuels made from sources that are not genuinely sustainable provide no emissions reductions, European aviation will emit an additional 0.38 Gt of CO_2 between 2023 and 2050.

The years in which various carbon budgets are depleted remain unchanged compared to a scenario where all biofuels deliver full climate benefits.

Infobox 4: An ambitious scenario that is not up to to the sector's decarbonisation challenge

Is reasonable aviation growth possible? Zooming in on the *European Commission's 2040 modelling scenario*

Despite a moderate traffic growth compared to what is projected by Airbus and Boeing (Infobox 1), the aviation emissions trajectory as modelled in the *European Commission's 2040 modelling scenario* is still not on the right path for decarbonisation.

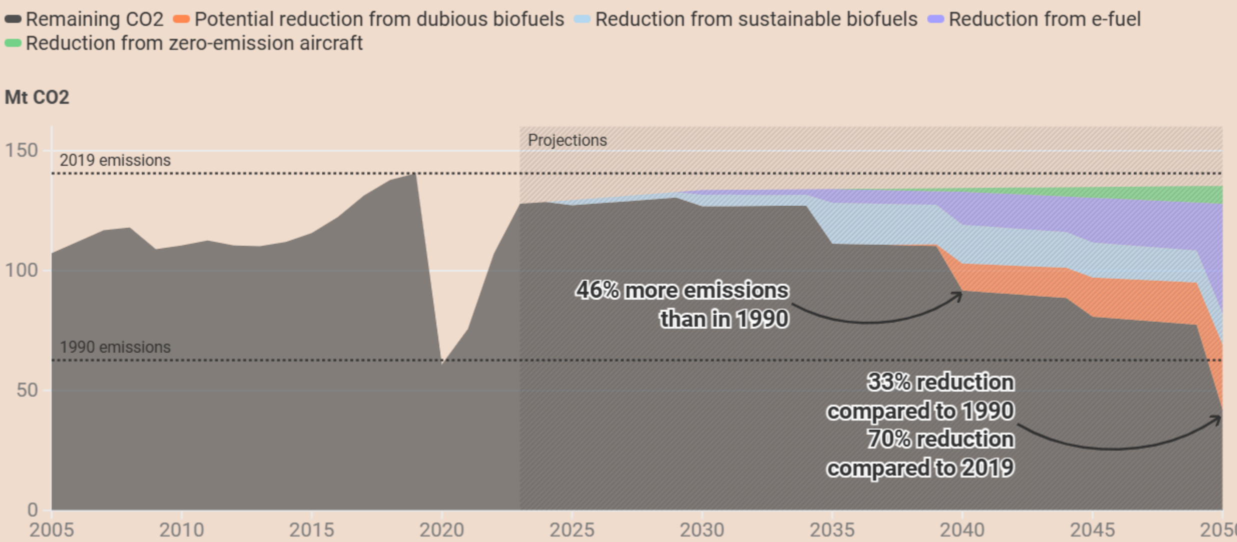
Due to the unscalable and limited potential of truly sustainable biofuels, we project that by 2037, the demand for biofuel will surpass the maximum sustainable supply. This shortfall will necessitate reliance on unsustainable biofuels, whose emissions reductions compared to fossil kerosene are uncertain (Infobox 2), as depicted in orange in the graph below.

Based on the *EC 2040 modelling scenario*, we calculate that:

- In 2040, European aviation will increase its emissions by 46% to 64% compared to 1990 while the overall economy is set to decrease its net emissions by 90% - giving aviation a free pass in the decarbonisation effort. This is still considerably better than the *Industry High Growth Scenario*, which is set to emit 118% to 155% more than in 1990.
- In 2050, flights departing from EU airports will still emit 42 to 69 Mt of CO_2 - when the EU pledged to have net zero GHG emissions. This is 10% more to 33% less CO_2 than in 1990, and 51% to 70% less CO_2 than in 2019.

European Commission's 2040 scenario for European aviation is not up to decarbonisation challenge

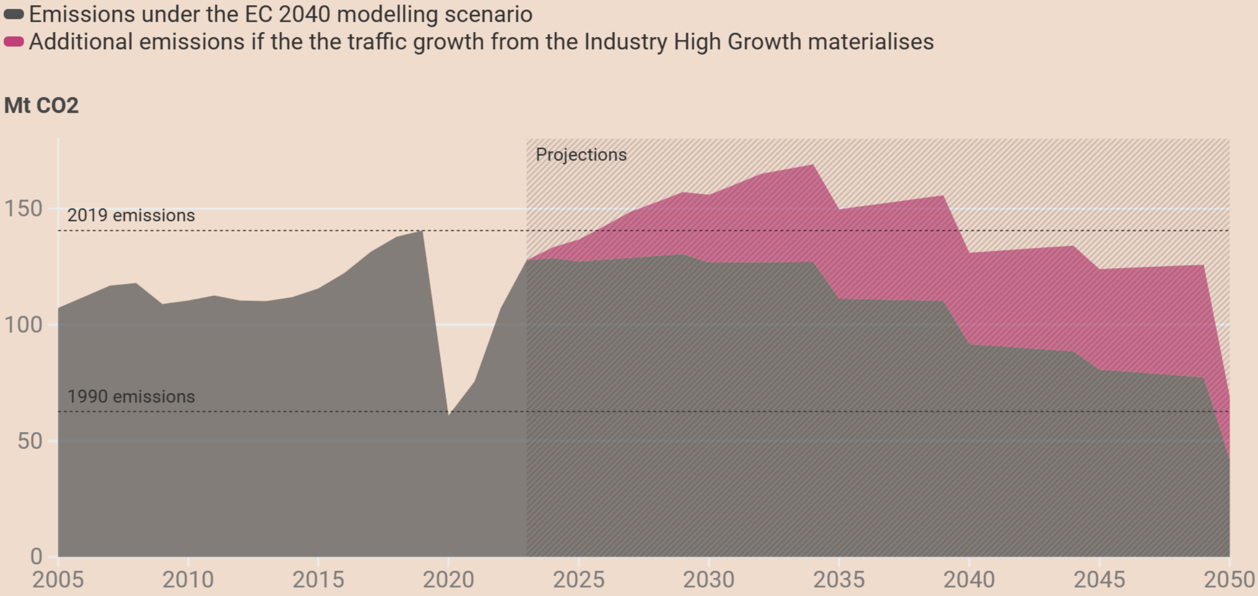
Overreliance on biofuels will drive the use of unsustainable ones



Source: T&E analysis of the European Commission's impact assessment of the 2040 target

Similarly to the *Industry High Growth Scenario*, EU aviation will exceed its carbon budget by 2026 - when aiming to limit global warming to 1.5°C with a 67% likelihood, using the grandfathering approach. It will however exceed its 1.7°C carbon budget in 2035, two years after the *Industry High Growth Scenario* and will only exceed its 2°C carbon budget in 2050.

960 additional million tonnes of CO_2 could be emitted if traffic growth is left unchecked



Source: T&E modelling based on the European Commission 2040 Impact assessment and Airbus and Boeing market outlooks

The European Commission's 2040 modelling is ambitious and its assumptions for air traffic growth are much lower than industry averages from Airbus and Boeing. **If a 3.3% traffic growth rate materialises -as depicted in the *Industry High Growth Scenario*, 960 Mt more CO_2 than planned in the EC 2040 modelling scenario could be emitted**. Therefore ensuring that the EU's modelled low growth rates of traffic materialise will demand serious policy measures to limit growth in high-polluting sectors like aviation (see conclusions & recommendations section).

Conclusions

Growth forecasted by Airbus and Boeing will counteract most of the efforts from the industry to reduce its emissions via SAFs and other green technology.

In 2050, aircraft taking-off from EU airports will still burn **24.2 Mt of fossil kerosene**, which means extracting 1.9 billion barrels of crude oil - based on EU refineries' average yield of 9% in 2022[5].

In 2049, the sector could be **burning as much fossil kerosene as in 2023**, and still be compliant with RefuelEU. Emissions will be just 3% lower than in 2019, assuming all biofuels deliver actual climate benefits.

Between 2023 and 2050, EU aviation will cumulatively emit 4.0 Gt of CO_2. This means **depleting its 1.5°C carbon budget by 2026**.

With such rapid growth, truly sustainable feedstocks will not be available in sufficient quantities. This would mean resorting to the use of unsustainable biofuels, cancelling the expected emission reduction from biofuels.

This could mean that **385 Mt of CO_2 savings from biofuels could be at risk** cumulatively between 2025 and 2050.

By 2050, **four out of every five litres of biofuel** supplied could derive from feedstocks that do not meet true sustainability standards.

E-fuels are green and scalable, but not to the point of decarbonising a rapidly growing sector.

In 2050, **585 TWh of renewable electricity** will be required to produce enough e-fuels to cover 35% of the fuel mix, as mandated by the ReFuelEU law.

This is more than Germany's total electricity demand in 2023 (505.8 TWh).

The European Commission’s 2040 modelling foresees an average yearly growth 60% lower than the Airbus and Boeing growth projections.

Despite a lower growth projection, and slightly higher uptake of alternative fuels and zero-emission aviation, this would still result in a **46% emissions increase by 2040 compared to 1990** - when the economy is meant to reduce its net emissions by 90%

The European Commission’s modelled growth projections could be severely weakened if it is not accompanied by serious policy measures to limit growth in high-polluting sectors like aviation. **If the *Industry High Growth* materialises, 960 Mt more CO_2 could be emitted than what is planned in the 2040 target scenario**.

Recommendations

1 Stop fueling growth of traffic by ending infrastructure expansion

If Europe is serious about its decarbonisation plans, the expansion of airport infrastructure is non-sensical. As long as the infrastructure continues to allow the burning of fossil fuels, more planes will continue to fly and emissions will rise.

- EU governments should stop approving new airport infrastructure projects, as these continue to add extra flights, emissions and energy pressure to decarbonise. Expansions and new projects currently planned are economically and environmentally unsustainable. Studies have shown that expansion of airports actually have much more limited economic benefits than claimed by the industry[30]. In terms of environmental impact, in Spain, for example, the planned expansion of the Madrid Barajas airport could result in increasing flights by 21% to over 500 thousand flights per year in 2030, translating into 35% more CO_2 emissions[31]. Expanding Barcelona airport could also result in CO2 emissions from aviation growing by a further 33%[32].
- The EU should support - not hinder - member states from developing policies to stop increasing airport flight caps or shift demand to other modes of transport. Similarly to what was introduced in France and Austria with the proposal to ban domestic flights when a viable train alternative is available, member states should be encouraged to restrict airport capacity growth in their own territories in view of the sector's climate objectives. A study commissioned by Schiphol airport[17] showed that in order to reach the country's climate objectives, i.e. cutting carbon emissions by at least 30% below 2019 levels before 2030, the airport would need to cap demand, especially long-haul flights. Despite this study, EU and international political pressures fought against the measure, and after having initially proposed to limit the airport cap to 460.000 flights, reducing emissions by up to 7%, 478.000 flights will be allowed to take off in 2025[33]. It is unacceptable for the aviation sector to continue to pressure countries out of important climate measures and EU regulators should support policies enabling the aviation sector to reduce its emissions.

2 Remove unfair fossil fuel subsidies

Similarly to continuing to support an infrastructure that will fuel polluting traffic, pricing of air tickets needs to address aviation's full climate costs, as it benefits from too many tax exemptions.

- The revision of the EU's Energy Taxation Directive which was proposed back in 2021, still has not removed the tax exemption aviation enjoys for the use of jet fuel, despite citizens and businesses having to pay taxes for the fuel they use for their cars, homes and company buildings. This urgently needs to be fixed: under the Polish Presidency of the EU Council in 2025, member states should approve a fuel tax for all flights departing the EU. If this is not approved at EU-level, member states should step in and compensate for that gap by applying similar levels of taxes for flights departing from their territory.
- The majority of international air tickets do not include VAT, despite citizens and businesses having to pay VAT on most products and services. Member states should ensure that ticket taxes are applied to all tickets sold, with differentiated tax rates based on distances.
- Nearly half of aviation emissions are still excluded from paying an effective carbon price under the EU's Emissions Trading System, whereas cement, chemicals and power sectors need to pay their fair share. The scheme should include all departing flights as soon as 2027.

3 Support the deployment of truly sustainable fuels

Alongside measures to limit air traffic growth, it is essential to support the deployment of sustainable aviation fuels. As many types of biofuels are questionably sustainable, priority should be given to e-fuels across all policies and support schemes developed in the EU.

- EU policymakers must uphold the ReFuelEU mandate, particularly the e-kerosene sub-targets. To ensure the targets are met, national competent authorities must set strong penalties for non-compliance as soon as possible. These penalties should be based on the benchmark price estimates given by EASA in its annual report on the European SAF market[18].
- Given the scale of upfront capital investments required to build first-of-a-kind e-kerosene plants, financial public support is essential. The announced Clean Industrial Deal and Sustainable Transport Investment Plan are great opportunities to channel funding into synthetic fuel production. A European capitalized market intermediary with double-sided auctions and a contracts-for-difference (CfD) mechanism could significantly accelerate the deployment of e-fuels. Using 25% of ETS revenues to fund a CfD scheme would cover half of the mandated volumes under ReFuelEU until 2040 (using a 20% price gap coverage level)[19]. Financial support schemes can also be developed at national level, such as grants to support early project development stages.

4 Maximise European railways’ climate potential

A performant rail system is one of the cornerstones of the zero-emission mobility system. Millions of Europeans rely on rail for zero-emissions journeys to travel, but policy change is required to maximise European rail climate potential and allow trains to better compete with planes.

- Fixing market failures to enhance rail services. Removing barriers to competition in the rail market - such as high rail tolls - will increase the offer and reduce the price gap between air and rail tickets. With the upcoming Single Digital Booking and Ticketing Regulation, the European Commission must also solve the burdensome booking of cross-border tickets that is stopping passengers travelling by rail despite international connections existing.
- Ensuring a proper implementation of the TEN-T Regulation to leverage the rail network. Targeted rail network infrastructure improvements must start, especially on upgrade (minimum 160km/h speed) and digitalisation (ERTMS) and where key lines between major urban areas are missing. Focusing on the TEN-T network will allow it to create new or upgraded lines where rail can be competitive with aviation.[34]

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Annex

Methodology

Note: A ‘yearly increase’ within a given period refers to the compound annual growth rate for this period.

$$CAGR = \left(\frac{V_{final}}{V_{begin}}\right)^{1/t} - 1$$

$CAGR = compound\ annual\ growth\ rate$

$V_{begin} = beginning\ value$

$V_{final} = final\ value$

$t = time\ in\ years$

1. Growth in passenger traffic

1.1 Baseline and historical data

To ensure consistency across the different projections, we apply relative growth rates derived from Boeing and Airbus market outlooks, as well as the European Commission’s impact assessment, to the same baseline of absolute passenger traffic departing from the EU in 2023. We use historical passenger traffic departing from the EU, sourced from STATFOR[20], up to 2022 - the most recent year available at the time of writing. We estimate EU passenger traffic from the EU in 2023 by applying the growth rate observed in Boeing’s projections for passenger traffic from Europe between 2022 and 2023.

1.2 *Industry High Growth Scenario*: Airbus and Boeing market outlook

We retrieve growth rates from Airbus and Boeing’s latest market outlooks[1,2] both published in July 2024. Passenger traffic is measured in revenue passenger kilometres (RPKs), or the number of passengers - excluding cabin staff-, flying over one kilometre.

Boeing’s dataset includes historical traffic flows between geographical regions (e.g. between Europe and the Middle East) from 2014 to 2023 as well as projected traffic in 2033 and 2043. To estimate passenger traffic departing from Europe, we divided the traffic flows by two, except for intra-European flows. We then calculate compound annual growth rates (CAGR) for two periods, 2023–2033 and 2034–2043, and use these rates to project passenger traffic through 2043 based on historical data. Although Boeing’s ‘Europe’ category includes non-EU countries (e.g., the UK), it provides the finest granularity available and is deemed a reasonable proxy to calculate EU growth rates.

Airbus, on the other hand, provides CAGRs for specific time periods (2019–2027 and 2027–2043) by geographic region pairs but does not include historical passenger traffic data. Based on Airbus's regional definitions, the best proxy for passenger traffic departing from the EU is a combination of flows labeled 'Central Europe' and 'Europe.' As with Boeing, this grouping includes non-EU countries such as North Macedonia, the UK, and Norway, but it is considered the most suitable proxy for projecting EU aviation growth.

To extend projections to 2050, we applied the CAGR from the latest time bracket in each market outlook: 2033–2043 for Boeing and 2027–2043 for Airbus.

It should be noted that Airbus outlook explicitly mentions that their forecast "connects drivers for air transport demand (macroeconomic demographic…) with existing measures related to the sector's decarbonisation through Sustainable Aviation Fuels (SAF) and CO2-prices"[1]. This means that the impact of RefuelEU and the Emissions Trading System is already taken into account in their modelling.

1.3 *European Commission's 2040 modelling scenario*

In its impact assessment for Europe's 2040 climate target[3], the European Commission elaborates on the contribution of each sector to reach an economy-wide greenhouse gases (GHGs) net reduction of 90% compared to 1990. This corresponds to a net emission reduction of -84% to -90% in 2050, compared to 2015 levels, the baseline used in the impact assessment. The impact assessment looks at the sectoral reductions compatible with the different 2040 target levels.

It should be noted that the targeted reduction aligns with the scope of the Climate Law, which covers only domestic and intra-EU aviation, excluding extra-EU aviation, which represents over half of current aviation emissions, from the target. However, the impact assessment includes modelling assumptions for extra-EU aviation for all scenarios, which we use in this report.

We specifically model a theoretical scenario positioned between scenarios 's2' and 's3', which result in net GHG reductions of 88% and 92%, respectively, compared to 1990. This approach aims at aligning with the communicated 2040 target of 90% net reduction relative to 1990 levels. We call this scenario the *European Commission (EC) 2040 modelling scenario*.

In these two scenarios, intra-EU aviation activity, measured in RPK, is projected to grow by 33.7% by 2030, 56.5% by 2040, and 74.1% by 2050, relative to 2015 levels. Extra-EU activity is expected to grow faster, by 35.7% by 2030, 59.9% by 2040, and 77.7% by 2050.

We use STAFOR activity data, categorized by scope (intra-EU including domestic, and extra-EU), to calculate overall EU traffic growth from the *EC 2040 modeling scenario* for 2015 to 2030, 2040, and 2050. From this, we determine the corresponding CAGR for the periods 2023–2030, 2031–2040, and 2041–2050, which we then apply to historical traffic data.

When compared to 2019 levels, this corresponds to growth of 6% by 2030, 25% by 2040, and 28% by 2050. Between 2023 and 2050, the compound annual growth rate under the EC 2040 modeling scenario is estimated at 1.4%.

2. Energy intensity improvement

The energy intensity is defined as the amount of fuel burnt to carry one passenger over 100 km.

It encompasses improvements in the aircraft and its engine (e.g. more seats per aircraft, more efficient engines, more aerodynamic designs) and the way aircraft are operated (e.g. higher load factors, route optimisation). The energy intensity improvement depicts the decrease in energy consumption per passenger carried over a kilometre.

We use the improvement in energy intensity to calculate how the fuel consumption is projected to grow *relative* to the activity (in RPK), in other words, to what extent the growth in fuel consumption decouples from the growth in traffic.

For consistency and in order to single out the effect of the demand in traffic, we apply the same energy efficiency improvement than the EC 2040 impact assessment[3] across scenarios (*Industry High Growth Scenario* and the *EC 2040 Modelling Scenario*).

The energy intensity is projected to decrease by 27% in 2040 and 34% in 2050 compared to 2015. This corresponds to an average yearly decrease in energy intensity of 1.25% between 2015 and 2040, and 1.00% between 2040 and 2050. On average over the 2015-2050 period, it means a yearly decrease of energy intensity of 1.18%.

We model a yearly decrease of energy intensity of 1.25% between 2023 and 2040, and 1.00% between 2041 and 2050.

Applying the 2015-2040 average energy efficiency improvement from 2023 onwards disregards the disruptions that could have happened between 2015 and 2023. Notably, load factors have dropped considerably during the COVID crisis. Worldwide and for commercial aviation, they went from 83.3% in 2019 to as low as 59.3% in 2020. They are however estimated to be 82.2% in 2023, not so far from pre-covid times[21]. Hence we consider that using 1.25% from 2023 is a reasonable proxy.

3. Fuel consumption

Fuel consumption growth rates are calculated by combining traffic growth rates with energy intensity improvement rates. Historical fuel consumption is derived from UNFCCC[22] emissions data by dividing emissions by the CO_2 content of fossil kerosene. To align with the report's focus on passenger aviation, fuel consumption from cargo flights - which represented 5% of European commercial emissions in 2018[23] -is excluded from the baseline.

4. Fuel mix

4.1. Industry High Traffic Growth scenario

RefuelEU[4] mandates fuel suppliers to blend an increasing share of sustainable aviation fuels (SAF) including specific shares for e-kerosene, as per the table below.

Year	2025	2030-2031	2032-2034	2035	2040	2045	2050
Overall SAF target	2%	6%		20%	34%	42%	70%
E-kerosene subtarget	/	Avg. 1.2% Min. 0.7%	Avg. 2% Min. 1.2% (2032-2033) Min. 2% (2034)	5%	10%	15%	35%

For the Industry High Growth Scenario, we assume that RefuelEU is met as indicated in the law, i.e. that neither the overall SAF mandate or the e-kerosene average subtarget is exceeded. This approach implies no interpolation between years with mandate increases. For example, in 2049, fuel suppliers blend 42% SAF—the level set by the 2045 mandate—as this remains compliant with the law.

When the requirements include both a minimum share per year and an average share over a time period, we assume that the average share applies to this entire period.

4.1. Fuel mix of the EC 2040 modelling scenario

The fuel mix in relative energy terms is provided in Figure 75 of the impact assessment for 2030, 2040, and 2050. As explained earlier (Annex 1.3), the fuel mix for the *EC 2040 modelling scenario* is taken as the average of scenarios 's2' and 's3' - which assume a slightly higher SAF blend than the RefuelEU mandate and incentives for the deployment of zero-emission aircraft (hydrogen and electric planes).

Due to the lack of data for 2025, 2035, and 2045, we assume that the shares of e-fuels and biofuels align with the RefuelEU blend targets. Since hydrogen also counts toward the RefuelEU target, our estimated fuel mix for 2045 exceeds strict compliance with RefuelEU—similarly to the EC 2040 modelling scenario fuel mix of 2050, which is provided in the impact assessment, where e-fuels, biofuels, and hydrogen surpass the 70% mandate.

To maintain consistency with the modelling of the fuel mix in the *Industry High Growth Scenario*, we do not assume a linear increase in the uptake of e-fuels and SAF between the years when mandates rise (2025, 2030, 2035, 2040, 2045, and 2050). However, we apply linear interpolation for zero-emission aviation to represent a more gradual adoption of the technology.

The table below shows the fuel mix (in energy terms) resulting from the average of scenarios 's2' and 's3'.

Year	2025	2030	2035	2040	2045	2050
biofuel	2%	4.3%	15%	24%	27.0%	35.0%
e-kerosene	/	1.7%	5%	12.1%	15.0%	33.8%
hydrogen	/	/	/	0.9%	2.9%	4.9%
electricity	/	/	/	0.2%	0.4%	0.6%

5. Resource requirements for e-fuels

5.1. Assumptions

Assumptions on the production of e-fuels are mainly based on Concawe's technical assessment[24]. We modelled the production of hydrogen from an alkaline electrolyser, as already commercially available. For the Fisher-Tropsch reaction, we assume a low-temperature process. The CO_2 capture processes (CO capture and reverse water gas shift to convert CO to CO_2) require heat. We assume in this report that part of this heat could be recuperated from the Fisher-Tropsch process and that the rest is supplied by an electric heater powered by renewable electricity.

We only considered point-source carbon capture, less energy intensive than Direct Air Capture (DAC), because all projects being developed in Europe at the moment are planning to use point sources of CO_2[14], which is cheaper than DAC.

5.2. Co-product and resource allocation

E-kerosene constitutes only a portion of the output from the Fischer-Tropsch process, which also yields co-products with varying carbon chain lengths such as diesel, gasoline, and liquid petroleum gas. One method of allocating the resource used to one specific output consists in allocating the input proportionally to its output share. This approach takes into account the valorisation of the other products, and considers that the remaining share of the input resource is allocated to the end use sectors of these valorised co-products. We use this approach in our analysis, which is conservative when it comes to the responsibility of the aviation sector.

The other approach consists in considering that the entire quantity of input is needed to produce each of the co-product. Depending on the selectivity of the process, the e-kerosene output could be as low as 32%, according to Concawe[24]. In simple terms, that means multiplying by three the quantities calculated in the analysis. With this approach, producing e-fuels up to the RefuelEU mandate will use 1830 TWh, or 31% of the wind and solar electricity produced in 2050 as projected by the Ten-Year Network development Plans 2024 projections[12].

5.3. Comparison with heat pump electricity needs

In their analysis of the largescale deployment of heat pumps by 2030 following the RePowerEU plan, the Joint Research Center calculated the yearly consumption of 52.4 million heat pumps, as the sum of the 30 million heat pump aimed at by RePower EU, the 11.4 millions heat pump already installed, and 11 million in newly constructed dwellings[25]. These 52.4 million heat pumps would consume 173 TWh to 216 TWh of electricity in 2030, depending on the share of oil and gas boiler replacement that are combined with building envelope renovation (40% or 60%). On average, this means a yearly consumption of 3.3 MWh to 4.1 MWh per heat pump. We use the central value (3.7 MWh) in this report to estimate the number of dwellings currently using oil and gas boilers that could be replaced by heat pumps, using the same amount of electricity as we calculated for the production of e-fuels for aviation in the Industry High Traffic Scenario in 2050 (585 TWh).

6. CO_2 emissions

We model tank-to-wing CO_2 emissions. To account for production losses in e-kerosene, we model an 85% reduction in CO_2 emissions compared to fossil kerosene until 2040, followed by a linear improvement to 100% by 2050, reflecting advancements in production processes and sustainable carbon sourcing. For sustainable advanced and waste biofuels (derived from sustainable feedstocks), we assume a constant 85% reduction in emissions compared to fossil kerosene through 2050. In contrast, for unsustainable biofuels (produced from unsustainable feedstocks), we model a range of potential emissions reductions, from no reduction relative to fossil kerosene to the same 85% reduction as sustainable biofuels (Infobox 2). Hydrogen and electric aircraft are assumed to be zero-emission.

7. Carbon budget of European passenger aviation

A carbon budget is a tool used to define climate targets and evaluate emission reduction pathways. It is the maximum amount of CO_2 that can be emitted to limit global warming to a specific level. In this report, we use a recent estimate of the remaining global carbon budget[15], starting from 2023.
To limit global warming to 1.5°C, 1.7°C and 2.0°C respectively with a 67% probability, the updated estimates of the global remaining carbon budget as of early 2023 is 150 $GtCO_2$, 500 $GtCO_2$ and 950 $GtCO_2$.

In this report, as explained in Section 7, we use a grandfathering approach to allocate a carbon budget. The grandfathering approach consists in allocating the share of the remaining carbon budget to a sector according to its historical contributions. This same approach was used in a recent report calculating the remaining carbon budget for aviation. [16]

However, the grandfathering approach disadvantages economically and technologically less developed countries in terms of their available budget share and it also contradicts the intention of Article 2.2 of the Paris Agreement, which binds the signatories to the principle of common but differentiated responsibilities.[26] The per capita approach assumes that each individual in the world is allocated an equal share of the remaining budget. Given that Europeans represent 5.6% of the world population in 2023, the corresponding remaining budgets are shown in the table below.

Estimated remaining carbon budget for EU passenger aviation from the beginning of 2023 (in Gt of CO_2). The carbon budgets in bold are the ones used in the report.						
	Grandfathering approach			Per capita approach		
Likelihood	50%	67%	83%	50%	67%	83%
1.5°C	0.82	**0.49**	0.33	0.35	0.21	0.14
1.7°C	1.96	**1.64**	1.15	0.83	0.69	0.48
2.0°C	4.42	**3.11**	2.62	1.87	1.32	1.11

8. Note on the *European Commission's 2040 modelling scenario*

Our calculations for the *European Commission's 2040 modelling scenario* are based on three key metrics from the Commission's own impact assessment:

- Growth in passenger traffic for 2030, 2040 and 2050, broken down by scope (intra-EU and extra-EU) and relative to 2015 (Annex 1.3);
- Decrease in energy intensity for 2040 and 2050, relative to 2015 (Annex 2);
- The fuel mix, expressed as shares of energy carriers, for 2030, 2040 and 2050 (Annex 4.1).

As explained in the different Annex sections, we made additional assumptions (e.g. emissions reductions from SAF), and we used external sources (e.g. SATFOR for the baseline for passenger traffic) to ensure consistency with the *Industry High Growth Scenario* and to extrapolate data for the 2023-2050 period.

These assumptions may differ from those used in the Commission's PRIMES-TREMOVE[27] transport model, which could lead to slight divergences in some of the aviation modelling outputs from the EC impact assessment.