Updated impacts **of a CO_2 ceiling** for Dutch aviation

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Content

Summary

The Civil Aviation Policy Memorandum contains the aim to limit CO_2 emissions of Dutch aviation to 2005-levels by 2030, reduce them by 50% (relative to 2005) by 2050 and to zero by 2070 (Ministerie van I&W, 2020). In order to safeguard that the goals will be met, the Civil Aviation Policy Memorandum proposes to implement a so-called CO_2 emissions ceiling for the international aviation sector (the 'CO_2 ceiling'). The aim of the CO_2 ceiling is to turn the CO_2 targets into enforceable targets that have to be reached by the aviation sector. Implementation of the CO_2 ceiling would shift the responsibility of reaching the targets from the government to the sector. It would also allow the sector to grow within clear environmental constraints.

This report is an update of the main impact assessment "Impacts of a CO_2 ceiling for Dutch aviation" (CE Delft, 2022b). In this update the impacts of the CO_2 ceiling policy options are assessed for eight newly defined scenarios.

In the main impact assessment 54 scenarios were defined which covered a wide range of possibilities in: the capacity of Dutch airports, European measures from the European Fit for 55 proposals, national climate policy and socio-economic development. Since then, important national, European and international policies have changed. The most important one for the CO_2 ceiling is the announcement of the Dutch government to reduce the capacity at Schiphol from 500,000 to 440,000 annual aircraft movements starting in IATA season 2023/2024. Also, the timing of the possible opening of Lelystad airport, the status of the Fit for 55 negotiations and CORSIA have been changed in the meantime. This update covers all these relevant policy changes in the eight baseline scenarios.

For the implementation of a CO_2 ceiling, there are three main policy framework options, which are defined as:

1. Airport option: A national CO_2 ceiling divided over airports and embedded in airport permits, comparable to limit values for airports with regard to noise and local air quality.
2. Fuel supplier option: A fossil fuel ceiling, which limits the amount of fossil fuels which fuel suppliers are allowed to supply to aircraft by auctioning permits.
3. Airline option: A national Emissions Trading Scheme, which establishes a closed ETS for airlines departing from Dutch airports.

Effectiveness in ensuring that the climate objectives for Dutch aviation are met

When the business-as-usual emissions exceed the CO_2 ceiling, the CO_2 ceiling will become restrictive. Whether this is likely, depends on various external factors such as economic growth, international and European climate policy, Dutch capacity constraints and additional Dutch climate policy. To explore these uncertainties, the main impact assessment distinguished 54 baseline scenarios. The study found that in most of these 54 scenarios, the CO_2 ceiling is not restrictive. In 9 out of 54 scenarios - the scenarios with either high-airport capacity or weakened Fit for 55 proposals - the CO_2 ceiling would be restrictive for more than a few years.

In this update eight new baseline scenarios are defined, including the latest policy development. In four out of these eight scenarios - the scenarios where the capacity of Schiphol stays constant at 440,000 flights - the CO_2 ceiling will not be restrictive.
In the two scenarios where the capacity of Schiphol is allowed to increase after 2029, and high economic growth is assumed, the CO_2 ceiling is restrictive for more than a few years. In the corresponding baseline scenarios with assumed low economic growth, emissions would only exceed the ceiling for a few years.

The number of years in which the CO_2-ceiling baseline is restrictive in the different baseline scenarios of this update is summarized in Table 1.

Table 1 - **Number of years for which the baseline scenarios from this update exceed the CO_2 ceiling**

Scenario	WLO Low	WLO High
Low capacity *Schiphol: 440,000 constant* *Lelystad: no opening*	Baseline scenario 1	Baseline scenario 2
Middle capacity 1 *Schiphol: 440,000 constant* *Lelystad: opening in 2025*	Baseline scenario 3	Baseline scenario 4
Middle capacity 2 *Schiphol: 440,000 until 2029, after that growth based on noise reductions. Hard cap of 630,000 due to safety and operational restrictions.* *Lelystad: no opening*	Baseline scenario 5	Baseline scenario 6
High capacity *Schiphol: 440,000 until 2029, after that growth based on noise reductions. Hard cap of 630,000 due to safety and operational restrictions.* *Lelystad: opening in 2025*	Baseline scenario 7	Baseline scenario 8*
Status baseline emissions	Never above ceiling | 5-15 years above ceiling	=> 15 years above ceiling

Note: The scenario indicated with a * has been modelled in this update of the impact assessment.

Therefore, it can be concluded that without government action, CO_2 emissions from aviation could exceed the CO_2 targets. This would not be in line with the policy goals as stated in the Civil Aviation Policy Memorandum and undermine the credibility of the Dutch efforts.

Ensuring that the CO_2 emissions from Dutch aviation do not exceed the ceiling, will give market actors certainty about supply and demand of sustainable aviation fuels and aircraft innovation. It also provides clarity to the aviation sector about the limits within which growth is possible according to the policy framework set by the Dutch government.

For these reasons, it can be concluded that a national CO_2 ceiling for aviation could be an effective instrument to ensure that the agreed CO_2 emission limits are not surpassed.

Impacts of a CO_2 ceiling

When the CO_2 ceiling is not restrictive, there will be no effects except limited costs, mainly for administrative purposes. For most of the scenarios in the main impact assessment and for half of the scenarios in this update, this is the case.

When the CO_2 ceiling is restrictive, the ceiling would affect the aviation sector, the environment, and the wider economy. In scenarios where the CO_2 ceiling is restrictive, the aviation sector has to reduce their CO_2 emissions. The sector could do this by limiting the number of flights, flying shorter distances, flying with the use of more efficient aircrafts or by blending more Sustainable Aviation Fuel (SAF). Sector parties are expected to make strategic decisions on the type of emission reduction they would apply. The mix of actions depends on the option of the CO_2 ceiling and on the exceedance of the ceiling.

In the Airport options, all CO_2 reduction results from either lower growth in the number of flights or flying shorter distances. This is because the emission reduction is achieved by constraining airport capacity. If airlines would voluntarily choose to invest in sustainability, this would be rewarded with higher airport capacities in the following years. In the Fuel supplier and Airline options, there is a direct incentive for airlines to become less carbon-intensive. As a result, part of the required reduction will be achieved through flying shorter distances, efficiency improvements and, if the CO_2 price is high enough, additional blending of SAF. The differences between the options increase as the CO_2 ceiling becomes more restrictive.

Note that none of the eight scenarios shows a *reduction* in the number of flights compared to previous years due to the CO_2 ceiling. A restrictive CO_2 ceiling in all scenarios instead, results in a limitation of the *growth* in the number of flights.

The resulting impacts of a restrictive CO_2 ceiling can be summarized as follows:
- Impacts on the aviation sector. In the Airport options, there is less growth for both European and intercontinental flights. In the Fuel supplier and Airline options the CO_2 ceiling leads to less growth in the intercontinental network, but the European network remains unaffected or even increases. When the auction revenues are channelled back into the aviation sector, the overall impact on aviation is the smallest of all considered options.
- Costs for the sector, the government and the Dutch economy. By far the most important cost item is purchasing CO_2 rights. Costs for the sector and the government differ to a large extent between the options. When fuel suppliers or airlines are regulated, costs are incurred by the sector for the auctioning of allowances (these are revenues for the government), unless the revenues are returned to the sector. When airports are regulated, there are no auctioning costs. When fuel suppliers or airlines are regulated and the auction revenues are for the state, the impact on the Dutch economy is positive because household expenditure increases. The impact is slightly positive when the airports are regulated, while the impact on the economy is negative when the auction revenues are returned to the aviation sector.
- Climate impacts. The climate impacts consist of direct impacts of the Dutch aviation sector and indirect impacts through evasion to foreign airports, changes in land transport, potential increases in emissions in other EU ETS sectors and the change in non-CO_2 climate impacts of aviation. In all options, the global greenhouse gas emissions are reduced if the ceiling is restrictive. The largest net reduction is found in the Fuel/Airline options.
- Local environmental impacts. When the CO_2 ceiling is restrictive, the changing flight patterns and use of smaller and newer aircrafts lead to a reduction of air pollution and noise emissions around airports in most options. Only for the Fuel/Airline options with auctioning income for the state there is a slight increase in LTO emissions and noise. In this option there is a stronger increase in flights with full-freighters, which have higher LTO and noise emissions compared to the average passenger aircrafts.

Comparing the options

If the CO_2 ceiling is never restrictive, the Airport option scores best due to the relative ease of implementation and relatively low administrative costs compared to the other options.

If the CO_2 ceiling is restrictive for several years, the advantages and disadvantages are spread between the options. The Airport options give more certainty about aviation CO_2 emissions and overall costs. However, the Fuel supplier and Airline options have the least impact on the aviation sector. On the other hand, the positive effects on the local environment of airports are the highest in the Airport option due to the reduction in the number of aircraft movements.

When comparing the options, one should take into account the likelihood of the CO_2 ceiling being restrictive. In the baseline scenarios where the capacity at Schiphol airport remains constant at 440,000 flights per year, the ceiling never becomes restrictive. However, it should be noted that the scenarios that are accessed in this study do not explore all uncertainties. If for instance the SAF blending obligations in the Fit for 55 proposals would be reduced or worldwide SAF production would not be able to supply the demand, the ceiling might become restrictive also with 440,000 flights.

If the capacity at Schiphol airport is allowed to increase from 2030 onward, the ceiling becomes significantly restrictive in the scenarios with high socio-economic growth (WLO High). In the WLO Low scenario, the ceiling only becomes restrictive for a couple of years. In this case it should also be noted that the scenarios do not fully explore all uncertainties. Like mentioned above, the realisation of the assumed SAF blending is also crucial here, which is dependent on the legislator and the availability of SAF.

The most important change compared to the outcomes of the main impact assessment is that, when considering the near future (until 2030), it is very unlikely that the CO_2 ceiling will become restrictive. This is a direct consequence of the announced capacity reduction at Schiphol between 2024 and 2029. Therefore, it can be argued that if a short-term perspective is applied, the Airport option with a three-year compliance period scores best.

If a longer-term perspective is applied, the uncertainty of the future capacity limits at Schiphol airport and the uncertainty around the opening of Lelystad airport make it reasonably likely that the ceiling becomes restrictive for some period. Therefore, the optimal policy choice in these scenarios is less clear: both the Airport option with a three-year compliance period and the Fuel supplier option with a stability mechanism (with auctioning incomes that are either for the state or funnelled back) are options that score well. However, both have different advantages and disadvantages. Therefore, it is not possible to identify a preferred option without assigning relative weights to the different criteria. This is a political choice which should not be made in this impact assessment.

1 Introduction

1.1 The CO_2 ceiling

The Civil Aviation Policy Memorandum contains the aim to limit CO_2 emissions of Dutch aviation to 2005-levels by 2030, reduce them by 50% (relative to 2005) by 2050 and to zero by 2070 (Ministerie van I&W, 2020). To safeguard that the goals will be met, the Civil Aviation Policy Memorandum proposes to implement a so-called CO_2 emissions ceiling for the international aviation sector (the ‘CO_2 ceiling’). The aim of this measure is to guarantee that agreed emission goals are met. Thus, it sets clear limits for permitted CO_2 emissions, with the possibility for the aviation sector to earn growth within those boundaries by introducing technological innovations and using sustainable aviation fuels (SAF) for operations.

The aim to introduce a CO_2 ceiling has been reaffirmed by the current government of the Netherlands in its coalition agreement (VVD et al., 2021). Moreover, the Dutch Parliament has supported the introduction of a CO_2 ceiling through two separate motions (Tweede Kamer der Staten Generaal, 2020a, 2020b). As part of the preparation for a legislative proposal, the ministry of Infrastructure and Water Management has commissioned an integral impact assessment of various options for implementation of the CO_2 ceiling. The main impact assessment (CE Delft, 2022b) has been carried out during the first half of 2022.

1.2 Cause for the update

In the main impact assessment (CE Delft, 2022b), detailed modelling with the AEOLUS model (Significance, 2020) and post-processing of the data has been applied to estimate and compare the effects of the different options of the CO_2 ceiling. Therefore, it was necessary to define the policy background and other assumptions for the modelling already early in 2022. In the meanwhile, important boundary conditions have been changed and hence parts of the study are outdated. The most important adjustments are listed below, for a detailed description see Section 2.1:
- the announced capacity reduction at Schiphol from 500,000 to 440,000 annual aircraft movements (take-offs plus landings);
- the shift in time of the potential opening of Lelystad airport;
- the current status of the Fit for 55 negotiations, e.g., the minimum blending mandate in the ReFuel EU Aviation proposal and the status of the Energy Taxation Directive (ETD);
- the results of the 41st triennial ICAO assembly on the future of CORSIA.

These changes made it necessary to carry out an update on the effects of the different options of the CO_2 ceiling. Throughout this report we refer to the previous impact assessment report of the CO_2 ceiling (“Impacts of a CO_2 ceiling for Dutch aviation - version September 2022”) as the ‘*main impact assessment*’ with the external reference to this report (CE Delft, 2022b). In this update we have not repeated the methodology because the methods used to assess the impacts are identical to the main impact assessment.

1.3 Scope

The policy options of the CO_2 ceiling that are considered within this report are identical to the eight sub-options in the main impact assessment, which are shortly outlined in the following paragraph.

There are three main options for the implementation of a CO_2 ceiling including eight sub-options in total:

1. Airport options: A national CO_2 ceiling divided over airports and embedded in airport permits, comparable to limit values for airports regarding noise and local air quality:
   - strict allocation of shares of the national CO_2 budget to individual airports; 3-year compliance cycle;
   - strict allocation of shares of the national CO_2 budget to individual airports; 1-year compliance cycle;
   - soft allocation of shares of the national CO_2 budget to individual airports; 3-year compliance cycle.
2. Fuel supplier options: A fossil fuel ceiling, which limits the amount of fossil fuels that fuel suppliers are allowed to supply to airport fuelling facilities[1] by auctioning permits:
   - auctioning revenues are retained as fiscal income for the state and a market stability mechanism is introduced;
   - auctioning revenues are funnelled back to the aviation sector and a market stability mechanism is introduced;
   - auctioning revenues are retained as fiscal income for the state and there is no market stability mechanism.
3. Airline options: A national Emissions Trading Scheme, which establishes a closed ETS for airlines departing from Dutch airports:
   - auctioning revenues are retained as fiscal income for the state;
   - auctioning revenues are funnelled back to the aviation sector.

For further elaboration on the specifications of the CO_2 ceiling policy options, see the main impact assessment. Parallel to this report a comprehensive legal analysis of the different options of the CO_2 ceiling is prepared by the ministry of Infrastructure and Water Management. It is possible that this legal assessment concludes that certain options are not feasible. In this case only the remaining options should be considered in the political decision-making process.

Due to the new boundary conditions for the CO_2 ceiling, it became necessary to define new baseline scenarios. These baseline scenarios cover the uncertainties caused by the yet uncertain future capacities at Schiphol airport and opening of Lelystad airport, as well as the socio-economic development described in the Dutch long-term WLO scenarios, called WLO High and Low (CPB & PBL, 2015). This results in eight (new) baseline scenarios for which emissions are compared with the CO_2 ceiling, as in the main impact assessment, maintains its absolute boundaries.

For the other dimensions that had been considered in the main impact assessment (see Table 1 of the main impact assessment for all policy dimensions), the most likely policy assumptions have been chosen. This includes the Dutch National SAF blending obligation and the Fit for 55 package of the European Commission. Note that it is still possible and likely that policies develop different than assumed in this update. If this is the case, the results of this update are still valid. The CO_2 ceiling will become more or less restrictive (in time and/or magnitude). The wide range of baseline studies analysed in this report and the main

[1] In practice this is a limit on the supply of fossil fuel to aircraft from which emissions are borne

impact assessment make it possible to estimate the effects by interpolating between considered baseline scenarios. Because of this wide range between the extreme baseline scenarios, it is likely that the real future will lie within this range.

In the Sustainable Aviation Policy Memorandum concrete agreements for the absolute emission reduction in the Dutch aviation sector in the years 2030, 2050 and 2070 are defined. The considered time period for this impact assessment is 2025 to 2050.
The period during which the CO_2 ceiling is restrictive will be longer if a weakened version of the Fit for 55 proposals were to be agreed upon and implemented. This also applies if there is not enough SAF available to fulfil the demand for the number of modelled flights in the scenarios.

The CO_2 ceiling also applies in the time period between 2050 and 2070, when CO_2 emissions from Dutch aviation have to be reduced further and reach zero at the end of this period. This time period is not analysed in this study since the AEOLUS model is not able to calculate effects beyond 2050. However, we presume that the CO_2 ceiling will no longer be restrictive when we extrapolate the SAF blending obligation in the ReFuel EU Aviation proposal beyond 2050. The SAF blending rate should reach 100% much earlier than 2070.

Selected baseline scenario in update

For one of the eight baseline scenarios the effects of the different options of the CO_2 ceiling are estimated and outlined in this report. This is the scenario with the highest demand for aviation (WLO High) and the highest allowed number of flights, as a consequence of the assumed opening of Lelystad airport and a significant growth in the amount of aircraft movements at Schiphol after 2029, given the applicable capacity rules. The selected baseline scenario leads to the highest amount of CO_2 emissions of all eight baseline scenarios. Hence, the CO_2 ceiling is most restrictive compared to all other possible future developments. This is different from the main impact assessment, where the effects in the report have been described for the so-called 'reference scenario'. Although this baseline scenario was also based on the WLO High scenario, it was a less extreme choice than the selected scenario in this update. When examining the results in this study, the reader has to consider that the effects will be smaller in case socio-economic growth is lower or the allowed capacities at Dutch airports will increase less than assumed in baseline scenario 8.

The results of baseline scenario 8 can best be interpreted as a realistic upper boundary for the effects of the CO_2 ceiling. This is a different choice compared to the main impact assessment, where the analysis was centred on the "reference scenario", which represents a likely future instead of an upper bound. We made this choice because the analysis of effects when the ceiling is restrictive is most useful for scenarios in which the CO_2 ceiling is restrictive for a reasonable amount of time.

The effects that are studied in detail in this update are the impacts on Dutch aviation and the environmental impacts. The analysis of the economic impacts and the social impacts is not fully updated, since these impacts are independent of the restrictiveness of the CO_2 ceiling (e.g., administrative costs) or can be explained rather straightforward from the impacts on Dutch aviation (e.g., changes in fuel cost). Hence, the impact assessment is still valid for most of these effects. Nevertheless, this update includes a qualitative interpretation of the estimated economic effects.

1.4 Outline of the report

This report is an update of the main impact assessment of the CO_2 ceiling.

In Chapter 2, we describe eight new baseline scenarios that explore the main uncertainties for the development of CO_2 emissions from Dutch aviation and how CO_2 emissions evolve in these scenarios. For one of the eight baseline scenarios, the impacts on Dutch aviation are estimated in Chapter 3 and the environmental impacts are discussed in Chapter 4.
In Chapter 5, the multi-criteria analysis of the main impact assessment is updated, taking into account the insights of the new baseline scenarios.
Finally, Chapter 6 presents the overall conclusions.

2 Emissions in baseline scenarios

In this chapter, we describe the modified policy assumptions for the CO_2 ceiling compared to the main impact assessment. Based on these assumptions, eight new baseline scenarios are defined. In these baseline scenarios, aviation at Dutch airports evolves differently until 2050, resulting in distinct estimates for the development of CO_2 emissions over time.

In Section 2.1 we discuss the changes in the policy assumptions compared to the main impact assessment. In Section 2.2 we specify the baseline scenarios that we constructed based on these assumptions. In Section 2.3 we discuss the development of the aviation sector in these baseline scenarios. Section 2.4 summarises the aviation CO_2 emissions and assesses to what extent the CO_2 ceiling limits are reached in the different scenarios.

2.1 Changes in policy assumptions

The main motivation for this update of the impact assessment is that there have been significant policy changes over the past year. Therefore, the policy assumptions which were made in the main impact assessment no longer reflect the current situation. In this update, we have incorporated the following main developments:

- In the “Hoofdlijnenbrief Schiphol” (Ministerie van I&W, 2022), the decision to reduce the maximum capacity at Schiphol airport from 500,000 flights per year to 440,000 flights per year was announced. This capacity reduction has been set for five years, starting in the IATA winter season of 2023/2024. After this five-year period, the Hoofdlijnenbrief states that “there is room for development of the aviation sector, but there should explicitly also be benefits for the local environment”[2]. This suggests that technological developments that reduce flight noise levels, for example, can result in growth of the number of flights, as long as a net reduction in noise levels around the airport remains. The details of this trade-off between growth of the aviation sector and reductions of externalities still need to be worked out.
- The developments of the Fit for 55 programme have led to two changes in our modelling assumptions:
  - We have slightly adjusted the SAF blending target for ReFuelEU Aviation in 2030. In the main impact assessment, we assumed that the SAF blending share in 2030 would be 5% (based on the Commission proposal) (EC, 2021b). Since both the European Parliament (2022) and the Council (Council of Ministers, 2022) have proposed a SAF blending obligation of 6% in 2030, we have now chosen to assume this percentage. For the year 2050, the European Parliament has also proposed to increase the blending obligation from 63 to 85% (which was the EuropeanCommission proposal). However, since the Council proposal aligns with the Commission proposal, we have maintained the assumption of 63%.
  - We now assume that there will be no tax on aviation fuels due to the ETD. The reason for this choice is that the outcomes of the negotiations for the ETD proposal are still very uncertain. With this choice, we align with the Klimaat- en Energieverkenning 2022 (PBL, 2022) which labelled the revision of the ETD as a “scheduled policy”.

[2] Text in Dutch: “Daarbinnen is er deels ruimte voor ontwikkeling van de luchtvaartsector, maar dit moet nadrukkelijk ook ten goede komen aan de omgeving”.

- At the 41st Assembly of ICAO, a net-zero CO_2 emission goal for international aviation in 2050 was agreed (ICAO, 2022). Also, a number of changes to the CORSIA system were made: from now on all emissions above 85% of the 2019-emission levels need to be offset or reduced.
- The aviation tax for departing passengers from Dutch airports is set to € 26.43, which will be the new tax from 2023 onwards (CE Delft, 2022a).
- It was recently announced that a decision will be taken in 2024 on whether Lelystad airport will open (Ministerie van I&W, 2022). We include both options in the scenarios and assume opening in 2025 in case this is decided.

Apart from these changes, all assumptions underlying the different scenarios are unchanged. A full overview of these assumptions can be found in Annex B of the main impact assessment.

In Annex A, we have documented exactly how we have translated these new policy developments into concrete modelling assumptions. Furthermore, we briefly describe the improvements of the used AEOLUS model, which have been implemented in the meanwhile.

2.2 Definition of 8 baseline scenarios

In this update of the impact assessment, we have constructed eight baseline scenarios which explore the following uncertainties:

- General (inter)national developments. We distinguish the “WLO Low” and “WLO High” scenarios (CPB & PBL, 2015) which represent either low or high socio-economic growth until 2050. Both scenarios are equiprobable.
- Capacity growth at Schiphol airport after 2029. It is still uncertain to what extent the aviation sector can “earn” growth due to technological developments (which reduce the noise or other environmental externalities of aviation) after 2029 (Ministerie van I&W, 2022). Therefore, we distinguish two possible developments[3]:
  - *No growth can be earned (lower limit).* In this scenario the airport capacity remains constant at 440,000 flights per year until 2050.
  - *If there are noise reductions, half of these improvements can be used to increase the number of flights.* In this scenario, the airport capacity can increase due to technological developments which lead to more quiet aircraft. However, since there are also other constraints on the airport capacity, such as safety and operational reductions, we have capped the airport capacity at 630,000 flights per year. This is consistent with the “high-capacity” assumptions for 2050 from the main impact assessment.
- Opening of Lelystad airport. We distinguish the possibilities in which Lelystad airport does and does not open.

The combinations of all situational conditions result in eight baseline scenarios. They are summarised in Table 2. Instead of attaching names to the scenarios, we refer to them as baseline scenarios 1 to 8 in this study.

[3] These assumptions focus on airport noise for modelling reasons. However, in line with the Hoofdlijnenbrief Schiphol it can be expected that other environmental constraints will also be limiting factors in the future. However, due to the uncertainty about how this will be implemented, we have adopted a simple modelling approach that considers only airport noise as a limiting factor.

Table 2 - Overview of the baseline scenarios

Scenario	WLO Low	WLO High
Low capacity *Schiphol: 440,000 constant* *Lelystad: no opening*	Baseline scenario 1	Baseline scenario 2
Middle capacity 1 *Schiphol: 440,000 constant* *Lelystad: opening in 2025*	Baseline scenario 3	Baseline scenario 4
Middle capacity 2 *Schiphol: 440,000 until 2029, after that growth based on noise reductions. Hard cap of 630,000 due to safety and operational restrictions.* *Lelystad: no opening*	Baseline scenario 5	Baseline scenario 6
High capacity *Schiphol: 440,000 until 2029, after that growth based on noise reductions. Hard cap of 630,000 due to safety and operational restrictions.* *Lelystad: opening in 2025*	Baseline scenario 7	Baseline scenario 8

2.3 Development of Dutch aviation in the baseline scenarios

In this section, we summarise the main developments of Dutch aviation in the eight baseline scenarios. Figure 1 presents the number of flights in the baseline scenarios at all Dutch airports.

Figure 1 - Number of flights in the baseline scenario at all Dutch airports

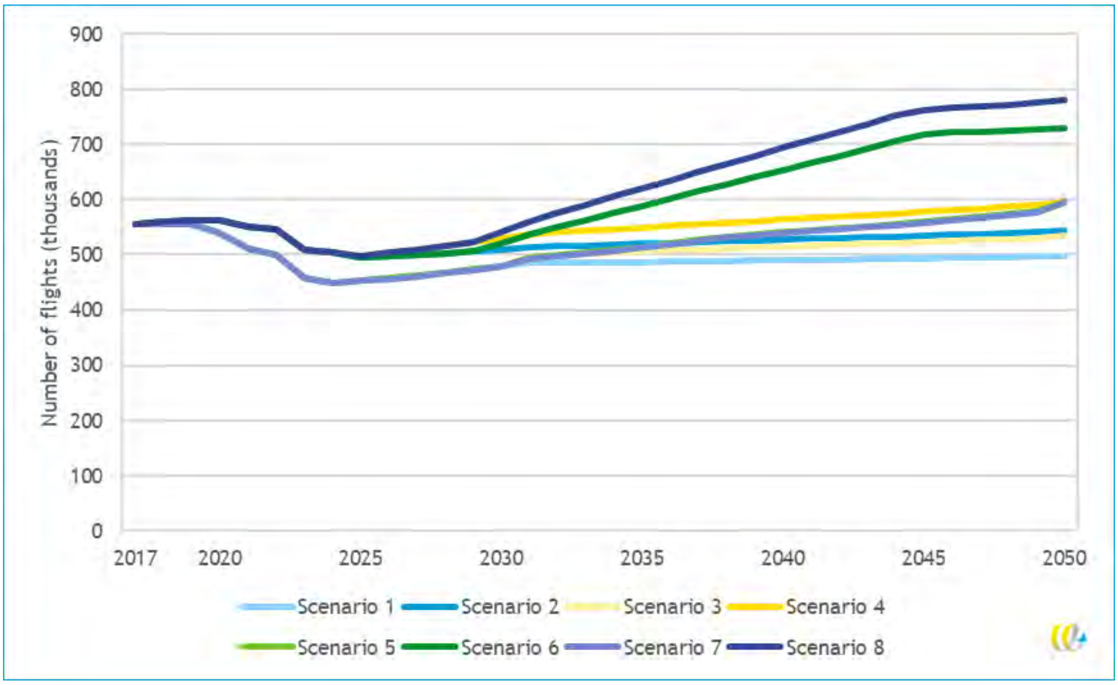


Figure 2 shows the number of flights at Schiphol airport. The light colours in each figure represent the WLO Low scenarios (scenarios 1, 3, 5 and 7), the dark colours represent the WLO High scenarios (scenarios 2, 4, 6 and 8).

Figure 2 - Number of flights at Schiphol airport in the baseline scenarios

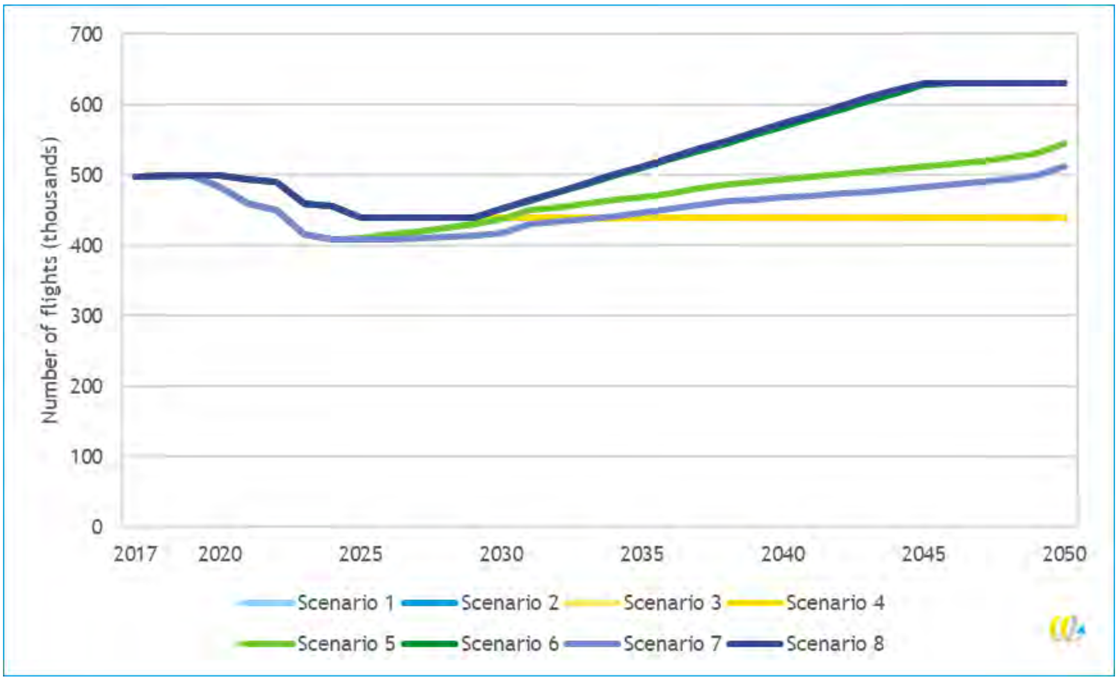


Figure 2 clearly displays the differences of Schiphol's capacity restrictions in the baseline scenarios. Scenarios 1 to 4 have a constant capacity of 440,000 flights. In all these baseline scenarios the demand is higher than the available capacity.

In baseline scenarios 5 to 8 an increase in the number of aircraft movements is possible after 2029. In WLO Low, this growth results in the number of flights at Schiphol being just above 500,000 in 2050. In these scenarios, the demand is lower than the available capacity. In the WLO High scenario the situation is completely different. Demand cannot fully be accommodated over the entire period despite of the robust growth in the number of flights until around 2045. Around that time, the number of flights is capped at 630,000. This is the hard cap of Schiphol due to safety and operational restrictions.

Figure 2 shows a similar pattern for the number of flights at all Dutch airports. Except that in scenarios 3, 4, 7 and 8 the number of flights is slightly higher (compared to 1, 2, 5 and 6) due to the opening of Lelystad airport in these scenarios. More information on the development of Dutch aviation in the baseline scenarios can be found in Annex C.

2.4 Projections of aviation emissions in baseline scenarios

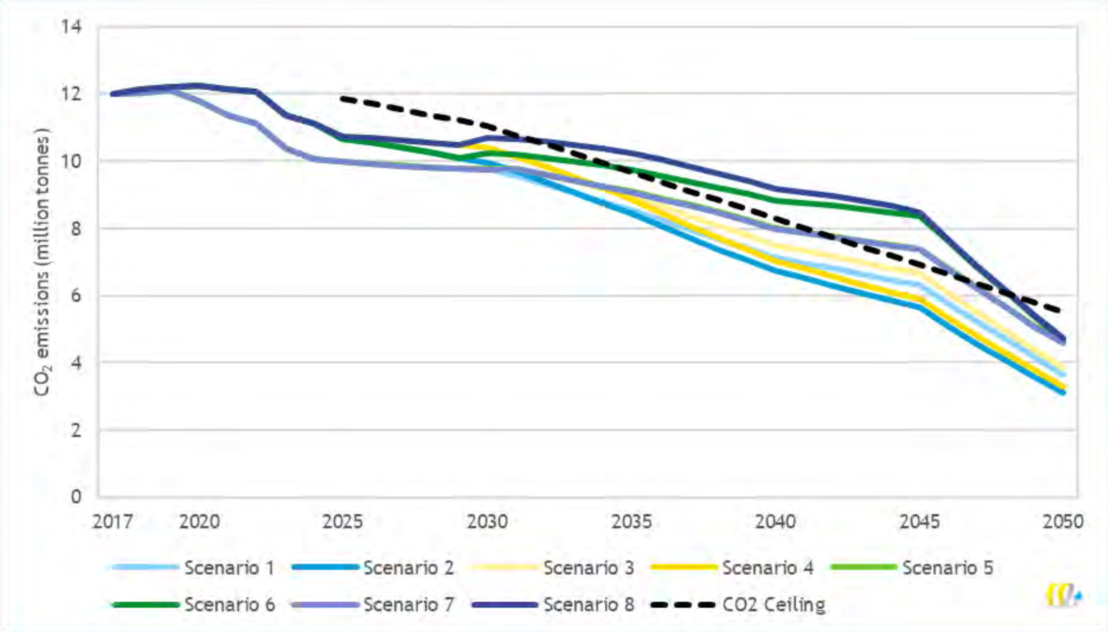
For all eight baseline scenarios the CO_2 emissions of commercial aircraft departing at Dutch airports are estimated with the AEOLUS model. The projections are shown in Figure 3[4]. Emissions peak in 2019 with approximately 12 million tonnes and decrease in all baseline scenarios towards 2050, when 3 to 5 million tonnes annual CO_2 emission remain.
In the intermediate years, the paths in the individual baseline scenarios are very different with some exceeding the CO_2 ceiling and others staying below the limit during the entire period. The key factors that determine the development of the emissions are the available capacity at Schiphol (440,000 aircraft movements until 2050 or growth after 2029) and the uncertainty in the macro-economic development (low growth in WLO Low versus high growth in WLO High).

In the scenarios with a constant capacity of 440,000 flights at Schiphol (scenarios 1, 2, 3 and 4) emissions stay below the CO_2 ceiling during the entire period. In the scenarios where growth in the number of flights at Schiphol after 2029 is possible (scenarios 5, 6, 7 and 8), emissions exceed the CO_2 ceiling. For the scenarios with low socio-economic growth (scenarios 5 and 7 based on WLO Low), emissions only surpass the ceiling for a small amount (less than 5%) and for five years. However, in the scenarios with high socio-economic growth (scenarios 6 and 8 based on WLO High), emissions exceed the CO_2 ceiling by up to 21% and for a period of fifteen years or more. The opening of Lelystad airport (compare for instance scenarios 6 and 8) has only a minor effect on the overall CO_2 emissions.

In this study we will investigate the effects of a CO_2 ceiling mostly on baseline scenario 8. This is the scenario with the highest CO_2 emissions in the baseline. It exceeds the CO_2 ceiling for over fifteen years for a significant amount, therefore making it well suited for an investigation of the effects of a restrictive CO_2 ceiling. It should be noted though that the magnitude of the effects is therefore based on the most 'extreme' scenario of all eight scenarios in this updated impact assessment.

4 The expected dip of CO_2 emissions from 2020 onwards caused by the reduction of aviation activities due to the COVID-19 pandemic is not modelled in AEOLUS. However, the lasting effects are incorporated in the forecasts assuming that the overall leisure demand returns to 2019-levels by 2024 and business demand is reduced by 5% relative to 2019 (for details see Section 2.3 in the main impact assessment). This implies that the estimates between 2020 and 2023 do not describe the realised emissions, but this has no effect since the CO_2 ceiling is expected to be introduced from 2025 onwards.

Figure 3 - **CO_2** emission projections in the baseline scenarios



In the main impact assessment 54 baseline scenarios have been defined, see Table 3, with the dimensions 1) socio-economic development (WLO Low and High), 2) airport capacity (low, middle, high), 3) European climate policy (Fit for 55 reduced, Fit for 55 as proposed, Fit for 55 increased) and 4) national SAF blending obligation (reduces ambition, as proposed, increased ambition). The eight baseline scenarios in this update distinguish 1) the socio-economic development (WLO Low and High) and 2) airport capacity with two variables, namely the capacity at Schiphol and the decision about the opening of Lelystad airport.

The other future uncertainties that were quantified in the scenarios of the main impact assessment (see Table 1 of the main impact assessment) are not considered in this update. Concretely, no distinction in European climate policy and national SAF blending is considered. For the Fit for 55 dimension, the assumptions in the update are between the 'reduced' and 'as proposed' ambition in the main impact assessment since it is assumed that the ETD will not be implemented but the other policies as proposed. For the national SAF blending, the assumptions in the update are in line with the reduced ambition of the previous study.

The capacity for Schiphol with the announced annual limit of 440,000 flights between 2024 and 2029 and potential growth thereafter, follows a very different path from the main impact assessment where capacity was constant 440,000 or linearly evolves to 440,000 or 630,000 in 2050. As a result of the announced capacity reduction, the CO_2 ceiling is not restrictive anymore in the period before 2032 and more severe around 2045 (see Figure 4), which was different in the main impact assessment (see Figure 5).

Figure 4 - **CO_2** emission projections for the four baseline scenarios based on WLO High of the updated impact assessment (this study)

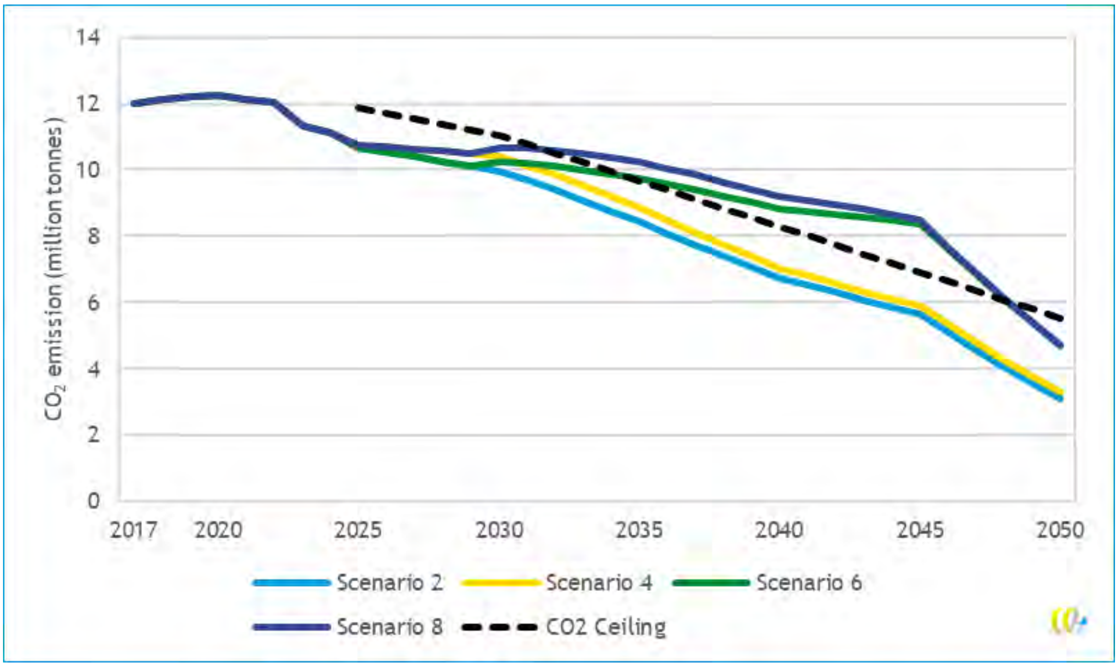


Figure 5 - **CO_2 emission projections of three baseline scenarios from the main impact assessment. The shown** scenarios are all based on WLO High, assume the Fit for 55 policies as proposed and no national SAF blending obligation. Airport capacity is varied. The middle capacity scenario is the reference scenario

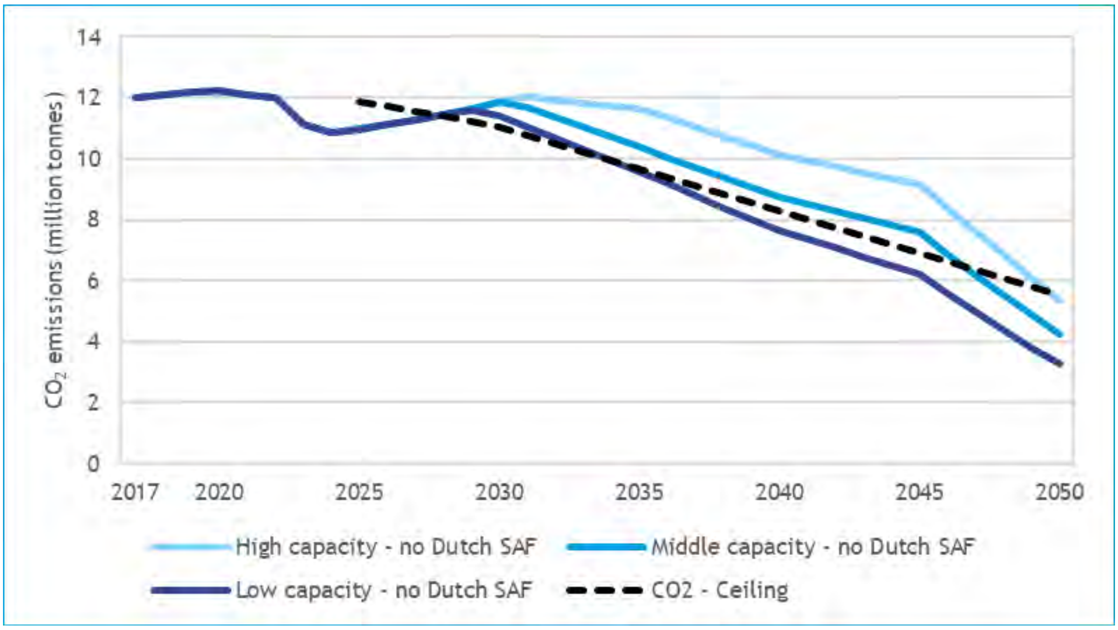


Table 3 summarises the baseline scenarios of the main impact assessment by colour coding them according to the number of years they exceed the CO_2 ceiling. There is an increased risk that aviation emissions exceed the CO_2 ceiling when a) the adopted legislation under the Fit for 55 package is weaker than the proposals made by the Commission; or b) the airport capacity is increased. The risk of exceeding the CO_2 ceiling is smaller when a) the adopted legislation under the Fit for 55 package is stronger than the proposals made by the Commission; b) the airport capacity is decreased; or c) when Dutch SAF blending follows the pathway proposed in the Civil Aviation Policy Memorandum.

Table 3 - Number of years for which baseline scenarios exceed the **CO_2** ceiling in the main impact assessment

	National SAF blending	WLO Low with COVID-19 recovery			WLO High with COVID-19 recovery		
		Airport Capacity Low	Airport Capacity Middle	Airport Capacity High	Airport Capacity Low	Airport Capacity Middle	Airport Capacity High
Fit for 55 reduced	Reduced ambition	1	2*	3	4	5*	6*
	As proposed	7	8	9	10	11	12*
	Increased ambition	13	14	15	16	17	18
Fit for 55 as proposed	Reduced ambition	19	20	21	22	23*	24*
	As proposed	25	26	27	28	29	30
	Increased ambition	31	32	33	34	35	36
Fit for 55 increased ambition	Reduced ambition	37	38	39	40	41	42
	As proposed	43	44	45	46	47	48
	Increased ambition	49	50	51	52	53	54
Status baseline emissions	Never above ceiling		< 5 years above ceiling	5-15 years above ceiling	=> 15 years above ceiling		
	Scenarios indicated with a * have been modelled in the main impact assessment						

When applying the same colour code to the updated baseline scenarios we obtain the results as shown in Table 4.

Table 4 - Number of years for which the baseline scenarios from this update exceed the CO_2 ceiling

Scenario	WLO Low		WLO High	
Low capacity *Schiphol: 440,000 constant* *Lelystad: no opening*	Baseline scenario 1		Baseline scenario 2	
Middle capacity 1 *Schiphol: 440,000 constant* *Lelystad: opening in 2025*	Baseline scenario 3		Baseline scenario 4	
Middle capacity 2 *Schiphol: 440,000 until 2029, after that growth based on noise reductions. Hard cap of 630,000 due to safety and operational restrictions.* *Lelystad: no opening*	Baseline scenario 5		Baseline scenario 6	
High capacity *Schiphol: 440,000 until 2029, after that growth based on noise reductions. Hard cap of 630,000 due to safety and operational restrictions.* *Lelystad: opening in 2025*	Baseline scenario 7		Baseline scenario 8*	
Status baseline emissions	Never above ceiling	5-15 years above ceiling		=> 15 years above ceiling

Note: The scenario indicated with a * has been modelled in this update of the impact assessment.

In short, in the scenarios with a constant capacity of 440,000 flights until 2050, CO_2 emissions of international commercial flights departing from Dutch airports are projected to never be above the CO_2 ceiling. In scenarios with growth of Schiphol after 2029, emissions will exceed the ceiling for a few of years in case socio-economic growth is low. In scenarios where Schiphol is allowed to grow beyond a capacity of 440,000 and high socio-economic growth will take place, emissions will remain above the ceiling for a long period of time. The same could potentially happen in other scenarios if the ambition of the Fit for 55 proposals would be reduced or SAF production is not scaled up sufficiently to meet worldwide aviation demand.

3 Impacts on Dutch aviation

3.1 Introduction

In this chapter we present the impacts of the CO_2 ceiling on Dutch aviation.
The methods are identical to the methods that had been applied in the main impact assessment. The description of the methods is not repeated in this report but can be looked up in the main impact assessment. In all baseline scenarios in which the capacity of Schiphol remains at 440,000 annual flights (baseline scenarios 1, 2, 3 and 4), CO_2 emissions stay below the CO_2 ceiling during the entire period. Therefore, the CO_2 ceiling is not restrictive and does not affect aviation activities. In baseline scenarios 5 and 7, where Schiphol can grow after 2029 and low socio-economic development is assumed (WLO Low), the CO_2 ceiling is exceeded from 2042 until 2047 by a few percent. Therefore, there will be limited effects in these years. In baseline scenarios 6 and 8, where Schiphol can grow after 2029 and high socio-economic development is assumed (WLO High), the CO_2 ceiling is exceeded by up to 21% and for a longer period of time. This is between 2035 and 2048, if Lelystad airport does not open, and between 2032 and 2048 if Lelystad airport is assumed to open.

The baseline scenarios in this update distinguish three dimensions, 1) capacity Schiphol, 2) opening Lelystad airport and 3) socio-economic development. The first two dimensions describe the uncertainty of political decisions that must be taken in the near future by the Dutch government, whereas the third dimension describes the uncertainty in the development of the demand for aviation. The two scenarios WLO Low and WLO High represent either low or high socio-economic growth.

In this chapter, we first assess the different actions that airlines can take to reduce their CO_2 emissions (Section 3.2). Thereafter, we discuss the different effects of these behavioural responses. The impact on passengers travelling through Dutch airports is discussed in Section 3.3. We then consider the impacts on flights (Section 3.4), destinations and network quality (Section 3.5). The impact on air freight is presented in Section 3.6. We then discuss the demand for fossil kerosene as well as different types of sustainable alternatives (Section 3.7).

In all these analyses, the effects of the different sub-options of the CO_2 ceiling are compared to the baseline, the situation without a CO_2 ceiling. We show all impacts for baselines scenario 8, the scenario in which the CO_2 ceiling is the most restrictive of all baseline scenarios. In baseline 6 the effects are comparable, in baseline 5 and 7 they occur during a shorter period and the magnitude is smaller. In baseline scenarios 1 to 4 the CO_2 ceiling has no effect on the impacts described in this chapter.

3.2 How do airlines reduce their CO_2 emissions?

When the CO_2 ceiling is restrictive, airlines must reduce their CO_2 emissions. They can do this in four different ways:
1. Reducing the fuel use by decreasing the average length of flights, for example by realising a shift from intercontinental aviation to intra-EU aviation.
2. Reducing the fuel use by decreasing the number of flights.
3. Efficiency improvements (in this study, we only quantified efficiency improvements due to fleet renewal).

4. Additional blending of SAF.

In this study, it is assumed that airlines will act rationally and therefore choose the least costly option to reduce CO_2 emissions. Table 5 provides a schematic overview of how the different behavioural responses will be used by airlines. The main difference between the different options for the CO_2 ceiling is that in the Airport option there is no direct incentive to reduce CO_2 emissions, which means that not all options for CO_2 reduction are utilised. This is true given the assumption of a prisoner's dilemma which causes collective action not to be taken[5].

Table 5 - **Development of the number of passengers (x 1,000) at Dutch airports without CO_2 ceiling (reference** scenario baseline)

	Option to reduce CO_2 emissions	Airport option	Fuel supplier option	Airline option
Large effects on aviation	Fewer flights	This option will be used, because the number of available slots is reduced	Since there is a direct incentive for airlines to decrease CO_2 emissions (buying CO_2 permits costs money), there is an incentive to utilize the most cost-effective option. Therefore, efficiency improvements and SAF blending will be chosen whenever this is more cost-effective compared to changing the flight schedule (i.e. when the CO_2 prices are high).	Since there is a direct incentive for airlines to decrease CO_2 emissions (buying CO_2 permits costs money), there is an incentive to utilize the most cost-effective option. Therefore, efficiency improvements and SAF blending will be chosen whenever this is more cost-effective compared to changing the flight schedule (i.e. when the CO_2 prices are high).
	Shorter flights	There is no direct incentive for airlines to focus on shorter flights*		
	Efficiency improvements	There is no direct incentive for airlines to improve the efficiency of aircraft*		
Small effects on aviation	Additional SAF blending	There is no direct incentive for airlines to blend additional SAF*		

* This is because there is a prisoner's dilemma, which results in a situation where it is not beneficial for individual airlines to invest in reducing CO_2 emissions individually.

The chosen action by the airlines to reduce emissions determines the effects on the aviation sector. Later in this chapter, we discuss these effects in more detail: the effects on aviation volumes are discussed in Sections 3.3, 3.4 and 3.6. The effects on SAF use are discussed in Section 3.7. Fleet renewal is not discussed in detail in this document, since the discussion in Paragraph 3.7 of the main impact assessment is still valid.

Figure 6 shows per ceiling option the absolute CO_2 reduction from the different possible responses from the airlines for scenario 8. This is the scenario with the highest demand and the largest effects of the CO_2 ceiling. The effects in scenario 6 are comparable, those in scenarios 5 and 7 are much smaller and occur only between 2042 and 2047. In baseline scenarios 1 to 4, the CO_2 ceiling is not restrictive and does not lead to any reaction from airlines.

5 See Section 3.3.3 of the main impact assessment for a discussion of the prisoner's dilemma.

First, it can be seen that in the Airport option slightly more CO_2 reduction is obtained compared to the other options. The reasons for this are clarified in Section 4.2. Furthermore, in the Airport options all CO_2 reduction is obtained by a reduction of aviation volumes (mostly by a reduction of the number of flights). In the Fuel supplier/Airline options where the auctioning income is for the state, efficiency improvements also have some share in the CO_2 reduction and a shift to shorter flights is the most important reaction of airlines. In the Fuel supplier/Airline options, where the auctioning income is funnelled back, almost all CO_2 emissions reduction is obtained by a shift to shorter flights. The average distance of flights is reduced to such an extent that even more flights are possible compared to the baseline (the negative dark blue bar).

Figure 7 shows the same data as relative shares of the CO_2 reduction. It can furthermore be seen that the option of additional SAF is only used to some extent in the Fuel supplier and Airline options. This is because by the year 2040, the marginal costs of blending extra SAF have just become sufficiently low to be attractive, compared to the costs of fossil kerosene due to the EU ETS and the CO_2 ceiling permit costs. From 2040 onwards, the use of SAF will become increasingly important, as shown in Figure 27.

Figure 6 - Absolute **CO_2** emission reduction of reduced aviation volumes, efficiency improvements and additional SAF blending in 2040 for scenario 8

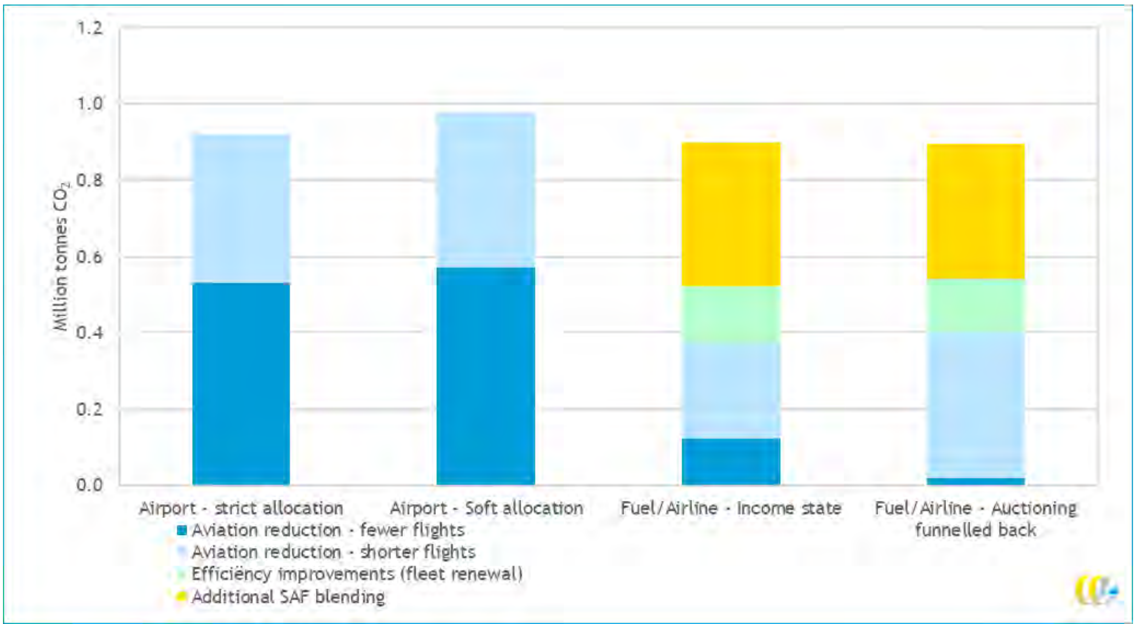


Figure 7 - Relative **CO_2** emission reduction of reduced aviation volumes, efficiency improvements and additional SAF blending for scenario 8

3.3 Impacts on number of passengers at Dutch airports

3.3.1 Introduction

In this section we discuss the impact of the different options of the CO_2 ceiling on the number of passengers for baseline scenario 8. This is the scenario with the highest demand and the largest effects of the CO_2 ceiling. The effects in scenario 6 are comparable, those in scenarios 5 and 7 are much smaller and occur only between 2042 and 2047. In baseline scenarios 1 to 4 the CO_2 ceiling is not restrictive and does not affect the number of passengers.

The number of passengers flying from different Dutch airports in baseline scenario 8 is shown in Table 6. The total number of passengers at all Dutch airports is growing rapidly. Lelystad airport is assumed to open in 2025. In this baseline scenario, Schiphol is allowed to grow beyond 440,000 flights annually from 2029 onwards. Therefore, there is strong growth in the number of passengers in 2040 and 2050, see Section 2.3.

Table 6 - Development of the number of passengers (millions) at Dutch airports without **CO_2** ceiling (baseline scenario 8)

Airport	2017	2030	2040	2050
Total	76.2	96.6	135.9	160.1
Amsterdam	68.4	80.8	112.9	130.8
Lelystad	0.0	5.2	7.8	10.4
Eindhoven	5.7	7.5	10.8	12.7
Rotterdam	1.7	2.6	3.6	5.0
Maastricht	0.2	0.3	0.3	0.4
Groningen	0.2	0.3	0.5	0.7

3.3.2 Results

Figure 8 shows the expected growth of the total number of passengers for all Dutch airports. In scenario 8, passenger volumes double from 76 million in 2017 to 160 million in 2050. The reduced demand due to the COVID-19 pandemic (dip between 2020 and approximately 2024) is not modelled and therefore not visible in the figure. However, long-term effects of the pandemic are incorporated in all baseline scenarios, see methodology in the main impact assessment. The decrease in the number of passengers in 2023 is caused by the increase of the aviation tax, which is announced for this year. Moreover, Schiphol airport's capacity will be reduced from 500,000 to 440,000 flights by 2025. Both measures lead to a reduction in demand at Dutch airports. In 2025, Lelystad airport is assumed to open and from 2029 onwards Schiphol's capacity is increased steadily. Both measures are drivers for passenger growth.

Until 2032, the CO_2 ceiling is not restrictive. Hence, none of the options have any effect on Dutch aviation. During the period of 2032 to 2049 the CO_2 ceiling is restrictive. All options lead to a reduction in the total number of passengers compared to baseline during this period. In the Airport option this causes airports to limit the growth of the number of flights until the CO_2 emissions are below the ceiling level again. This will directly lead to a reduction of the number of passengers flying via Dutch airports compared to the baseline. In the Fuel supplier and Airline options something different happens; here the prices of the emission rights increase. We assume that airlines will recuperate the increased costs through higher ticket prices. These higher prices result in a decrease of the number of passengers.

The overall limitation of the growth of the number of flights is significantly larger in the Airport options[6] compared to the Fuel supplier/Airline options, due to two main reasons:

1. Airports do not have influence on the type of flights operated within a slot. Their only lever is to reduce the overall number of flights at the airport, resulting in a proportionate decrease of long and short flights. In the Fuel supplier and Airline options this is different. Airlines will increase the ticket prices by the increased costs of the emission rights for specific routes. These cost increases are higher for passengers on longer routes, causing a shift of passengers towards shorter routes. Passengers on shorter flights have lower CO_2 emissions, therefore more passengers are allowed to fly using the same CO_2 budget. *(For further explanation, see further in this section the results on European OD and intercontinental OD passengers; or Section 3.4.2 for the results on European/intercontinental flights).*
2. We assume that in the Fuel supplier and Airline options airlines blend extra SAF when this is economically viable. During a restrictive CO_2 ceiling the prices of the emission rights will increase. At some point, the CO_2 costs of kerosene will make kerosene so expensive that SAF (without the additional CO_2 costs) will become the cheaper fuel. At this point, airlines will choose to blend extra SAF (above the minimum required blending), making more flights and thus more passengers possible. This effect occurs from 2040 onwards *(See Section 3.7 for results on SAF blending).*

[6] The 'bend' we see in the results of the Airport options around 2045 follows from the ReFuelEU Aviation proposal's blending requirements in combination with the decreasing CO_2 ceiling. Up to 2040 the SAF blending requirements increase steadily to 32%, while in 2045 there is a relatively smaller increase up to 38%, after which the requirement jumps to 63% in 2050.

Whether the assumption is correct that only in the Fuel supplier and Airline options extra SAF blending will occur, and not in the Airport options, is still under discussion. The main arguments are summarised in the following textbox.

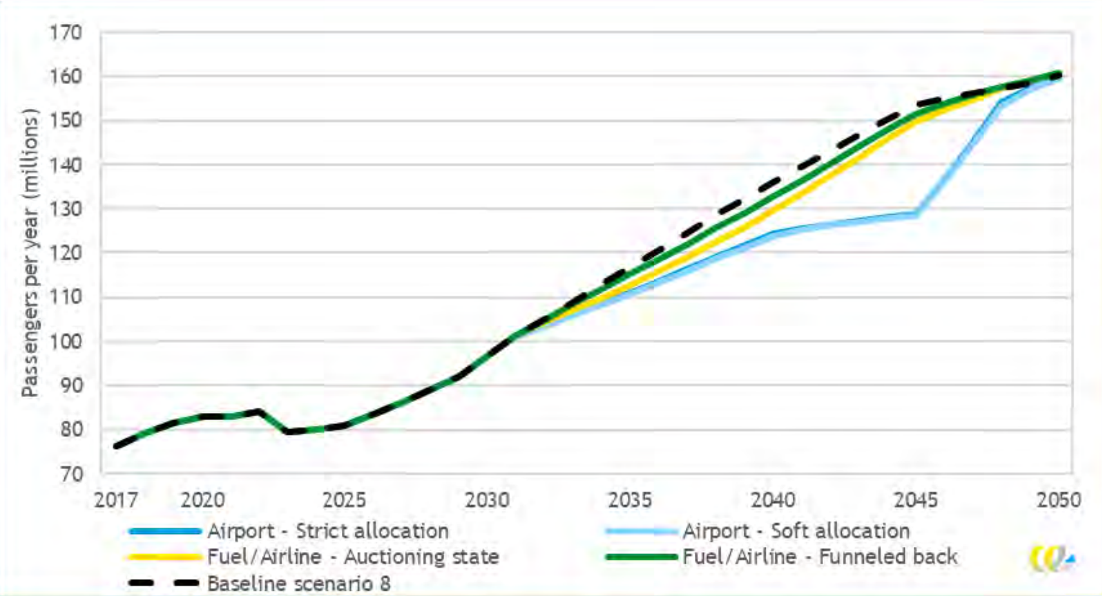
Textbox 1 - Discussion on blending extra SAF in the Airport options

In principle airlines could choose to blend extra SAF or improve efficiency through fleet renewal as well in the Airport options. However, in the Airport options this does not give the airline a direct advantage: more slots will become available for all airlines to use. Individual airlines will be facing a 'prisoners dilemma'. If 'airline green' decides to blend extra SAF this should lead to increased ticket prices. If the competitor 'airline grey' decide not to blend more SAF to meet the CO_2 ceiling targets, they can offer lower ticket prices and would gain market share from 'airline green'. Since the slots which become available due to the CO_2 reduction of 'airline green' would be distributed over all airlines, 'airline green' and 'airline grey' would profit from this. Therefore, the rational decision seems for all airlines to not blend extra SAF. However, there are two possible ways out of this prisoner's dilemma:

1. For airports where one airline has most of the market share (such as KLM has at Schiphol), it could be beneficial for this airline to blend more SAF since most of the extra slots that will become available are going to this airline[7].
2. The airlines operating at Dutch airports could also choose to sign an agreement to collectively blend more SAF.

If due to these reasons more SAF is blended or efficiency is improved in the Airport options, the results of the Airport options would shift towards the results of the Fuel supplier and Airline options (since additional SAF blending would result in more possible passenger movements at the same CO_2 emission level). Note that the additional blending of SAF is only significant from 2040 onwards since until then de prices are expected to be too high. The additional efficiency improvements through fleet renewal are relevant for all years.

Figure 8 - Total number of passengers at Dutch airports



[7] However, it should be noted that in reality this is more complex because 50% of the slots could be assigned to "new entrants", which would in most cases be at the disadvantage of the airline with already a high-market share.

Note: In these figures the sub-options with equivalent modelling outcomes are grouped together. Also, no upper and lower bound values are displayed, which makes the two different Airport - strict allocation sub-options indistinguishable.

For scenario 8, the effects of all the different sub-options on the number of passengers in 2040 compared to the baseline are shown in Table 7. 2030 and 2050 are excluded from the table, since the CO_2 ceiling is not restrictive in these future years. In sub-option Airport - Soft allocation, the allocation of CO_2 budget is corrected for noise permits, allocating slightly more budget towards regional airports and less towards Schiphol compared to strict allocation. Therefore, the effects on regional airports are smaller (except for Lelystad airport, which is part of the Schiphol budget in this study) and the effects on Schiphol are larger. In the Airport options demand exceeds the capacity at Schiphol, leading to a shift of passengers from Schiphol to regional airports. For the Fuel supplier and Airline options this is caused by the passenger shift of long intercontinental routes to shorter European routes. Regional airports mostly fly to European destinations and therefore are likely to face an increase in the number of passengers.

For four sub-options (Airport - strict allocation, Airport - soft allocation, Fuel supplier/ Airline - auctioning state and Fuel supplier/Airline - no stability mechanism) we see ranges indicated in Table 7. The main outcome is based on the corresponding model run and can be seen as the 'mean value'. The ranges indicate deviations from the mean value, caused by inflexibility in the system due to either: the shorter compliance cycle (three-year or one-year for the Airport - strict option) or having no stability mechanism (for the Fuel supplier option). The ranges are determined with an additional analysis of historic fluctuations in aviation demand (see main impact assessment). Due to these fluctuations, the total number of flights in the period 2024-2050 is expected to be lower for the three sub-options:

1. In the Airport - strict allocation option with a three-year compliance cycle, the total number of flights in this period can be expected to be 0.8% lower compared to a situation with infinite flexibility.
2. In the Airport - strict allocation option with a one-year compliance cycle, the total number of flights in this period can be expected to be 1.0% lower compared to a situation with infinite flexibility.
3. In the Airport - soft allocation option with a 3-year compliance cycle, the total number of flights in this period can be expected to be 0.8% lower compared to a situation with infinite flexibility.
4. In the Fuel supplier - no stability mechanism option, the total number of flights in this period can be expected to be 0.2% lower compared to a situation with infinite flexibility.

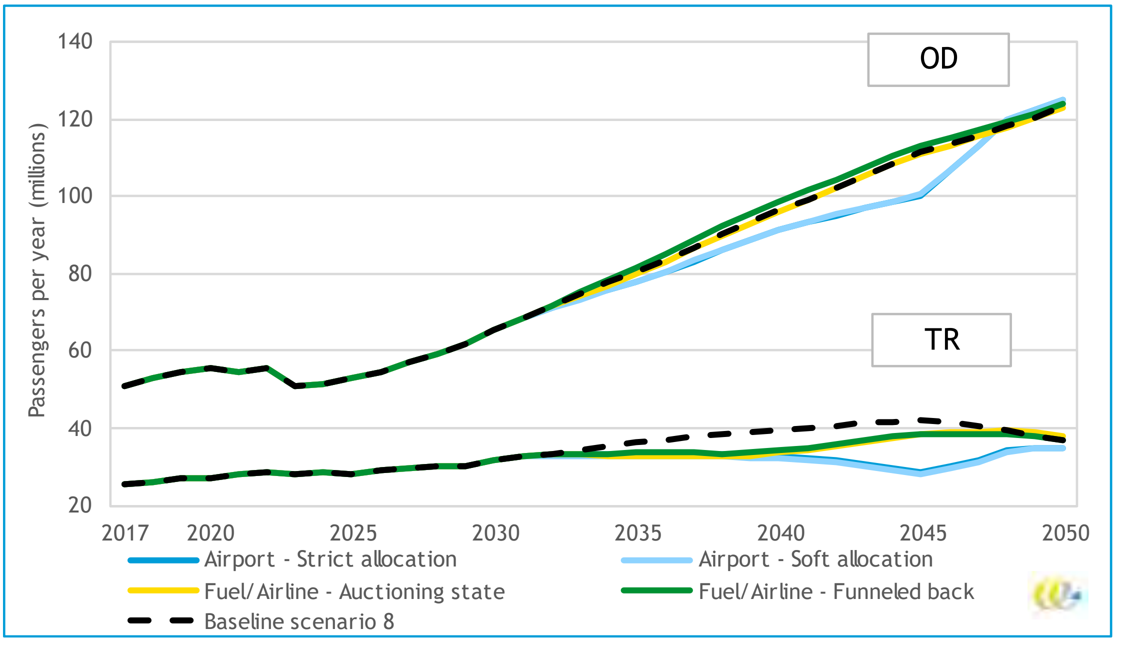
Table 7 - Impacts on number of passengers at Dutch airports in baseline scenario 8 for 2040 (millions per year)

Airport	Airport - Strict allocation (3-year cycle)	Airport - Strict allocation (1-year cycle)	Airport - Soft allocation (3-year cycle)	Fuel supplier - Auctioning state	Fuel supplier - Auctioning funnelled back	Fuel supplier - no stability mechanism	Airline - Auctioning state	Airline - Funnelled back
Total	-11.61 (-17.72 to -11.61)	-11.61 (-18.27 to -11.61)	-12.03 (-18.11 to -12.03)	-6.22	-3.17	-6.22 (-6.63 to -5.82)	-6.22	-3.17
Amsterdam	-10.1 (-15.15 to -10.1)	-10.1 (-15.6 to -10.1)	-11.25 (-16.24 to -11.25)	-5.81	-3.28	-5.81 (-5.81 to -5.81)	-5.81	-3.28
Lelystad	-0.78 (-1.13 to -0.78)	-0.78 (-1.16 to -0.78)	-0.85 (-1.19 to -0.85)	-0.33	0.01	-0.33 (-0.47 to -0.19)	-0.33	0.01
Eindhoven	-0.6 (-1.1 to -0.6)	-0.6 (-1.14 to -0.6)	-0.01 (-0.54 to -0.01)	0.08	0.06	0.08 (-0.12 to 0.28)	0.08	0.06
Rotterdam	-0.07 (-0.24 to -0.07)	-0.07 (-0.26 to -0.07)	0.04 (-0.13 to 0.04)	-0.14	0.01	-0.14 (-0.2 to -0.08)	-0.14	0.01
Maastricht	0.01 (-0.01 to 0.01)	0.01 (-0.01 to 0.01)	0.01 (-0.01 to 0.01)	-0.02	0.00	-0.02 (-0.02 to -0.01)	-0.02	0.00
Groningen	-0.08 (-0.1 to -0.08)	-0.08 (-0.1 to -0.08)	0.02 (-0.01 to 0.02)	0.00	0.02	0 (-0.01 to 0.01)	0.00	0.02

Note: For the sub-options Airport - Strict allocation (3-year cycle), Airport - Strict allocation (1-year cycle), Airport - Strict allocation (3-year cycle) and Fuel supplier - no stability mechanism, additional analysis was made based on the underlying AEOLUS runs to reflect the potential effects of fluctuations in aviation demand.

Figure 9 distinguishes the effects of the CO_2 ceiling on origin-destination passengers[8] (OD) and transfer passengers (TR). For all options, the drop in transfer passengers is much larger than the decrease in OD passengers. In the Airport options the drop of transfer passengers in 2045 is 29% compared to 9% for OD passengers. This is due to the fact that the price elasticity of transfer passengers is higher. Transfer passengers evade to competing hubs outside the Netherlands (or direct connections) when ticket prices increase, or connections become less attractive as a consequence of lower frequencies. For OD passengers this is less likely since this requires travelling to an airport abroad.

Figure 9 - Development of the number of OD and transfer passengers (TR) at Dutch airports



OD passengers at Dutch airports are further segmented by their destination. Figure 10 shows the effect for OD passengers with a European destination. In the Airport options passenger volumes decease, whereas the number of passengers increases in the Fuel/Airline options. The reason is a shift from long to short routes in the Fuel supplier and Airline options.
In these policy options either fuel suppliers or airlines have to buy an amount of CO_2 emission rights corresponding to their CO_2 emissions. We assume that the costs of these emission rights are passed through to the ticket prices of the passengers proportionally to the amount of CO_2 emitted on their flight. Therefore, passengers on longer intercontinental flights will face a higher price increase on their tickets than passengers on shorter European flights.

In the Airport options this shift does not occur, so there seems no incentive for individual airlines to adapt their network from long-haul to short-haul. In the Airport options there only is influence on the number of flights, not the destination and lengths of flights.
In the Fuel/Airline - Funnelled back option, there is a slightly larger increase in the number of passengers than in the Auctioning state option. The reason for this is that the previously

[8] Origin-destination passengers are passengers who have their origin or destination at a specific airport, in this case at a Dutch airport. The other category is transfer passengers who, in this case, only make a transfer at a Dutch airport.

mentioned shift from intercontinental to European flights is even stronger in this policy option. In the Fuel supplier/Airline - Auctioning funnelled back option the income raised by the auctioning of CO_2 permits is funnelled back to the sector. We assume a 100% cost pass through, such that all ticket prices are decreased by a fixed amount. This reduction in fixed costs will be relatively larger for short European routes with lower ticket prices[9], generating additional demand.

Figure 10 - Development of the number of OD passengers to European destinations at Dutch airports

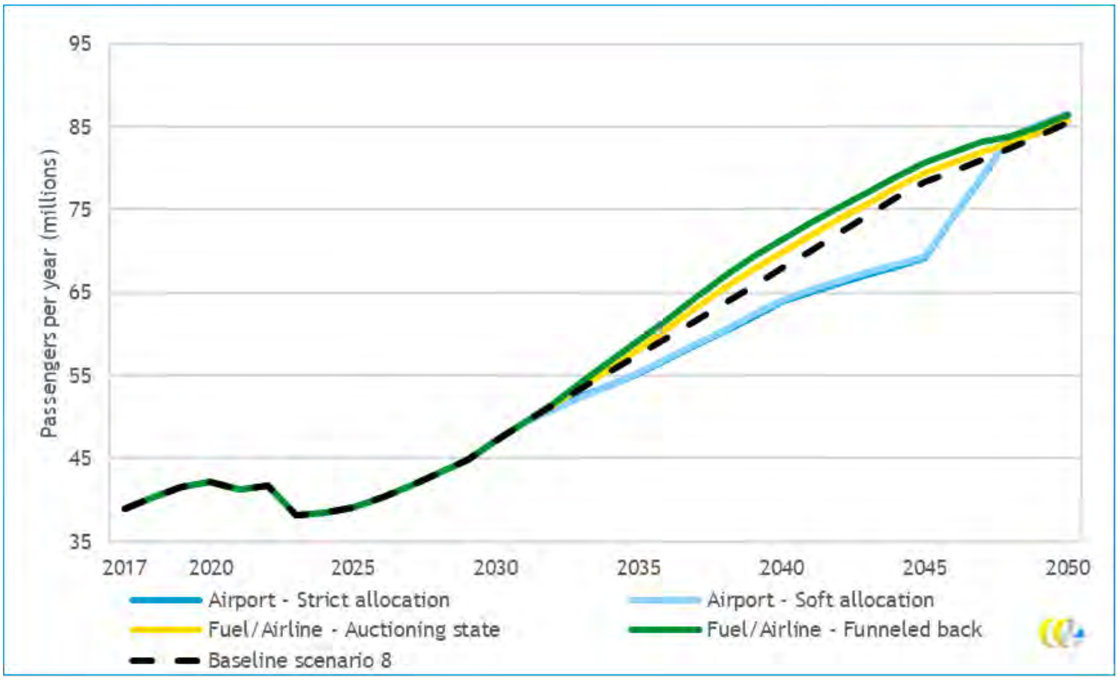
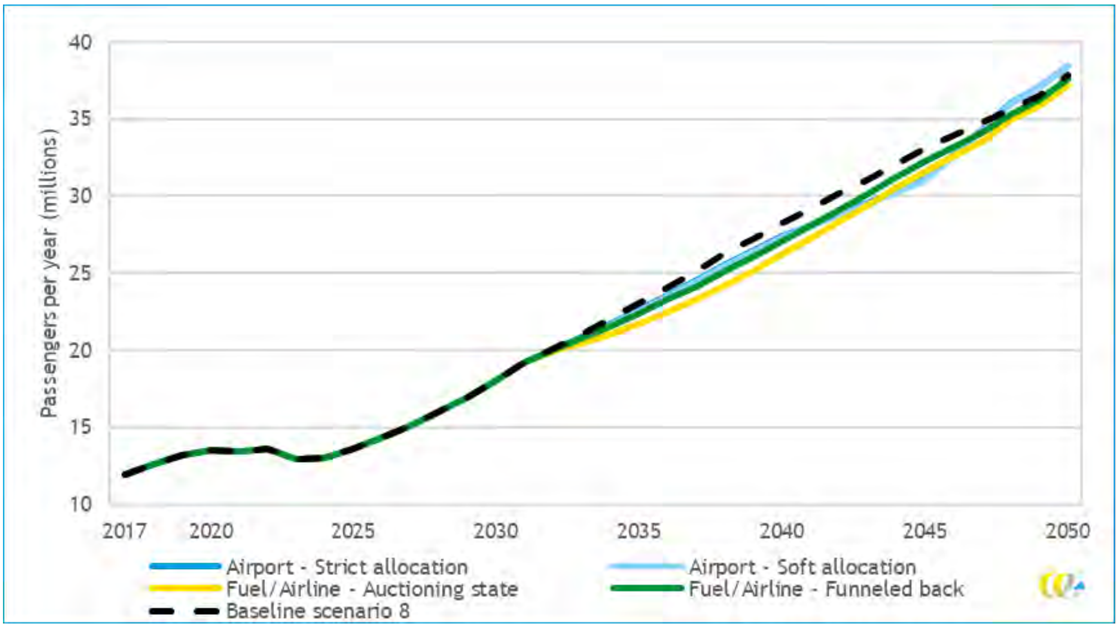


Figure 11 shows the impacts on intercontinental OD passengers. The effects of the CO_2 ceiling options are rather small and overall, quite similar. The Fuel supplier and Airline options have a slightly larger decrease in passengers. This is because ofthe larger ticket price increases on long intercontinental flights, as already explained in the previous paragraph. What we do not see, is that there also is a shift within the intercontinental segment.

An additional effect, not depicted in the figure, is a shift in passenger demand from far intercontinental destinations (such as South America) to more nearby intercontinental destinations (like North Africa). This decrease of the average flight distance in the intercontinental segment leads to significant CO_2 emission reductions.

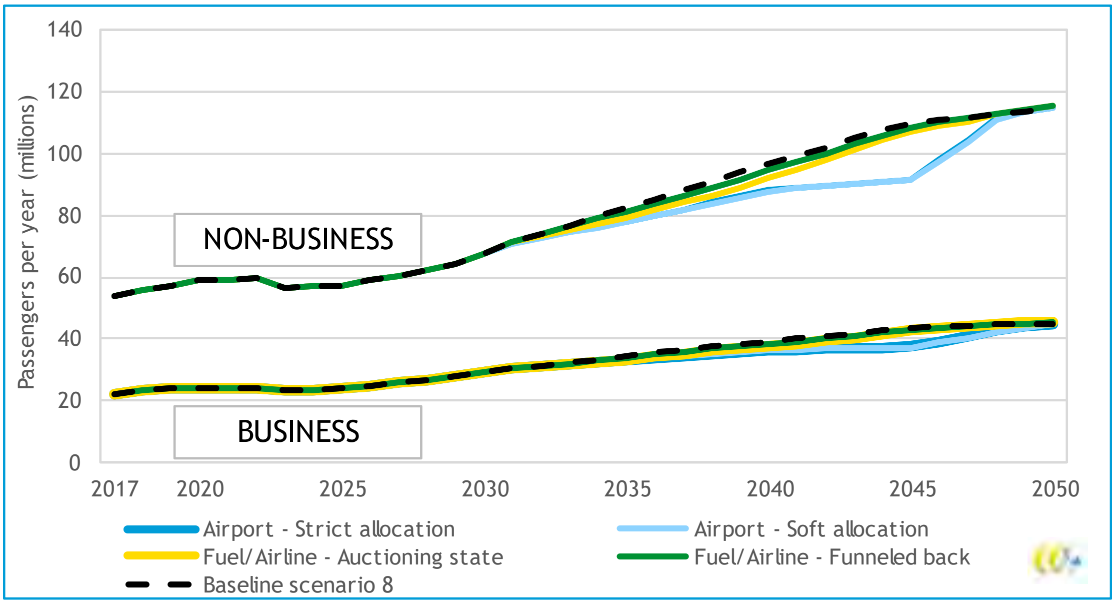
[9] Note, that there is a relatively large uncertainty in how the funneling back of auctioning revenues would work out in practice. In this study it is assumed that this will lead to the same absolute reduction in ticket prices for all segments. However, alternative responses of airlines are also imaginable, which would result in different impacts on individual market segments.

Figure 11 - Development of the number of intercontinental OD passengers at Dutch airports



The total number of passengers can also be split by travel purpose into business and non-business passengers (leisure). This is depicted in Figure 12. The relative decrease for both business as non-business passengers is about equal in the Airport options. However, since the non-business passenger category is larger, it contributes more to the decrease of the total passenger demand under the CO_2 ceiling. In the Fuel supplier and Airline options, the reductions are small, as already described for the total number of passengers.

Figure 12 - Development of the number of business and non-business passengers at Dutch airports



3.3.3 Evasion

In this section we discuss evasion effects and distinguish two types:

1. Passengers who in the baseline would make a flight with origin or destination at a Dutch airport, but now shift to an airport in a surrounding country or to land transport.[10]
2. Passengers who in the baseline would make a transfer stop at a Dutch airport (Schiphol), but now transfer at a foreign airport or choose a direct connection.

For the first type of evasion, we compared the decrease of OD passengers at Dutch airports to the change of OD passengers at foreign airports (adjusted route choice) and the change in number of passengers that travel by car and train to their destination (adjusted mode choice). Adjusted mode choice is only considered for passengers travelling to destinations within Europe. For intercontinental destinations, air travel is the only feasible option for the majority of passengers[11]. Therefore, we discuss evasion separately for European and ICA passengers.

The 2040-results for European OD passengers are shown in Figure 13. For the Airport options, a significant share (41 to 43%) of the 4 million passengers who would no longer use Dutch airports are now switching to a foreign airport. A smaller share switches to land transport (25 to 35%) and the other 24 to 33% chose to travel less.

For the Fuel supplier and Airline options the behaviour is opposite. For both the auctioning state as the funnelled back options, there is an increase in the number of OD passengers with European destinations at Dutch airports. This is due to the shift from long flights to short flights, described in the previous section. These passengers would have travelled via a foreign airport, by land transport or not at all in the baseline.

In the option where auctioning income is funnelled back, the increase in the number of OD passenger using Dutch airports is largest. This is caused by the funnelling back of the auctioning revenues, which creates extra demand for passengers using relatively cheap European routes. The increase in passengers is mainly driven by passengers who would have used foreign airports (36%) and by people who would not have travelled at all in the baseline (40%). Note, the percentages mentioned here are shares of the reduction on European OD passengers using Dutch airports. Compared to the share of the total number of European OD passengers in baseline scenario 8, there is -1.8 to 2.4% evasion to foreign airports.

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10 The AEOLUS model does not consider capacity restrictions at foreign airports. Therefore, the calculated effects represent the maximum potential evasion. If the airports abroad cannot accommodate the demand evasion effects are reduced.

11 In AEOLUS land transport is only considered for destinations within Europe. Also, passengers could choose to fly to another destination, this is however not modelled in AEOLUS. For more information on AEOLUS see (Significance, 2020).

Figure 13 - Impacts on OD passengers with European destinations to and from Dutch airports and foreign airports; impacts on land transport and non-travellers in 2040

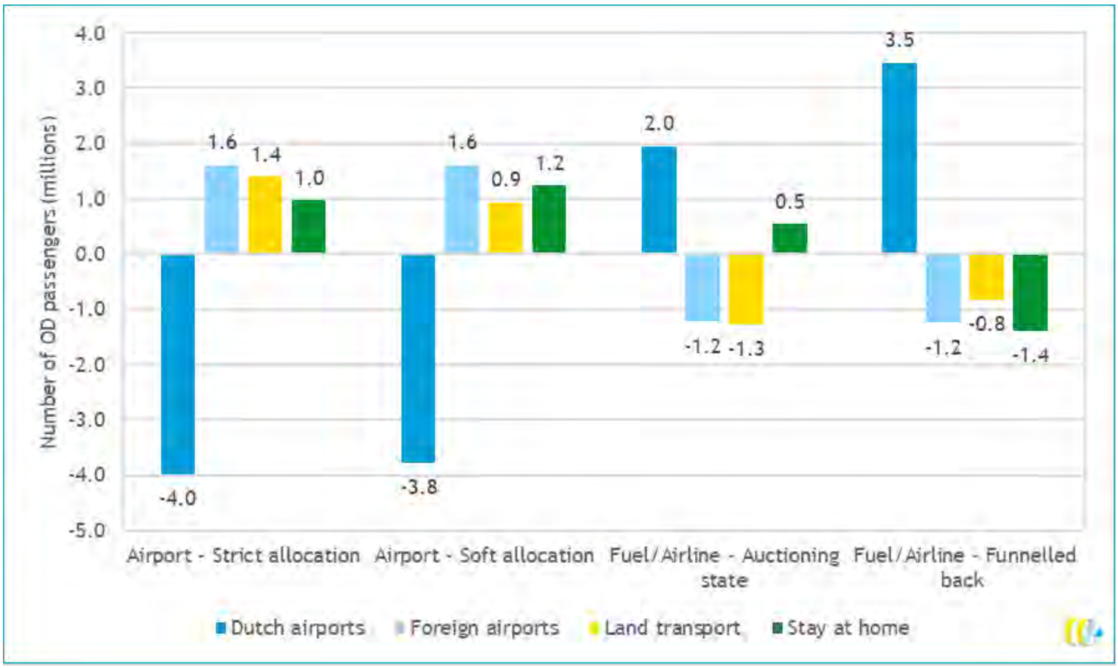


Figure 14 shows the results for intercontinental OD passengers. Here, all options show the same trend, namely a decrease in intercontinental OD passengers via Dutch airports: these passengers mostly choose to go through foreign airports (45 to 87%) or reduce to travel (13 to 56%). Land transport is not an option for intercontinental travel. Compared to the share of the total number of intercontinental OD passengers in baseline scenario 8, about 2.5 to 3.7% of the passengers evade to foreign airports.

Aggregation of the evasion effects of OD passengers with European and ICA destinations. In the Airport options European and intercontinental passengers show similar behaviour. The effects add up and result in a strong drop in OD passengers at Dutch airports. Of those who adapt their journey, about 50% travel from a foreign airport, 20 to 30% travel over land and the remaining 20 to 30% travel less. In the Fuel supplier and Airline - auctioning state options the overall effect of passengers at Dutch airports is almost zero since the effects of the European and ICA segments cancel. However, there are less people using land transport and more reducing travelling. In the Fuel supplier and Airline - funnelled back option the European OD effects are larger than the intercontinental OD effects. Therefore, there is a net increase in Dutch OD passengers. In the baseline they would have travelled via a foreign airport, by land or would not travel at all. Compared to the share of the total number of OD passengers in baseline scenario 8, there is -0.3 to 2.5% evasion to foreign airports.

Figure 14 - Impacts on intercontinental OD passengers to and from Dutch airports and foreign airports; impacts on land transport and non-travellers in 2040

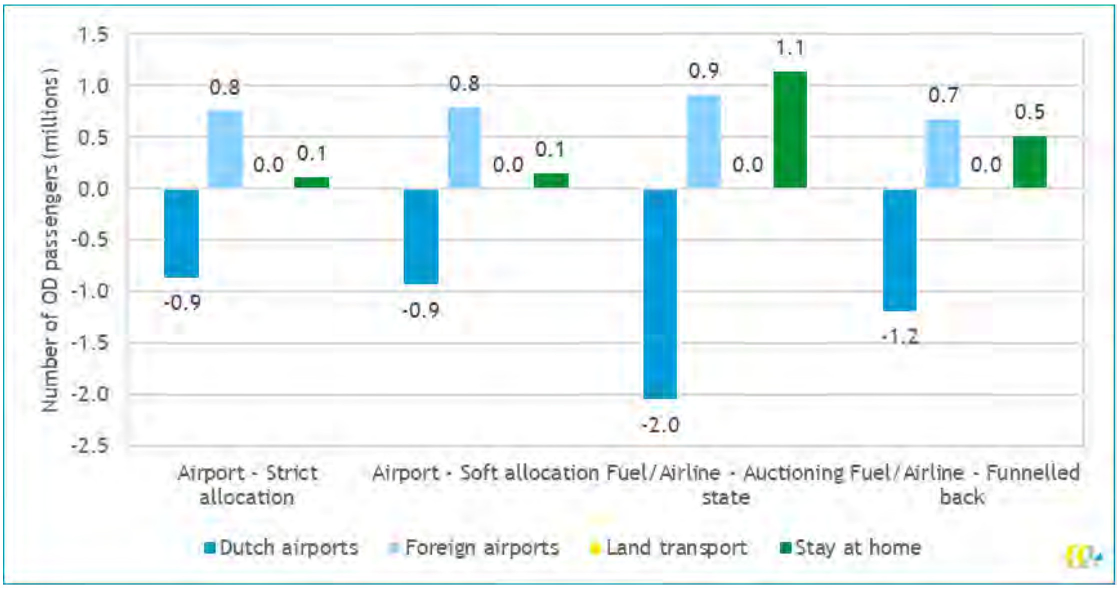
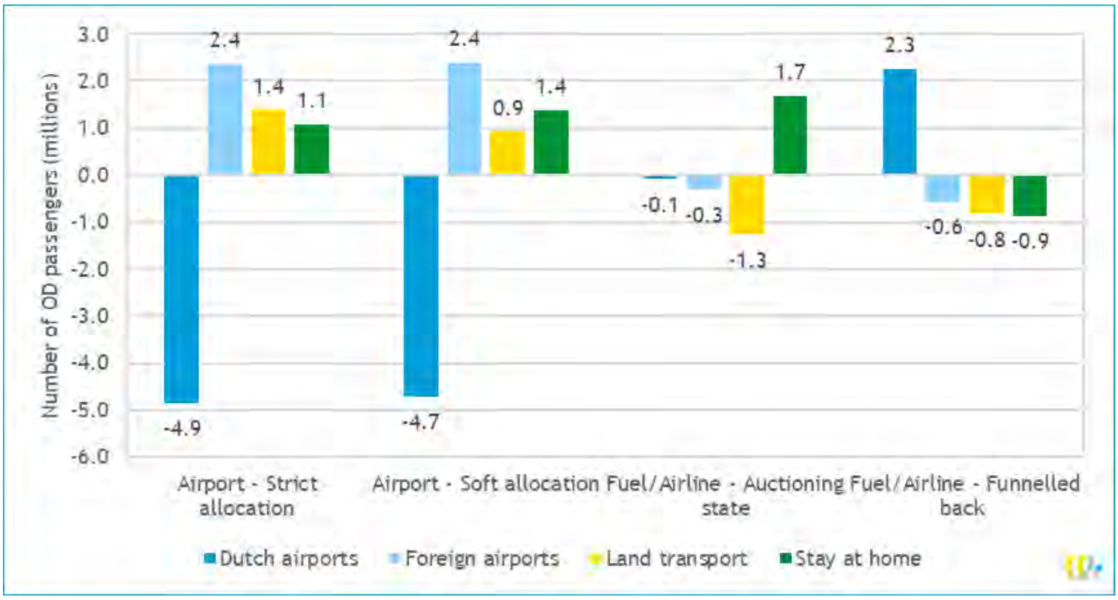
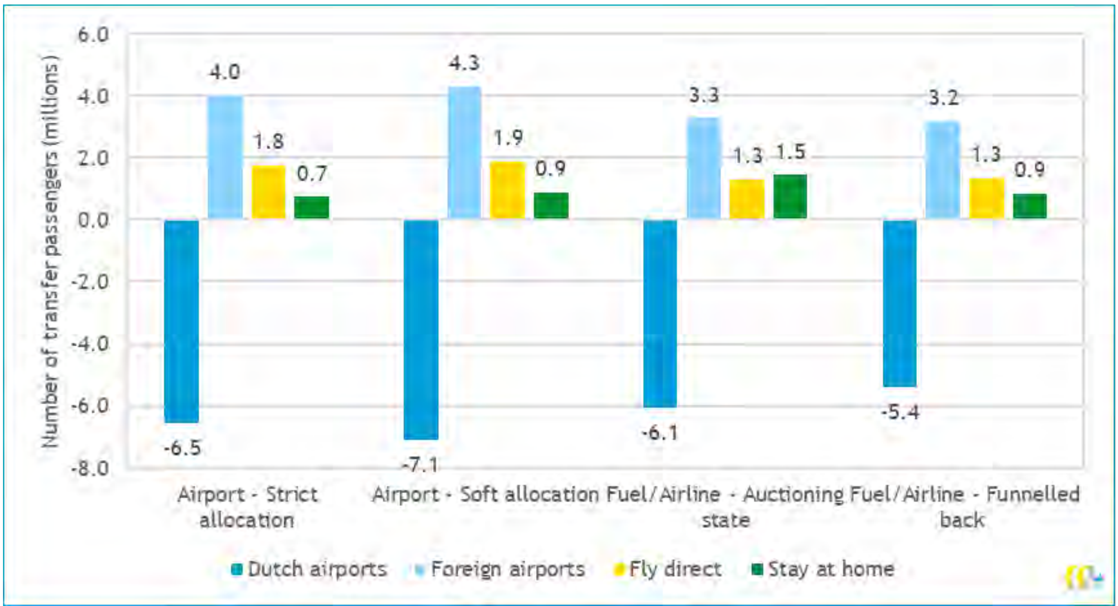


Figure 15 - Impacts on total OD passengers to and from Dutch airports and foreign airports; impacts on land transport and non-travellers in 2040



For transfer passengers something quite different happens. The decrease of transfers at Schiphol leads to more transfers at foreign hubs, more passengers choosing direct flights (skipping the transfer stop completely) and a reduction of travel. The results for 2040 are displayed in Figure 16. The number of transfer passengers decreases in all options and result in similar evasion patterns. About 60% of the transfer passengers will use a foreign hub for their transfer stop and 25% will take a direct flight to their destination if the CO_2 ceiling is restrictive. The remaining 15% of the passengers travel less. Compared to the share of the total number of transfer passengers in baseline scenario 8, there is about 8.1 to 10.8% evasion to foreign hubs.

Figure 16 - Impacts on transfer passengers through Dutch hubs and foreign hubs; impacts on direct flights and non-travellers in 2040



3.4 Impacts on flights

3.4.1 Introduction

In this section we discuss the impact of the different options of the CO_2 ceiling on the number of flights for baseline scenario 8. This is the scenario with the highest demand and the largest effects of the CO_2 ceiling. The effects in scenario 6 are comparable, those in scenarios 5 and 7 are much smaller and occur only between 2042 and 2047. In baseline scenarios 1 to 4, the CO_2 ceiling is not restrictive and does not affect the number of flights.

Table 8 displays the number of flights per airport in baseline scenario 8. The number of flights grows over time for all airports, except for Schiphol between 2017 and 2030. This is caused by the change in capacity restrictions at Schiphol. In 2017 the number of flights was close to the previous capacity limit of 500,000 flights. In this baseline scenario the announced capacity reduction to 440,000 flights applies from 2025 onwards and is relaxed after 2029, allowing the airport to grow to 630,000 aircraft movements by 2050.

Table 8 - Development of the number of flights at Dutch airports in baseline scenario 8 (without CO_2 ceiling, thousands of flights per year)

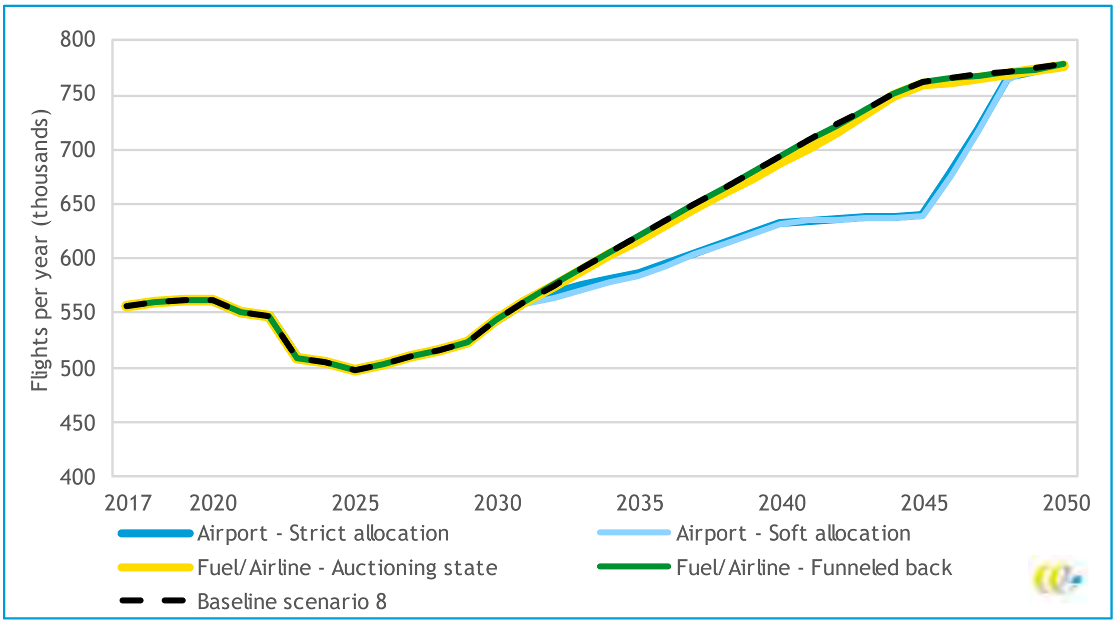
Airport	2017	2030	2040	2050
Total	556	543	694	779
Amsterdam	497	452	573	630
Lelystad	0	25	35	45
Eindhoven	35	36	48	55
Rotterdam	16	19	25	33
Maastricht	4	6	6	7
Groningen	3	4	6	9

3.4.2 Results

Figure 17 displays the total number of flights at Dutch airports for baseline scenario 8 and different CO_2 ceiling options. The drop in 2023 is caused by a reduction in demand because of the announced increase of the aviation tax. The drop in 2025 is caused by the announced capacity reduction at Schiphol.

In all options, there is a strong growth in the number of flights until 2050. Looking at the effects of the different policy options, we see that the Airport options led to systematically lower numbers of flights compared to the baseline for the period when the CO_2 ceiling is restrictive - from around 2032 lasting until 2048.[12] After this period the number of flights almost recovers to baseline. The Fuel supplier and Airline options have almost no effect on the total number of flights. These impacts are very similar to the development of the number of passengers. For a discussion of the difference, we therefore refer to Section 3.3.

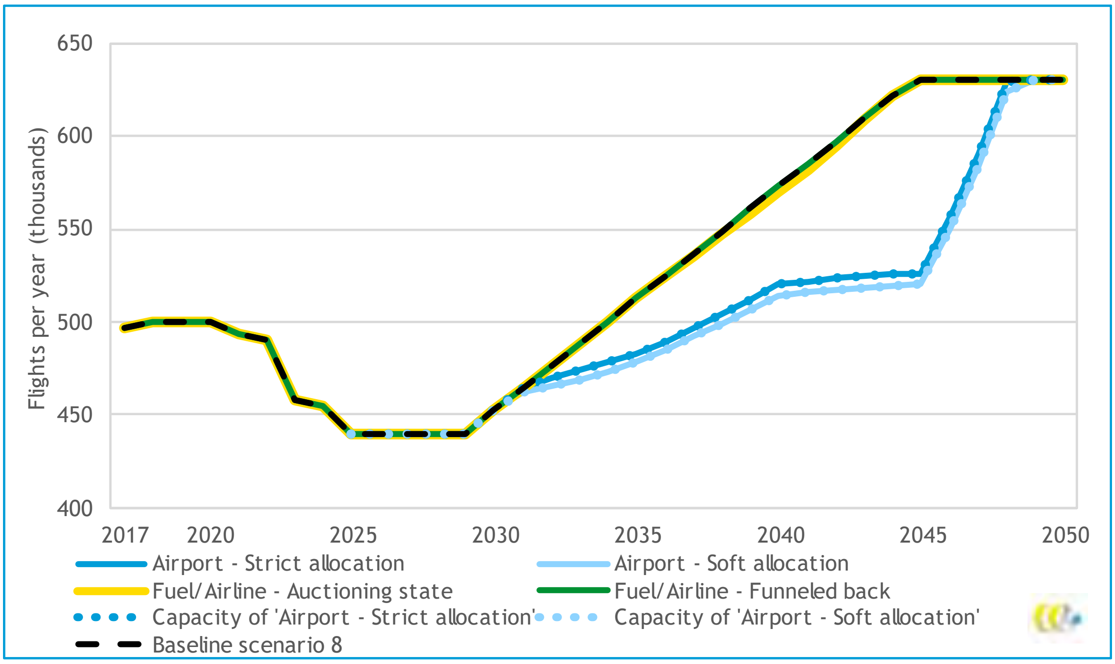
Figure 17 - Total number of flights at Dutch airports



12 The 'bend' in the results of the Airport options around 2045 results from the ReFuelEU Aviation proposal's blending requirements in combination with the linear decreasing CO_2 ceiling. Up to 2040 the SAF blending requirements increase steadily to 32%, while in 2045 there is a relatively smaller increase up to 38%, after which the requirement jumps to 63% in 2050.

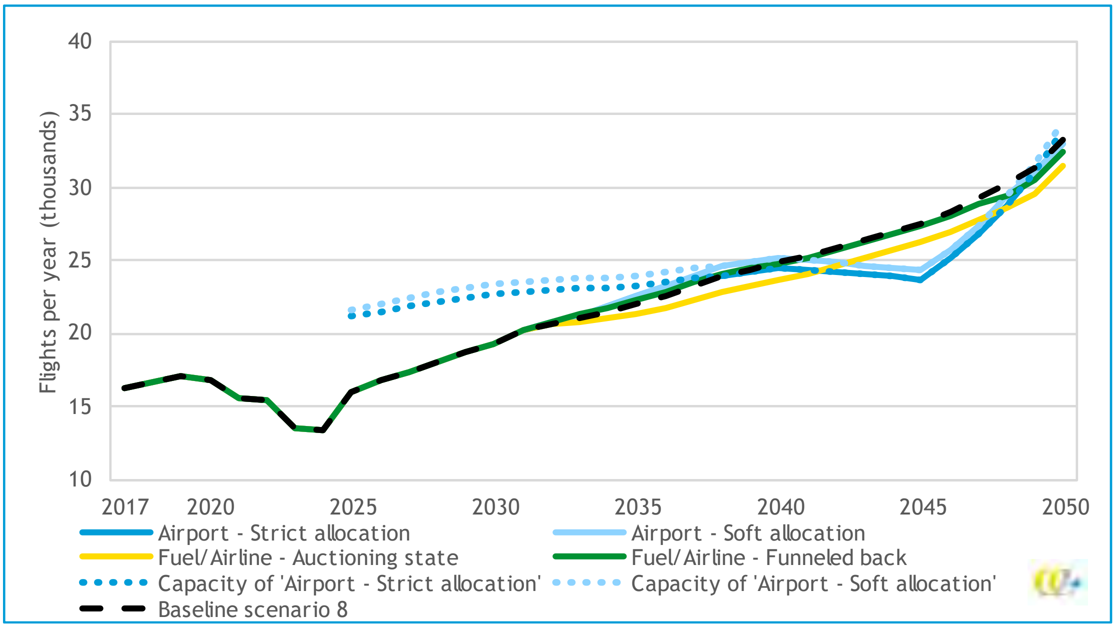
In Figure 18 the number of flights at Schiphol airport is displayed for the different options. Also, the capacity for Schiphol following from the CO_2 ceiling Airport options is plotted with dotted lines.[13] Around 2032, when the number of flights from the Airport - options (blue lines) start to vary from the other options, the Airport capacity of Schiphol is instantly reached (the solid blue lines overlap with the blue dotted lines). For some regional airports, see Figure 19 for Rotterdam The Hague airport as an example, it takes longer (until at least 2040) before the Airport capacity is reached. This unused capacity makes the Airport options slightly more restrictive in practice (in 2035 for example 0.4 to 1.3% more CO_2 is saved than in the other options). This effect occurs for the airports of Rotterdam, Maastricht and Groningen. Note that this effect is significantly smaller than in the CO_2 ceiling options in the reference baseline scenario of the main impact assessment, where 22 to 35% more CO_2 was saved in the Airport options. Here also Eindhoven airport was affected. With Eindhoven being the second largest airport in the Netherlands, the effect was larger there.

Figure 18 - Total number of flights to and from Schiphol airport



13 We assume an introduction of the CO_2 ceiling in 2025, therefore the CO_2 ceiling capacity lines start at 2025.

Figure 19 - Total number of flights at Rotterdam The Hague airport



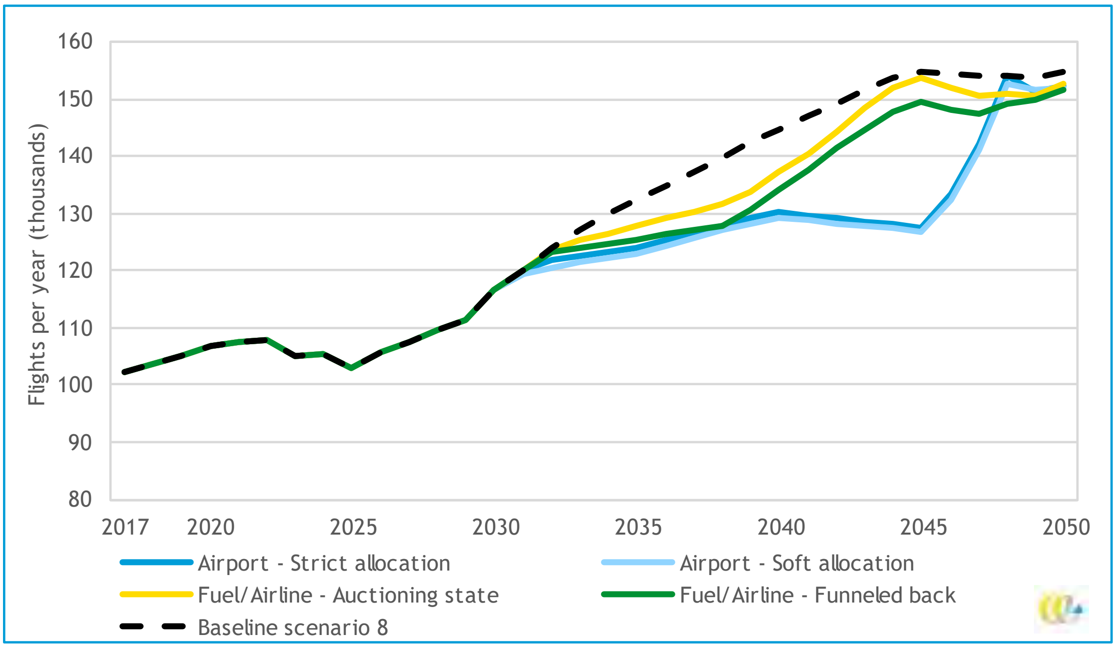
The effect from all the different sub-options of the CO_2 ceiling on the number of flights in 2040 compared to baseline scenario 8 is shown in Table 9. We only show the effects in 2040 because the CO_2 ceiling is not restrictive in 2030 and 2050, therefore there are no effects in these future years. The impacts on flights are very similar to the impacts on passengers. Since for the sub-option Airport - Soft allocation the allocation of CO_2 budget is corrected for noise permits, this option has slightly more flights at regional airports than in the strict allocation sub-option. The table also shows that for Rotterdam airport the number of flights increases in the Airport options. As shown in Figure 18 there is more demand than capacity at Schiphol airport and spare capacity at Rotterdam airport. Hence, flights will shift from Schiphol to Rotterdam airport. In the other options, the number of flights at regional airports sometimes also increases.

Table 9 - Development of the number of flights in 2040 at Dutch airports compared to the baseline (thousands per year). The ranges in brackets indicate the expected fluctuations of travel demand, which are not modelled in AEOLUS

Airport	Airport - Strict allocation (3-year cycle)	Airport - Strict allocation (1-year cycle)	Airport - Soft allocation (3-year cycle)	Fuel supplier - Auctioning state	Fuel supplier - Auctioning funnelled back	Fuel supplier - no stability mechanism	Airline - Auctioning state	Airline - Funnelled back
Total	-50.5 (-82.1 to -50.5)	-50.5 (-84.9 to -50.5)	-52.9 (-84.4 to -52.9)	-5.7	0.0	-5.7 (-7.8 to -3.5)	-5.7	0.0
Amsterdam	-46.1 (-72 to -46.1)	-46.1 (-74.4 to -46.1)	-50.8 (-76.5 to -50.8)	-2.6	0.0	-2.6 (-2.6 to -2.6)	-2.6	0.0
Lelystad	-2.9 (-4.5 to -2.9)	-2.9 (-4.6 to -2.9)	-3.2 (-4.8 to -3.2)	-1.7	-0.1	-1.7 (-2.3 to -1.1)	-1.7	-0.1
Eindhoven	-1.2 (-3.5 to -1.2)	-1.2 (-3.8 to -1.2)	0 (-2.4 to 0)	0.0	0.0	0 (-0.9 to 0)	0.0	0.0
Rotterdam	0.5 (-0.8 to 0.5)	0.5 (-0.9 to 0.5)	0.8 (-0.5 to 0.8)	-1.1	-0.1	-1.1 (-1.6 to -0.7)	-1.1	-0.1
Maastricht	0 (-0.3 to 0)	0 (-0.3 to 0)	0 (-0.3 to 0)	-0.1	0.0	-0.1 (-0.2 to 0)	-0.1	0.0
Groningen	-0.7 (-1 to -0.7)	-0.7 (-1 to -0.7)	0.2 (-0.1 to 0.2)	-0.1	0.2	-0.1 (-0.2 to 0)	-0.1	0.2

Figure 20 shows the total number of intercontinental flights, these are long-distance flights with high CO_2 emissions per passenger. Between 2032 and 2040, the impact of all options is very similar. The CO_2 ceiling leads to a reduction of 7,000 to 14,000 flights per year. However, Section 3.3.2 showed that in the Fuel supplier and Airline options there is a shift from longer to shorter flights. What this figure does not show is that this shift is also within the segment of intercontinental flights. So longer intercontinental flights shift to shorter intercontinental flights. This saves significant amounts of CO_2, allowing more flights to be possible with the same CO_2 budget. In the eight years after 2040, the Airport option is more restrictive than the other two. This is because after 2040 it becomes economically viable for airlines to blend more SAF in the Fuel supplier and Airline options. They will then use this possibility to schedule additional flights. In the Airport option, it is assumed that airlines will not blend additional SAF.[14] After 2048 the ceiling is not restrictive anymore.

Figure 20 - Development of the number of intercontinental flights at Dutch airports[15]



For flights to European destinations the situation is very different. Figure 21 shows the total number of European flights at Dutch airports. When comparing the options, it becomes clear that there is only a reduction of flights within Europe in the Airport options. There even is a small increase in the number of European flights in the Fuel supplier and Airline options. This is due to the shift of long to short flights in these options. There is no such shift in the Airport options. For more explanation about this shift, see Section 3.3.2 about the effects on intercontinental and European passengers. After 2040, in the Fuel supplier and Airline options, airlines will use the possibility to blend more SAF.

14 See the discussion in Section 3.3.2 for a more elaborate explanation of this assumption.

15 The 'bend' in the results of the Airport options around 2045 results from the ReFuelEU Aviation proposal's blending requirements in combination with the linear decreasing CO_2 ceiling. Up to 2040 the SAF blending requirements increase steadily to 32%, while in 2045 there is a relatively smaller increase up to 38%, after which the requirement jumps to 63% in 2050.

Comparing the impact of the Airport option, we find that the number of intercontinental flights decreases slightly more (17% in 2045), compared to 15% for European flights. However, note that aircraft on intercontinental flights carry on average significantly more passengers than on European flights. Therefore, as we saw in Section 3.3.2, the Airport options reduce the passenger volume on short-distance flights more than on intercontinental flights.

Figure 21 - Development of the number of flights to European destinations at Dutch airports

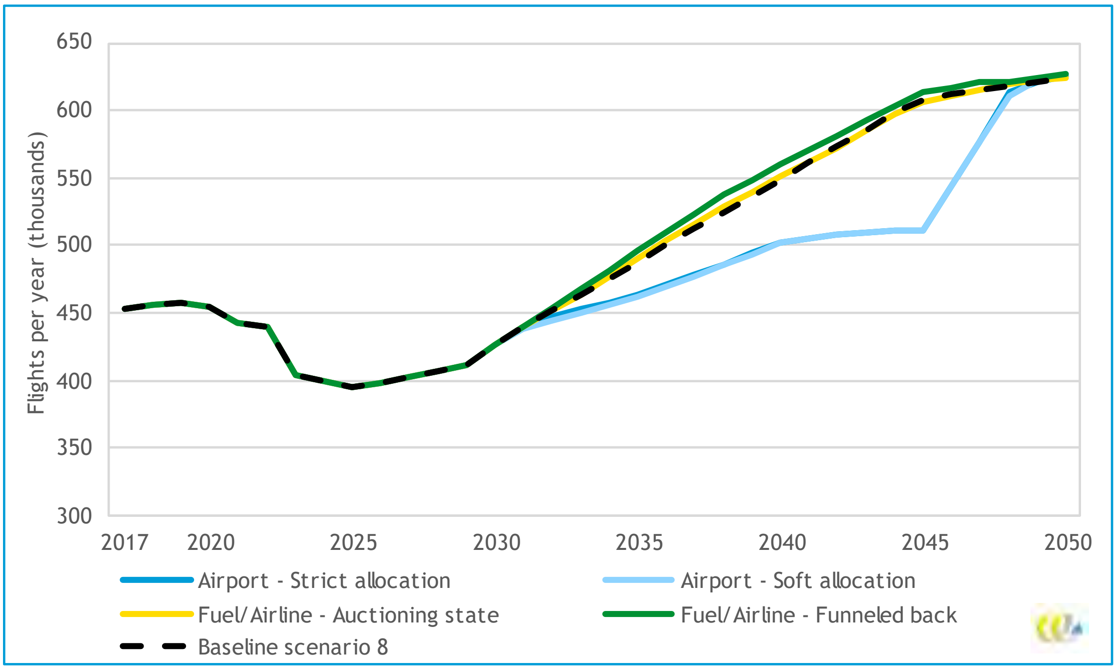


Figure 22 shows the development of passenger flights and Figure 23 shows the development of full-freight flights. Since the vast majority of flights are passenger flights (96% in 2019), the results for passenger flights are almost identical to the development of the total number of flights.

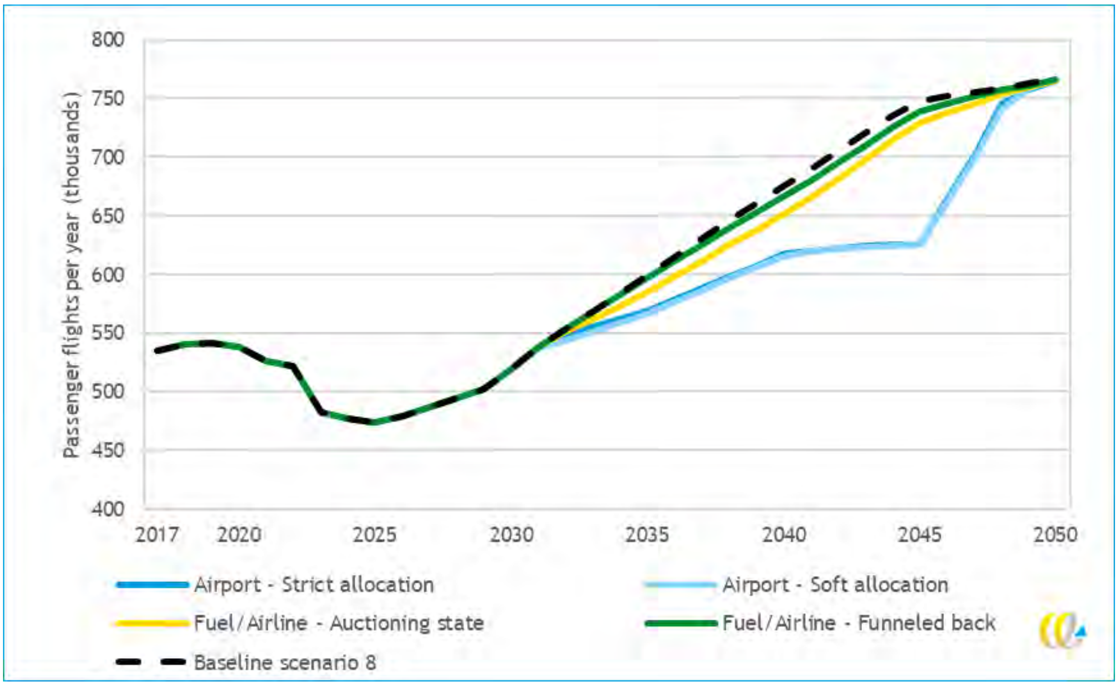
The modelled results show that the number of full-freight flights is significantly affected by the CO_2 ceiling. However, these results must be interpreted with care. In the AEOLUS model, freight modelling is very simplified and thus less accurate than the estimates for passengers. With the current model version, it was not possible to model the effects on freight rates from the Fit for 55 proposals and the CO_2 ceiling[16]. This limits the conclusions that can be made based on these quantitative results. Moreover, the share of full-freighter flights is very small (about 2 to 4%) compared to passenger flights.

In relative terms the number of full-freighters increases significantly between 2032 and 2045, however this number is small in absolute terms considering the total number of flights from Dutch airports. During previous capacity constraint periods (2017-2019) crowding out of full-freighter flights was observed as a result of lower on time performance of full-freighter aircraft and consequent loss of grandfather rights. A capacity surplus available at

16 The main effect that affects the number of Full-freighters are changes in the scarcity costs in AEOLUS. These shadow costs reduce demand in case demand is higher than the available capacity at airports.

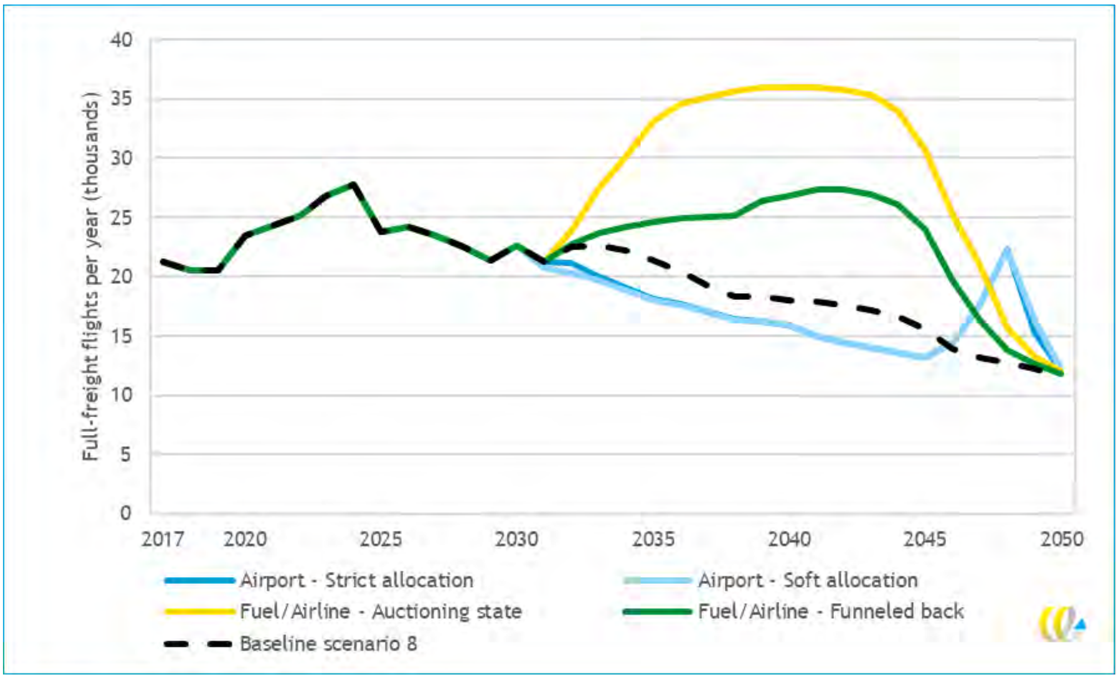
Schiphol and Maastricht airport resulting from COVID recovery, may allow for increased numbers of full-freighter flights, however, this is highly uncertain.

Figure 22 - Development of the number of passenger flights at Dutch airports



Note: This figure starts at 400,000 flights, while the figure below starts at 0 flights.

Figure 23 - Development of the number of full-freighter flights at Dutch airports



3.5 Impacts on the network and connectivity

Connectivity describes how the Netherlands is connected to the rest of the world by passenger flights. Two important aspects related to connectivity are the number of destinations and the frequency with which these destinations are visited.
In line with SEO, (2021) we distinguish three types of connectivity:

1. Direct connectivity is the direct number of flights to a certain destination per time interval.
2. Indirect connectivity describes the indirect connections to a certain destination with a layover at another hub per time interval.
3. Hub connectivity describes all indirect connections from other destinations with a layover at Schiphol airport to a certain destination per time interval.

Indirect flights (indirect- and hub connectivity) are less attractive compared to a direct flight (or other indirect flights). How much more unattractive they are, depends on the delays from layovers and detour factors. Therefore, it is common to express the different types of connectivity in connectivity units (CNUs) which range from 0 to 1, depending on the amount of delay.

In our analysis we only included direct connectivity, due to the available data.
The following textbox clarifies why, what could and could not be quantified.

Textbox 2 - Limitations in the discussion of impacts on connectivity

There are several limitations in the AEOLUS model which limit our possibilities to calculate the different types of connectivity:

1. AEOLUS consists of a limited number of destination zone (seventeen within Europe and twelve intercontinental). Individual airports within these zones are not specified. Therefore, the AEOLUS model is not suitable to calculate changes in the number of destinations that can be reached and the frequency with which individual airports are visited.
2. AEOLUS does not model the profitability of individual routes for specific airlines. Therefore, it is impossible to model the strategic reactions from the airlines which affect the connectivity.
3. It was not possible to determine CNUs for indirect- and hub connectivity, since this requires detailed information about the detour factors and layover times that is not modelled with sufficient detail in AEOLUS.

With these limitations in mind, we were able to quantify only a limited part of the effects on connectivity: the direct connectivity aggregated per geographical zone. With this aggregation still meaningful insights about the effects on direct connectivity can be obtained. For the impacts on indirect connectivity and hub connectivity, that are not quantified, we did include a qualitative discussion based on the available information.

In the remainder of this section, we discuss the impact of the different options of the CO_2 ceiling on the connectivity of Dutch airports in scenario 8. This is the scenario with the highest demand and the largest effects of the CO_2 ceiling. The effects in scenario 6 are comparable, those in scenarios 5 and 7 are much smaller and occur only between 2042 and 2047. In baseline scenarios 1 to 4, the CO_2 ceiling is not restrictive and does not affect the connectivity.

3.5.1 Direct connectivity

Since individual airports are not modelled in AEOLUS, it was not possible to determine the impacts of the CO_2 ceiling on the connectivity of Dutch airports with particular foreign airports. However, the effects on the total number of flights per year per geographical zone are modelled. This can be seen as an aggregated indicator of the effects on direct connectivity.

There are no effects on the direct connectivity in 2030 and 2050, since in these years the ceiling is not restrictive. The effects of the different options for the CO_2 ceiling in 2040 in baseline scenario 8 are shown in Table 10. The decrease in direct connectivity is largest in the ceiling per airport sub-options and lowest in the Fuel supplier/Airline sub-options, where the revenues are funnelled back. An explanation of these differences is provided in Section 3.3. The extra information that can be seen from this table is that there are significant differences between geographical regions. On average, the decrease in intercontinental aviation is larger compared to EU aviation. In the Fuel supplier/Airline sub-options with funnelling back of income, an increase in direct connectivity to EU destinations is even observed.

We also analysed the effects on the different alliances in 2040 (see Table 11). For all options, the reduction of the number of flights is larger for SkyTeam than for other full-service carriers and low-cost carriers. This can be explained because SkyTeam offers a much larger share of intercontinental flights[17]. Since those flights emit most CO_2, the impact on the SkyTeam network is largest. In addition, SkyTeam has a high share of price sensitive transfer passengers, which evade relatively easy to competing hubs abroad.

It should be noted that, although there are significant effects on the connectivity in 2040 due to the restrictive CO_2 ceiling *compared to the baseline scenario*, the overall direct connectivity does not decrease compared to the current situation. Before the pandemic around 560 flights connected the Netherlands with the rest of the world. In baseline scenario 8 this number grows to 632,000 in the Airport option and 694,000 flights in the Fuel supplier and Airline options. Therefore, the effects on the connectivity should be interpreted as a reduced growth rather than a decline in the number of flights.

Table 10 - Change on the number of flights due to the CO_2 ceiling per geographical zone compared to the baseline

	2040			
	Airport - strict allocation	Airport - soft allocation soft	Fuel/airline - auctioning state	Fuel/Airline - funnelled back
Germany	-11.3%	-11.8%	3.2%	4.8%
France	-9.6%	-10.0%	-0.5%	0.4%
UK	-6.2%	-5.9%	-0.8%	0.8%
Belgium/Luxemburg	-1.4%	-1.4%	-3.1%	-2.2%
Scandinavia	-11.0%	-10.4%	-3.2%	-1.6%
Switzerland/Austria	-11.0%	-11.4%	6.0%	7.6%
Spain	-7.2%	-7.5%	1.3%	3.9%

[17] SkyTeam could adjust their business plan to offer more intra-EU flights. However, these behavioural responses are very difficult to predict and model. Furthermore, it can be expected that such a change of the business activities will be costly. Therefore, we do conclude that other full-service carriers and low-cost carriers would probably gain some market share at the cost of SkyTeam.

	2040			
	Airport - strict allocation	Airport - soft allocation soft	Fuel/airline - auctioning state	Fuel/Airline - funnelled back
Portugal	-5.7%	-6.4%	-2.9%	0.2%
Italy	-9.8%	-10.4%	-3.5%	-0.9%
Greece	-8.4%	-8.6%	0.6%	4.0%
South-East Europe	-8.7%	-9.5%	2.2%	5.5%
Eastern Europe	-10.5%	-10.4%	0.7%	2.7%
Central America	-8.5%	-9.2%	-14.5%	-12.8%
South America	-9.3%	-10.0%	-12.1%	-10.8%
Africa	-11.7%	-12.2%	-21.9%	-16.9%
Asia	-10.4%	-11.3%	-18.2%	-15.4%
Middle East	-3.4%	-3.6%	-11.4%	-8.1%
USA	-10.5%	-11.4%	-17.2%	-14.2%
Canada	-8.2%	-8.9%	-19.3%	-16.1%
EU total	-8.4%	-8.5%	-0.1%	1.9%
Intercontinental total	-9.4%	-10.2%	-17.1%	-14.0%
Total	-8.6%	-8.8%	-3.5%	-1.3%

Table 11 - Change in number of flights for the different alliances compared to the baseline

	Alliance	Airport - strict allocation	Airport - soft allocation soft	Fuel/airline - auctioning state	Fuel/Airline - funnelled back
2040	SkyTeam	-15.4%	-16.8%	-11.8%	-9.8%
	Other FSC	-1.9%	-1.4%	6.7%	8.4%
	Low-cost	-3.7%	-2.8%	1.1%	3.9%

3.5.2 Number of destinations and frequency

It is neither possible to model changes in the number of destinations nor the changes in frequency to individual destinations from the Dutch airports with the AEOLUS model. Therefore, instead of a quantitative analysis a quantitative estimation is performed.

Routes with high frequencies are often characterised by high competition and low margins. In case of a restricting ceiling on the number of aircraft movements, it is likely that airlines adjust marginally profitable routes first. This will probably be achieved by decreasing the frequencies to destinations (maybe partly compensated by the utilisation of larger aircraft). If this is not enough, marginally profitable routes might be closed resulting in a decrease of non-stop destinations from the Netherlands.

A recent study quantified the effects of a reduction of the yearly number of flights at Schiphol to 460,000 (PWC Strategy& et al., 2022). This reduction is roughly comparable to the reduction which can be seen in the ceiling per Airport option (Figure 18). The report estimated the reduction of the destinations with more than ten flights per year to be in the range of 0 to 11%, depending on the market reaction.

In the Fuel supplier and Airline options the decrease in direct connectivity is much smaller compared to the ceiling per Airport option (see Table 10). Therefore, we do not expect a significant drop in the number of destinations. However, especially in the sub-options where the incomes are funnelled back, we do observe a significant difference in the effects on intercontinental and European destinations: the number of flights to EU airports is affected much less or even grows compared to the baseline, whereas the number of intercontinental flights decreases significantly. Therefore, it is likely that the EU network is not much affected, whereas the number of international destinations might decline.

3.5.3 Indirect connectivity and hub connectivity

We were not able to quantify the effects on indirect connectivity since this not only depends on the changes in direct connectivity but also on the developments at other airports. However, in general a decrease in the number of direct connections to hub airports results in less indirect connections via these hubs. Therefore, we can conclude that the indirect connectivity will be lower in 2030 compared to the baseline in all sub-options (with the largest reductions in connectivity for the ceiling per airport sub-options).

Hub connectivity is a measure for the quality of he transfer network at Schiphol. Therefore, the hub connectivity does not directly affect the Dutch traveller.[18] However, indirectly the hub function of Schiphol does allow for an extensive network which the people flying from the Netherlands benefit from.

We were not able to quantify the effects on hub connectivity because this would require specific information about the impact of the CO_2 ceiling on flight schedules. However, based on the changes in the direct connectivity it is obvious that, due to the reductions in the number of flights to destination zones, the number of destinations and/or the frequencies to these destinations will be reduced. The first leads to less travel options for transfer passengers and the second on average to longer transfer times. Both effects reduce the hub connectivity compared to the baseline[19].

3.6 Impacts on cargo

3.6.1 Introduction

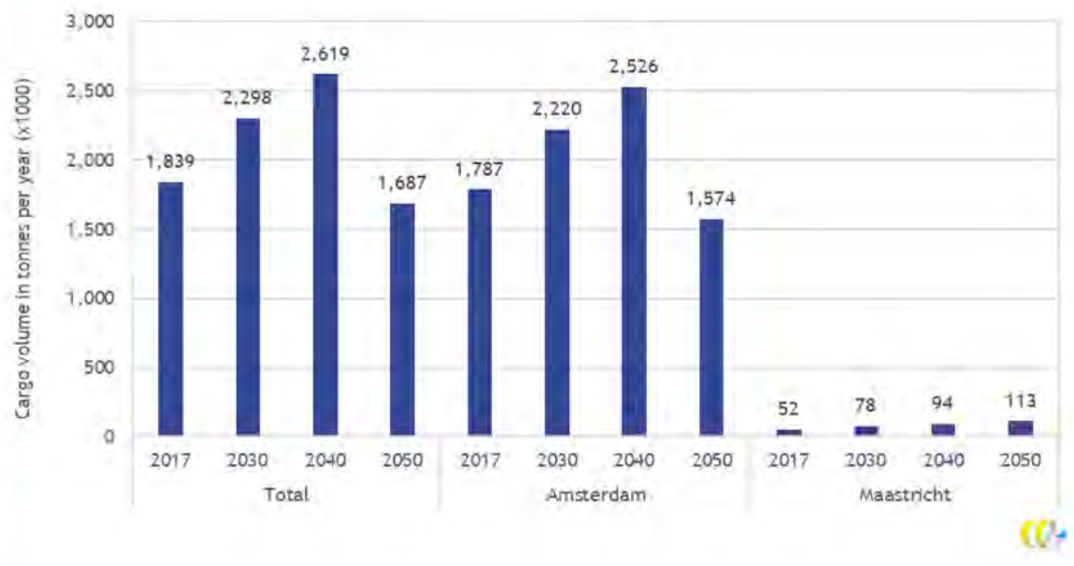
In this section we discuss the impact of the different options of the CO_2 ceiling on the cargo volume for baseline scenario 8. This is the scenario with the highest demand and the largest effects of the CO_2 ceiling. The effects in scenario 6 are comparable, those in scenarios 5 and 7 are much smaller and occur only between 2042 and 2047. In baseline scenarios 1 to 4, the CO_2 ceiling is not restrictive and does not affect the cargo volume.
For air cargo in the Netherlands only Schiphol and Maastricht airport are considered relevant, since at the other regional airports no cargo is transported. Schiphol facilitates both full-freighter airlines and passenger airlines that carry belly cargo on their passenger aircraft, whereas Maastricht focusses only on the full-freighter segment.

Figure 24 shows the volume of cargo transported in baseline scenario 8 without a CO_2 ceiling. We see a significant increase of cargo volumes, both at Schiphol and Maastricht airport, which is comparable to the development of passenger aviation.

[18] This is because travellers with a layover in the Netherlands are typically not Dutch.

[19] As an example, consider flights between Spain and Schiphol and flights between Schiphol and Scandinavia. If the direct connectivity between both connections and Schiphol decreases, it is obvious that also the hub connectivity decreases. However, the exact decrease depends on for example the time of day of the specific flights that are removed from the schedule or the destinations that are removed.

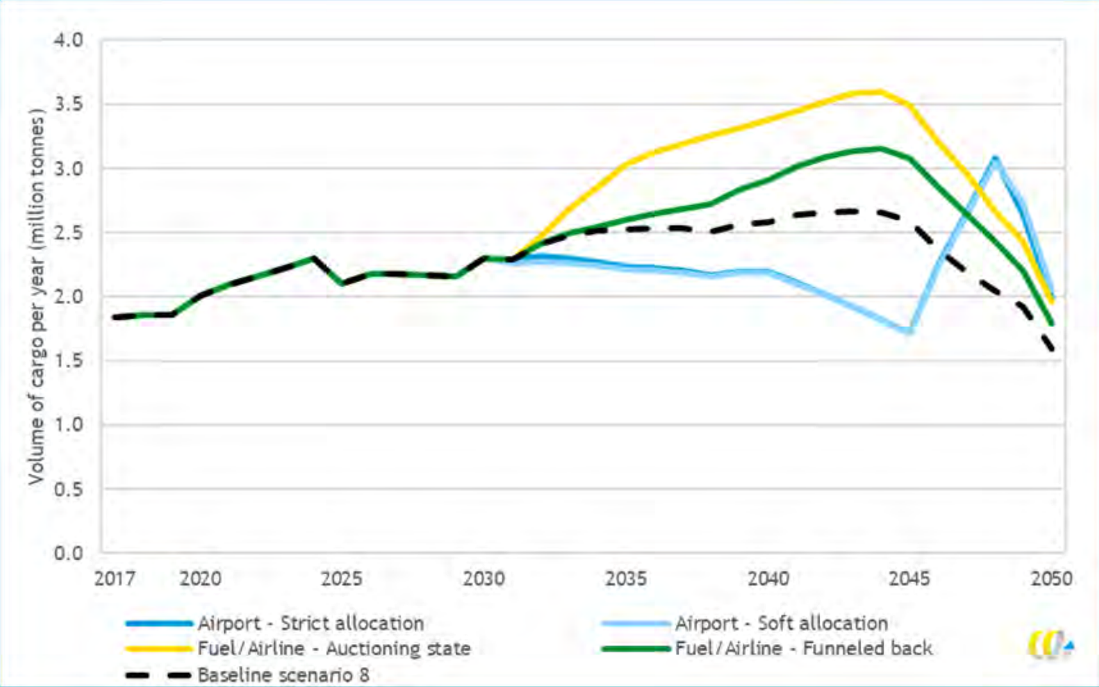
Figure 24 - **Development of cargo volume at Dutch airports without CO_2 ceiling** in baseline scenario 8 (thousand tonnes per year)



3.6.2 Results

The total volume of cargo transported at Dutch airports in scenario 8 and in the CO_2 ceiling options is indicated in Figure 25. In the period between 2025 and 2032, the CO_2 ceiling has no impact on the volume of cargo due to the new modelling assumptions on capacity restrictions. The total cargo volume is equal in the baseline scenario and in any of the variants. However, during the restrictive years, the effects can get significant depending on the option. Detailed results for the impacts on cargo volume at Schiphol and Maastricht airport are presented in Table 12. Because the ceiling in 2030 and 2050 is not restrictive, only the results for 2040 are presented.

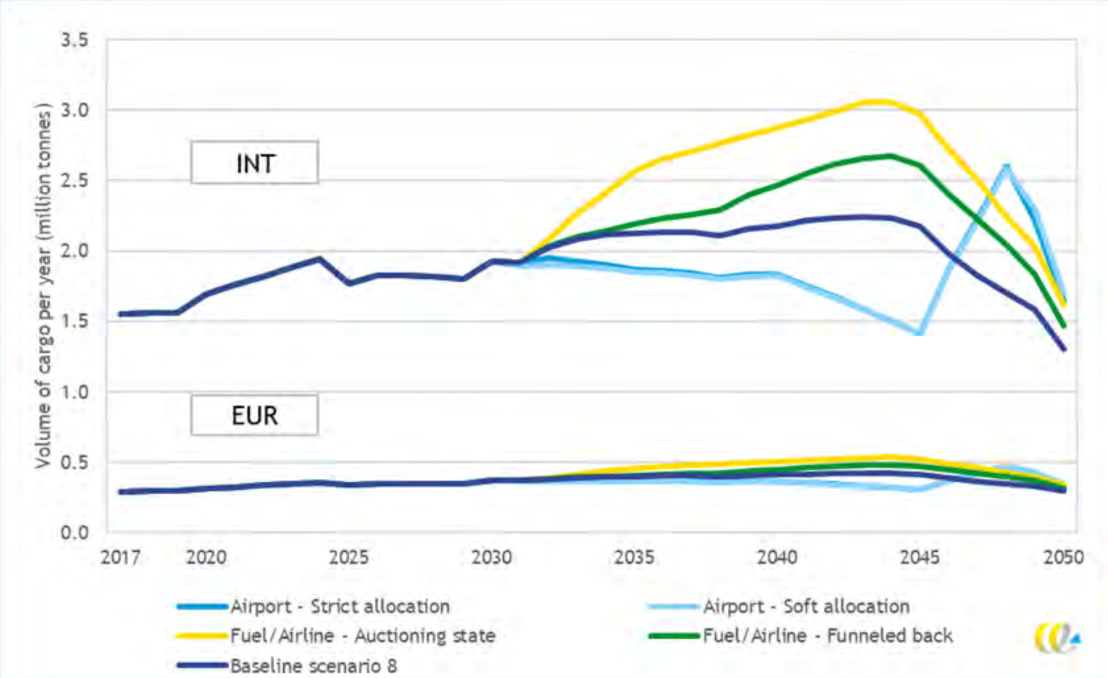
Figure 25 - Development of total volume of cargo at Dutch airports



The decrease in airport variants from 2032 onwards is caused by the restrictive CO_2 ceiling. The mechanism in the Airport options using scarcity costs has a relatively higher impact on freight than the mechanism with CO_2 costs for the Fuel supplier and Airline options.
In the fuel supplier and airline variants of the CO_2 ceiling, cargo volume gradually increases in the period first period the CO_2 ceiling is restrictive (2032 to 2045), compared to the number of full-freighter flights operated for which a gradual decrease during that same period is shown in Figure 23. This can be explained by the fact cargo operators may use a part of the freed-up slots (by decrease of ICA passenger flights) as new capacity for full-freighters, which will lead to a growth of air cargo volume.

The main impact assessment describes the general implications of a shift in air cargo capacity on the total cargo volume at airports. These mechanisms are still valid for the analysis outlined in this section with the updated scenarios. The main statement from the implications on shifts in air cargo capacity is a decrease in full-freighter capacity and is generally expected to have a significant effect on total cargo volumes transported at an airport. See Table 12 for detailed results of the effects on cargo volume by airport.

Figure 26 - Development of EU and intercontinental cargo volume transported at Dutch airports



The effect of the CO_2 ceiling is mainly seen at air cargo transported at intercontinental routes. To a lesser extent the ceiling affects European air cargo as well. This can be explained by the fact that certain product groups mainly use air transport as mode of transport in case transported intercontinentally, whereas continental cargo is performed mainly by road trucking, which is not part of the AEOLUS model.

Table 12 - Impacts on the cargo volume at Dutch airports in 2040 (thousand tonnes per year)

CO_2 ceiling variant	Total	Amsterdam	Maastricht
Airport - Strict allocation (3-year cycle)	-386 (-494 to -386)	-386 (-489 to -386)	0 (-5 to 0)
Airport - Strict allocation (1-year cycle)	-386 (-504 to -386)	-386 (-499 to -386)	0 (-5 to 0)
Airport - Soft allocation (3-year cycle)	-397 (-504 to -397)	-397 (-500 to -397)	0 (-5 to 0)
Fuel - Auctioning state	798	798	0
Fuel - Auctioning funnelled back	329	329	0
Fuel - No stability mechanism	798 (788 to 809)	798 (798 to 798)	0 (-2 to 2)
Airline - Auctioning state	798	798	0
Airline - Funnelled back	329	329	0

3.7 Impacts on fuel consumption

3.7.1 Introduction

In this section we discuss the impact of the different options of the CO_2 ceiling on the fuel consumption for baseline scenario 8. This is the scenario with the highest demand and the largest effects of the CO_2 ceiling. The effects in scenario 6 are comparable, those in scenarios 5 and 7 are much smaller and occur only between 2042 and 2047. In baseline scenarios 1 to 4 the CO_2 ceiling is not restrictive and does not affect the fuel consumption.

Table 13 shows the consumption by type of aviation fuel in baseline scenario 8 per year. Whereas the market share of fossil kerosene was 100% in 2017, it is expected that 63% of fuel will be Sustainable Aviation Fuel (SAF) in 2050. The shares of SAF are deduced from the blending requirements in the ReFuelEU Aviation proposal (EC, 2021b) and the Renewable Energy Directive III proposal (EC, 2021a)[20].

Table 13 - Fuel consumption in reference scenario (million tonnes per year)

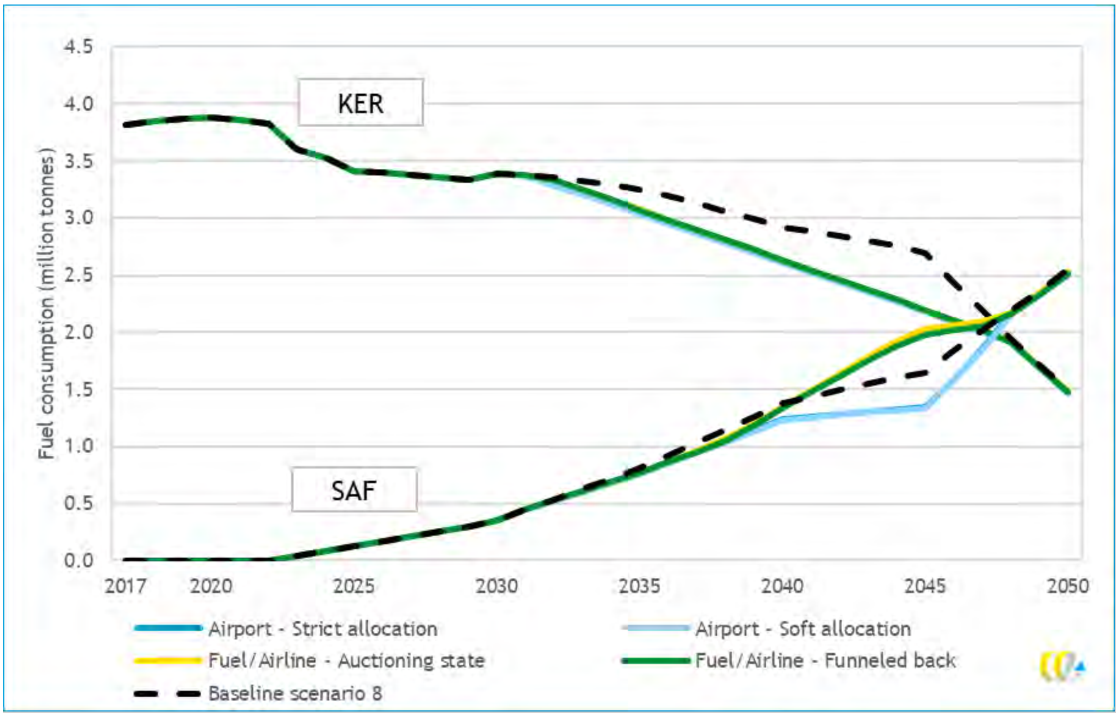
Year	Total	Kerosene	HEFA	Gas. + FT	ATJ	RFNBO
2017	3.81	3.81	0.00	0.00	0.00	0.00
2030	3.75	3.39	0.16	0.00	0.17	0.03
2040	4.29	2.92	0.20	0.42	0.41	0.34
2050	4.05	1.50	0.20	0.68	0.53	1.13

3.7.2 Results

Figure 27 shows the consumption of fossil fuel and SAF (total of all types) per year for the different CO_2 ceiling options. The consumption for fossil kerosene has a similar curve in all options. This is to be expected, since the fossil kerosene is directly linked to the CO_2 emissions (which in all cases must remain under the ceiling). The consumption for SAF is higher in the Fuel supplier and Airline options from 2040 onwards. We assume that in the Fuel supplier and Airline options there is the possibility for airlines to blend extra SAF when this is economically viable. During a restrictive CO_2 ceiling the prices of the emission rights will increase. From 2040 onwards the CO_2 costs of kerosene will make kerosene more expensive than SAF. At this point, airlines will choose to blend extra SAF, making more flights possible.

20 This concerns the 2021 version of proposals.

Figure 27 - Development of the consumption in fossil kerosene and SAF at Dutch airports



4 Environmental impacts

4.1 Introduction

This chapter presents the environmental impacts of the CO_2 ceiling for Dutch aviation. In all baseline scenarios in which the capacity of Schiphol remains at 440,000 annual flights (baseline scenarios 1, 2, 3 and 4), CO_2 emissions stay below the CO_2 ceiling during the entire period. Therefore, the CO_2 ceiling is not restrictive and does not affect the environmental impact of aviation in the Netherlands.

In baseline scenarios 5 and 7, where Schiphol can grow after 2029 and low socio-economic development is assumed (WLO Low), the CO_2 ceiling is exceeded from 2042 until 2047 by a few percent. Therefore, there will be limited effects in these years. In baseline scenarios 6 and 8, where Schiphol can grow after 2029 and high socio-economic development is assumed (WLO High), the CO_2 ceiling is exceeded by up to 21% and for a longer period of time. This is between 2035 and 2049, if Lelystad airport will not be opened and between 2032 and 2049 if opening of Lelystad is assumed.

The baseline scenarios distinguish three dimensions, 1) capacity Schiphol, 2) opening Lelystad airport and 3) macro-economic development. The first two dimensions describe the uncertainty of political decisions that have to be taken in the near future by the Dutch government, whereas the third dimension describes the uncertainty in the development of the demand for aviation. The two scenarios, WLO Low and WLO High, are both equally likely representing either low or high socio-economic growth. In this report, we have not repeated the methodology because the assumptions and method to access the impacts is identical to the main impact assessment.

This chapter starts with an assessment of the impacts on CO_2 emissions from aviation in Section 4.2. The methods are identical to the methods that had been applied in the main impact assessment. The description of the methods is not repeated in this report, but can be looked up in the main impact assessment. Section 4.3 analyses the impacts on CO_2 emissions from land transport, Section 4.4 on ETS and CORSIA, and Section 4.5 presents the overall impacts on global CO_2 emissions. Section 4.6 discusses the non-CO_2 climate impacts of aviation. The final two sections focus on local impacts: Landing and Take-Off (LTO) emissions in Section 4.7 and airport noise in Section 4.8.

4.2 Impacts on aviation CO_2 emissions

4.2.1 Introduction

In this section we discuss the impact of the different options of the CO_2 ceiling on the CO_2 emissions from aviation for baseline scenario 8. This is the scenario with the highest demand and the largest effects of the CO_2 ceiling. The effects in scenario 6 are comparable, those in scenarios 5 and 7 are much smaller and occur only between 2042 and 2047. In baseline scenarios 1 to 4, the CO_2 ceiling is not restrictive and does not affect the aviation CO_2 emissions.

In our analysis of the greenhouse gas (GHG) emissions we consider the 'well-to-tank' (WTT) emissions and 'tank-to-wing' (TTW) emissions separately[21]. The reason for presenting these emissions separately is that both the TTW and the WTT emissions determine the climate impact, whereas only the TTW emissions are considered in the design of the CO_2 ceiling. In line with the EU ETS accounting principles, it is assumed that SAF has zero TTW emissions, whereas the WTT emissions from the fuel production vary for the different types of aviation fuel, both fossil and SAF types.

Table 14 shows the greenhouse gas emissions in the baseline scenario 8.

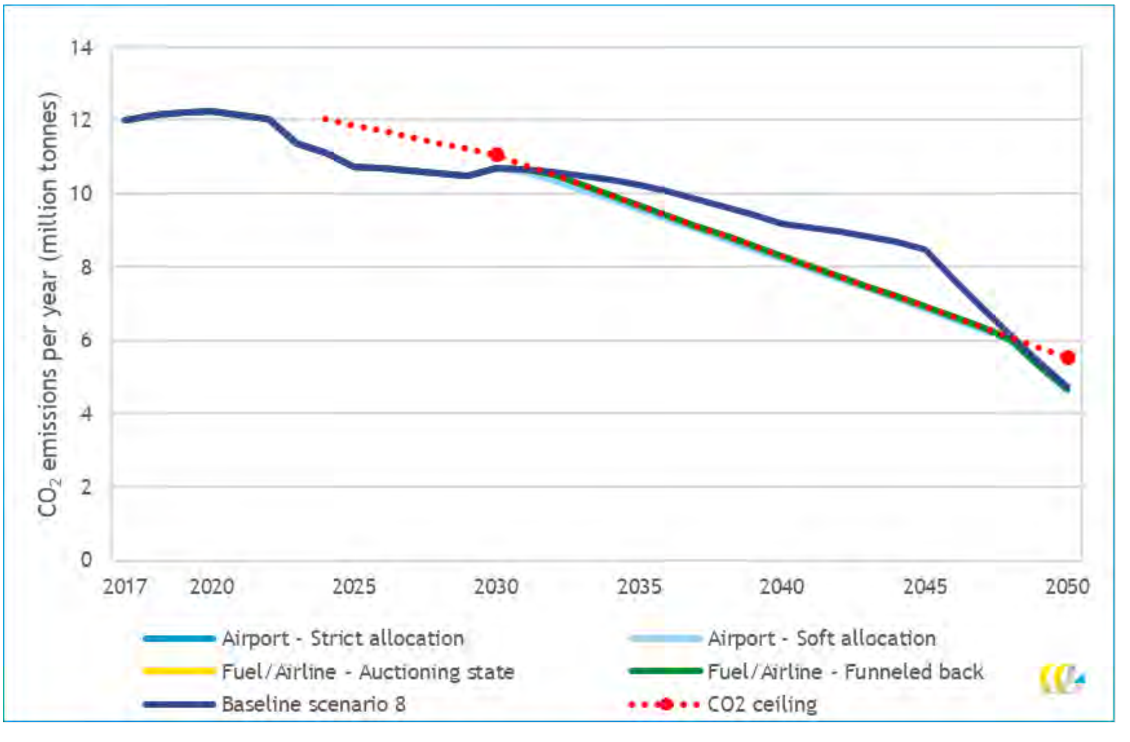
Table 14 - Baseline TTW and WTT CO_2 emissions for flights departing from Dutch airports (million tonnes)

Year	TTW CO_2 emissions	WTT CO_2 emissions
2017	12.0	2.5
2030	10.7	2.4
2040	9.2	2.7
2050	4.7	2.5

4.2.2 Results

Figure 28 displays the development of the TTW CO_2 emissions from flights departing from Dutch airports. The red dotted line represents the upper limit of the proposed CO_2 ceiling, while the red markers represent the CO_2 reduction targets from the Civil Aviation Policy Memorandum.

Figure 28 - Development of the TTW CO_2 emissions from flights departing from Dutch airports



[21] 'Well-to-tank' emissions are emissions associated with the production of the fuel. 'Tank-to-wing' emissions are the emissions associated with the combustion of the fuel in the airplane in stationary situations, at landing and take-off (LTO) and on-route.

We can see that in baseline scenario 8 the CO_2 ceiling is restrictive in the period 2032 until 2048. By summing over the difference between the baseline scenario and the options in this period, we find that the CO_2 ceiling saves respectively 11.5 and 12.6 million tonnes of cumulative TTW CO_2 emissions for the Airport - Strict allocation and Airport - Soft allocation options. For the Fuel supplier and Airline options 11.1 million tonnes TTW CO_2 emissions are saved.

In the Airport options, the emissions are slightly below the CO_2 ceiling in the period 2032-2040. This is a result of the fact that, in this option, the CO_2 ceiling is determined for each individual airport. At Schiphol and Lelystad airport the ceiling is reached from 2032, whereas the ceiling is not reached yet at some other regional airports. Therefore, not all available CO_2 budget is used on a national level. In the Fuel supplier and Airline options, the CO_2 ceiling is determined on a national level. Hence, in these options the full available CO_2 budget is used.

4.2.3 Evasion

Emissions at foreign airports are also affected by the Dutch CO_2 ceiling because of travellers changing routes. We distinguish two types of evasion here:
1. Passengers who in the baseline would make a flight with origin or destination at a Dutch airport, but now shift to an airport in a surrounding country[22].
2. Passengers who in the baseline would make a transfer stop at a Schiphol, but now transfer at a foreign airport or fly directly.

We investigate here the combined effect of these two types of evasion and compare the reduction of CO_2 emissions from flights departing at Dutch airports to the change in the CO_2 emissions from flights departing in the rest of the world. A detailed description of the effects on passenger level is presented in Section 3.3.3. The results for TTW and WTT emissions are displayed in Table 15.

The net aviation TTW and WTT CO_2 savings are in a range of 0.35 to 1.04 million tonnes CO_2 in 2040. The net savings are lower in the Airport options than in the other options, caused by a higher share of CO_2 evasion (~60%). In the Fuel supplier and Airline funnelled back significantly less (16%) CO_2 evasion occurs resulting in slightly higher net CO_2 savings. In the Fuel/Airline auctioning state options something different happens. Next to CO_2 savings from the decrease in flights at Dutch airports, there are also slight CO_2 savings due to decreases of flights in the rest of the world[23]. Therefore, the Auctioning State options have the highest net CO_2 savings.

[22] AEOLUS does not take into account capacity restrictions at foreign airports.

[23] For a more elaborate discussion of the negative evasion in the Fuel/Airline - Auctioning State options, see the textbox in Section 4.5.

Table 15 - Change in aviation TTW and WTT **CO_2** emissions (million tonnes) for the different **CO_2** ceiling options compared to baseline scenario 8

CO_2 ceiling option	**Aviation TTW CO_2 emissions**			**Aviation WTT CO_2 emissions**		
	Flights departing from Dutch airports	Flights departing from non-Dutch airports	Net effect	Flights departing from Dutch airports	Flights departing from non-Dutch airports	Net effect
Airport - Strict allocation (3-year cycle)	-0.92 (-1.33 to -0.92)	0.57	-0.35 (-0.76 to -0.35)	-0.27 (-0.39 to -0.27)	0.20	-0.07 (-0.19 to -0.07)
Airport - Strict allocation (1-year cycle)	-0.92 (-1.36 to -0.92)	0.57	-0.35 (-0.76 to -0.35)	-0.27 (-0.41 to -0.27)	0.20	-0.07 (-0.19 to -0.07)
Airport - Soft allocation (3-year cycle)	-0.98 (-1.38 to -0.98)	0.59	-0.39 (-0.79 to -0.39)	-0.29 (-0.41 to -0.29)	0.21	-0.08 (-0.2 to -0.08)
Fuel - Auctioning state	-0.90	-0.15	-1.04	-0.20	-0.01	-0.21
Fuel - Auctioning funnelled back	-0.90	0.26	-0.63	-0.21	0.08	-0.13
Fuel - No stability	-0.9 (-0.92 to -0.87)	-0.15	-1.04 (-1.07 to -1.02)	-0.2 (-0.21 to -0.19)	-0.01	-0.21 (-0.22 to -0.21)
Airline - Auctioning State	-0.90	-0.15	-1.04	-0.20	-0.01	-0.21
Airline - Funnelled back	-0.90	0.26	-0.63	-0.21	0.08	-0.13

4.3 Impacts on land transport CO_2 emissions

4.3.1 Introduction

In this section we discuss the impact of the different options of the CO_2 ceiling on CO_2 emissions from land transport for baseline scenario 8. This is the scenario with the highest demand and the largest effects of the CO_2 ceiling. The effects in scenario 6 are comparable, those in scenarios 5 and 7 are much smaller and occur only between 2042 and 2047. In baseline scenarios 1 to 4, the CO_2 ceiling is not restrictive and does not affect the land transport CO_2 emissions.

The CO_2 ceiling can have an impact on land transport CO_2 emissions in several ways:

a Passengers choosing for different use of the car and train in the before-/after transport. This could potentially lead to fewer car and train kilometres in the before/after transport to Dutch airports.

b Passengers choosing to travel from foreign airports instead of Dutch airports. This leads on the one hand to less kilometres for the before/after transport to Dutch airports and on the other hand to more kilometres for the before/after transport to foreign airports. The net effects depend on the distances to the airports.

c Passengers choosing to not fly anymore. This leads to a reduction in before/after transport to airports.

d Passengers choosing to use the car or train as an alternative to flying. This leads on the one hand to fewer car and train kilometres in the before/after transport to Dutch airports. On the other hand, this leads to more kilometres by people travelling by car or train to the destinations. The latter is much bigger than the first, otherwise it would be useless to consider the plane as a travel option.

4.3.2 Results

The resulting impacts on CO_2 emissions by land transport are displayed in Table 16. The impacts from rail transport are negligible. This is because the (electric) passenger trains have a low impact in emissions compared to cars. However, also the impacts from cars and therefore the total land transport CO_2 impact is relatively small, compared to the CO_2 impact from aviation.

For the Airport options there is an increase in land transport emissions. These sub-options have the largest decrease in passengers at Dutch airports and a large fraction of those passengers is expected to travel to their destination by land transport. For the Fuel supplier and Airline options we see the opposite: there is a decrease in land transport emissions. This is due to the shift of long to short flights in these options. Short flights become more attractive, so there actually is an increase in the number of passengers on short flights compared to the baseline of scenario 8. These passengers would have used the car or train to travel to their destination without the CO_2 ceiling.

Table 16 - Changes in WTW CO_2 emissions by land transport in 2040 (million tonnes per year)

CO_2 ceiling option	Car	Train	Total
Airport - Strict allocation (3-year cycle)	0.016	0.000	0.017
Airport - Strict allocation (1-year cycle)	0.016	0.000	0.017
Airport - Soft allocation (3-year cycle)	0.018	0.000	0.018
Fuel supplier - Auctioning state	-0.028	0.000	-0.028
Fuel supplier - Auctioning funnelled back	-0.049	0.000	-0.050
Fuel supplier - No stability	-0.028	0.000	-0.028
Airline - Auctioning State	-0.028	0.000	-0.028
Airline - Funnelled back	-0.049	0.000	-0.050

4.4 Impacts on EU ETS and CORSIA

4.4.1 Introduction

In this section we discuss the impact of the different options of the CO_2 ceiling on the effectiveness of EU ETS and CORSIA for baseline scenario 8. This is the scenario with the highest demand and the largest effects of the CO_2 ceiling. The effects in scenario 6 are comparable, those in scenarios 5 and 7 are much smaller and occur only between 2042 and 2047. In baseline scenarios 1 to 4, the CO_2 ceiling is not restrictive and does not affect the effectiveness of EU ETS and CORSIA.

In theory, the introduction of a Dutch CO_2 ceiling for aviation could influence the effectiveness of EU ETS and CORSIA through price effects borne by compliance costs and scarcity cost, among others. In this section, we investigate whether such a mechanism is likely, and if so, what the effect size might be for the different options of the CO_2 ceiling. We also pay attention to the question to what extent the introduction of the CO_2 ceiling can lead to emission reductions within CORSIA and the EU ETS. In this report we have not repeated the methodology because the assumptions and method to access the impacts is identical to the main impact assessment.

4.4.2 Results

EU ETS waterbed effect

Table 17 summarises the extent to which potential emissions reductions in the different ceiling options result in net reduction or will leak away due to the EU ETS waterbed effect.

Table 17 - Size of the EU ETS waterbed effect in 2040 due to additional emission reductions by the CO_2 ceiling

	Airport - Strict allocation	Airport - Soft allocation	Airline/Fuel supplier - state auctioning	Airline/Fuel supplier - funnelled back
Waterbed effect of NL aviation and catchment area	0.11%	0.10%	0.06%	-0.02%

Since the cap of the EU ETS approaches zero in 2040 and becomes zero in 2050, we do not expect the Total Number of Allowances in Circulation (TNAC) to exceed the threshold anymore in 2040. Allowances will become scarce when less expensive abatement measures have already been implemented. We hence assume that intra-European emissions reduction will leak to other ETS participants in 2040 (by the waterbed effect). By 2050, the EU ETS cap has reached zero and the CO_2 ceiling is not restrictive in scenario 8. As a result, the CO_2 ceiling can no longer meaningfully influence the effectivity of the system. Potential banked allowances will be scarce and very much sought after - if airlines that reduce their CO_2 emissions due to the CO_2 ceiling have some remaining banked allowances, they will sell these to other ETS participants.

In Paragraph 4.5.2 we show how large the absolute effect is of the EU ETS waterbed effect.

EU ETS price effects

The mutations to CO_2 emissions from flights departing from the catchment area (including the Netherlands) was shown previously in Table 15. Differences with baseline emissions are quite modest.

As stated earlier, in 2030 the CO_2 ceiling is not restrictive and does therefore establish no additional emission reduction in the aviation sector. Consequently, there is likely no impact on the allowances and ETS prices. By 2040, only 75 million allowances are allocated to the market. Furthermore, we assume the ETS price has risen to € 200 at that point.
We therefore find a small price change by the waterbed effect. By 2050, the CO_2 ceiling is no longer restrictive and hence does not influence the EU ETS. In addition, the ETS cap has reached zero at that time.

Table 18 - Potential ETS price reductions in 2040 resulting from emission abatement in the catchment area (including NL)

	Airport - Strict allocation	Airport - Soft allocation	Airline/Fuel supplier - state auctioning	Airline/Fuel supplier - funnelled back
Price effect	€ 0.21	€ 0.21	€ 0.12	-€ 0.04
ETS prices	€ 199.79	€ 199.79	€ 199.88	€ 200.04

CORSIA price effects

Similarly, as in the main impact assessment we observe that the impact of the CO_2 ceiling on ETS prices is very limited. Prices for offsetting under CORSIA are significantly lower than EU ETS prices. More importantly, the share of emissions of the Dutch aviation sector relevant for the CORSIA scope (all global international non-intra-EU flights) is very small. This means, price impacts on CORSIA from additional CO_2 emission reduction by the CO_2 ceiling are negligible.

4.5 Total impact on global CO_2 emissions

4.5.1 Introduction

In this section we discuss the impact of the different options of the CO_2 ceiling on the global CO_2 emissions for baseline scenario 8. This is the scenario with the highest demand and the largest effects of the CO_2 ceiling. The effects in scenario 6 are comparable, those in scenarios 5 and 7 are much smaller and occur only between 2042 and 2047. In baseline scenarios 1 to 4, the CO_2 ceiling is not restrictive and does not affect the global CO_2 emissions.

We combine the CO_2 effects found in the previous paragraphs to determine the total impact on global CO_2 emissions.

Apart from the modelling results so far presented, we estimate the impact of possible behavioural responses, which have not been modelled. These are:

- Voluntary emission reductions in the Airport option. It is possible that airlines will take voluntary action to reduce emissions under the CO_2 ceiling when they are faced with a threat that airport capacity will be limited. Such action could comprise reduced outbound tankering, increased inbound tankering, increased use of sustainable aviation fuels, etc. This will result in more airport capacity and reduced evasion by passengers.
- Reduced outbound tankering and increased inbound tankering. According to Peeters et al., (2021), 1-5% excess fuel is sold at Dutch airports on intra-EEA flights. In case Dutch aviation CO_2 emissions are projected to increase above the ceiling, or in case fuel sold at Dutch airports becomes more expensive in the Fuel supplier option, it becomes more attractive to reduce outbound tankering or to increase inbound tankering. The total maximal leakage of emissions due to a shift in tankering is estimated to be 4% of total Dutch aviation emissions.

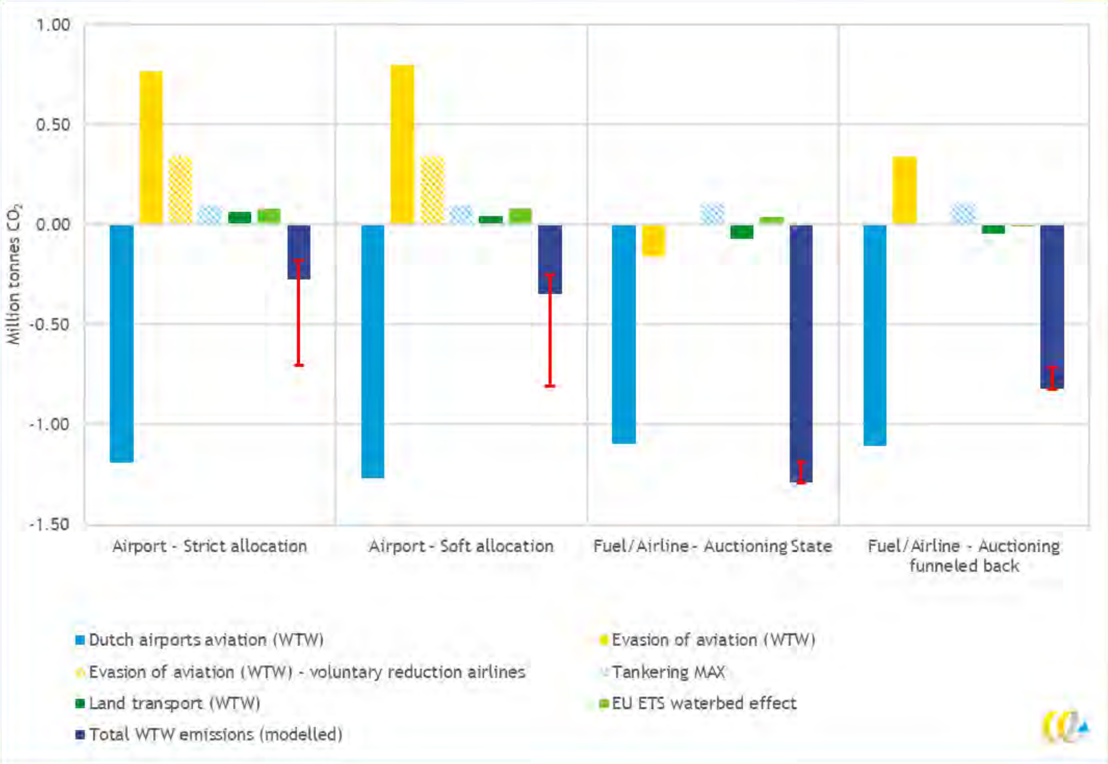
4.5.2 Results

Figure 29 presents the change in global CO_2 emissions in scenario 8 for 2040. It combines the effects of the total CO_2 emissions from aviation, land transport and other sectors (via EU ETS interactions). We observe that all the CO_2 ceiling policy options yield a net reduction of the CO_2 emissions. The figure also estimates of behavioural responses that have not been modelled are incorporated. This includes voluntary action by airlines in the Airport options and tankering in all options. The modelled impacts are presented as solid columns, the non-modelled estimates as shaded columns. The estimates for all sub-options are summarised in Table 19.

We can see that all policy options show significant net CO_2 reductions ranging from 0.28 to 1.29 million tonnes for the modelled results in 2040. The net reductions are highest for the Fuel supplier and Airline Auctioning State options. This is caused by the relatively small amount of evasion here (for more explanation on this, see the following textbox).
The red error bar represents the variance in the net CO_2 reductions due to voluntary emission reductions by airlines (in the Airport options) and tankering. Increased inbound tankering could lead to an increase in net CO_2 emissions and therefore represents the upper side of the error bar. Voluntary emission reduction by airlines (in the Airport options) could lead to more emission reduction, and therefore represents the lower side of the error bar.

The shaded yellow columns in the Airport options indicate that when airlines take voluntary action, they can reduce CO_2 evasion to the level of other policy options. This level of evasion is considerably lower than the level without voluntary emission reduction by airlines (solid yellow columns). Another possible behavioural response is an increase in tankering, indicated by the shaded blue bar. With these impacts, the net global CO_2 emissions would still decrease in all cases, as indicated by upper end of the red error bar.

Figure 29 - Change in global **CO_2 emissions in scenario** 8 in 2040



Note: In this figure we used a red error bar to show the uncertainty in the total WTW emissions due to voluntary emission reduction of airlines and increased inbound tankering.

Textbox 3 - Why is evasion negative in the Fuel/Airline - Auctioning State options?

It can seem counterintuitive that there is negative CO_2 evasion in the Fuel/Airline options. This can be explained by the way in which CO_2 is assigned to either Dutch airports or foreign airports. The CO_2 of a flights is assigned to the airport of departure. Therefore, if due to the CO_2 ceiling there is a decrease in the number of passengers on for example the route Schiphol - Spain - Singapore, only the CO_2 savings from the decreases in flights Schiphol - Spain is assigned to the Netherlands. The CO_2 savings from the decreases in flights on the routes Spain - Singapore, Singapore - Spain and Spain - Schiphol are all assigned to foreign airports. Also note that flights returning from intercontinental destinations to Schiphol do not have to oblige to the ReFuelEU Aviation blending requirements, we assume a fuel mix of 100% kerosene for these returning flights. Therefore, when there is a decrease in intercontinental OD passengers, most of the CO_2 savings will come from the returning flights, which are assigned to foreign airports. Now the Fuel/Airline auctioning state options have the strongest decrease in intercontinental OD passengers. Therefore, this effect is such large in these options that it outweighs the increases in CO_2 on foreign airports, resulting in net negative CO_2 evasion.

Table 19 - Change in total CO_2 emissions of aviation, land transport and other EU sectors combined; the different CO_2 ceiling options compared to baseline (million tonnes)

CO_2 ceiling option	Effects on global aviation **CO_2 emissions**		Effects on land transport **CO_2 emissions**	**Effect on CO_2** emissions in other EU ETS sectors	Total combined effect on global **CO_2** emissions
	The Netherlands aviation WTW emissions	Evasion of aviation WTW emissions	Land transport WTW emissions	EU waterbed effect	Total WTW emissions
Airport - Strict allocation (3-year cycle)	-1.19 (-1.72 to -1.19)	0.77	0.06	0.08	-0.28 (-0.81 to -0.28)
Airport - Strict allocation (1-year cycle)	-1.19 (-1.77 to -1.19)	0.77	0.06	0.08	-0.28 (-0.85 to -0.28)
Airport - Soft allocation (3-year cycle)	-1.27 (-1.79 to -1.27)	0.80	0.04	0.08	-0.35 (-0.87 to -0.35)
Fuel supplier - Auctioning state	-1.10	-0.16	-0.07	0.04	-1.29
Fuel supplier - Auctioning funnelled back	-1.11	0.34	-0.05	-0.01	-0.82
Fuel supplier - No stability	-1.1 (-1.13 to -1.06)	-0.16	-0.07	0.04	-1.29 (-1.32 to -1.26)
Airline - Auctioning State	-1.10	-0.16	-0.07	0.04	-1.29
Airline - Funnelled back	-1.11	0.34	-0.05	-0.01	-0.82

4.6 Non-CO_2 climate impacts of aviation

4.6.1 Introduction

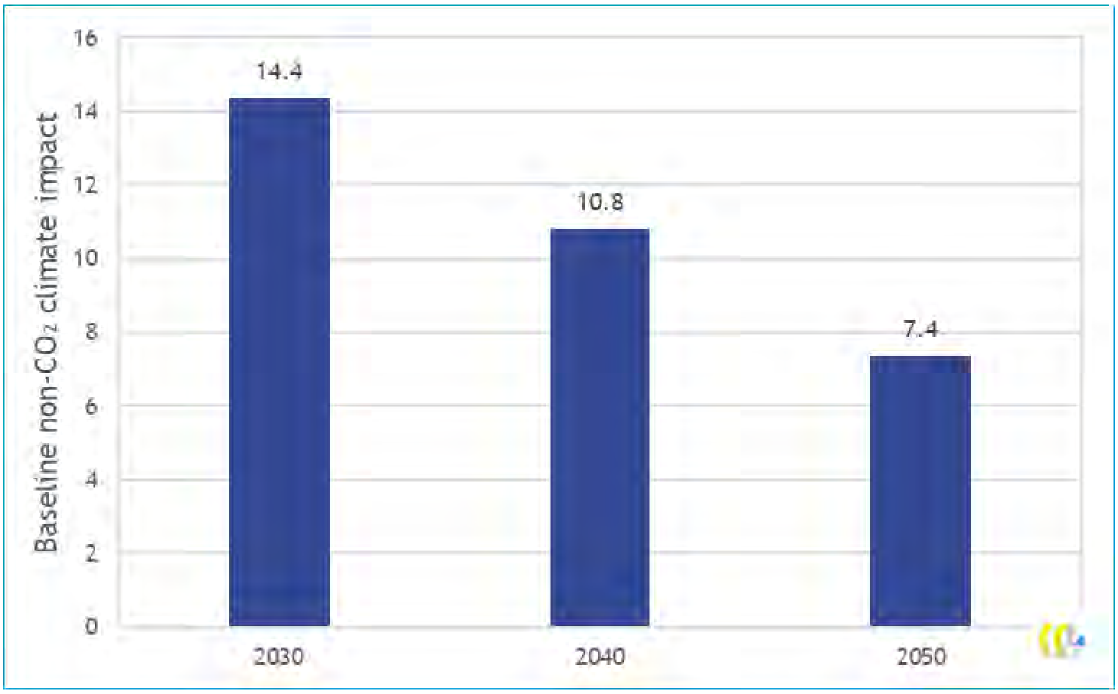
In this section we discuss the impact of the different options of the CO_2 ceiling on the non-CO_2 climate impacts of aviation for baseline scenario 8. This is the scenario with the highest demand and the largest effects of the CO_2 ceiling. The effects in scenario 6 are comparable, those in scenarios 5 and 7 are much smaller and occur only between 2042 and 2047. In baseline scenarios 1 to 4, the CO_2 ceiling is not restrictive and does not affect the non-CO_2 climate impacts of aviation. In this report we have not repeated the methodology because the assumptions and method to access the impacts is identical to the main impact assessment.

In addition to climate impacts due to CO_2 emissions, aviation also causes non-CO_2-related global warming effects. The magnitude of these effects is yet uncertain but recent literature suggests that aviation’s non-CO_2 impact on global warming may be of the similar magnitude as CO_2 emissions. We use an estimation of a twice as high global warming effect compared to solely the direct CO_2 impact (EASA et al., 2020, Lee et al., 2021). The largest non-CO_2 impacts stem from the formation of contrails and contrail cirrus, and NO_x emissions[24].

There are four ways in which the Dutch CO_2 ceiling could influence net non-CO_2 emissions. First, the CO_2 ceiling could lead to a reduction in the number of flights, causing both a reduction of CO_2 and non-CO_2 emissions and climate impacts. Second, the magnitude of the non-CO_2 effects described above is heavily dependent on cruise height and, in turn, on flight distance (Dahlmann et al., 2021). The Dutch CO_2 ceiling could hence influence the non-CO_2 emissions and impacts in case airlines modify their destination network and/or route frequencies and average route lengths. Third, the use of SAF can decrease contrail formation because SAF generally has a lower concentration of aromatics, including naphthalenes, which cause particulate matter (PM) emissions (CE Delft, 2022c).[25] Fourth, changes in utilised aircraft type resulting from the CO_2 ceiling can lead to changes in non-CO_2 emissions and impacts. The direction of this change depends on the characteristics of the old and new plane.

The estimated non-CO_2 climate impacts of Dutch aviation in baseline scenario 8 are presented in Figure 30.

Figure 30 - Non-**CO_2 climate impacts** of Dutch aviation in baseline scenario 8 **(million tonnes CO_2e, GWP*100)**



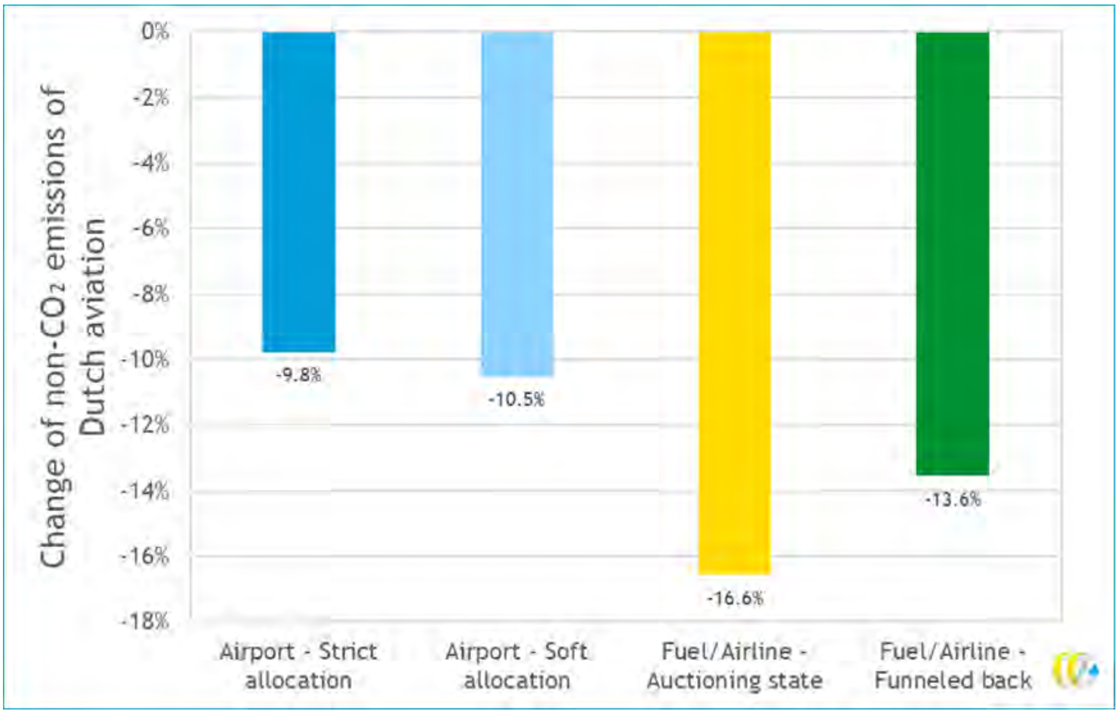
[24] See the main impact assessment for an elaborate outline of literature on non-CO2 impacts of aviation.

[25] If airplanes will also fly on hydrogen - in addition to SAF - in the future this would probably increase contrail formation.

4.6.2 Results

The impact of the different options of the CO_2 ceiling on non-CO_2 climate impacts of Dutch aviation in 2040 are displayed in Figure 31. As can be seen the introduction of the CO_2 ceiling leads to a 10-17% reduction of non-CO_2 climate impact from Dutch aviation.
These are explained by a reduction in the number of flights (mostly in the Airport options), decrease in the average length of flights and higher SAF blending percentages (mainly in the fuel supplier and Airline options).

Figure 31 - Impacts on Dutch aviation non-**CO_2 emissions** due to the **CO_2** ceiling in 2040



The non-CO_2 climate impact of Dutch aviation is only a small impact on the global level of non-CO_2 climate impact caused by aviation. In absolute terms, the reduction in non-CO_2 climate impact by the CO_2 ceiling is depending on the sub-option 0.4 million tonnes to 1.8 million tonnes CO_2-eq.

4.7 Impacts on air pollutant LTO emissions

4.7.1 Introduction

In this section we discuss the impact of the different options of the CO_2 ceiling on the emissions of air pollutants during the landing and take-off (LTO) phase for baseline scenario 8[26]. This is the scenario with the highest demand and the largest effects of the CO_2 ceiling. The effects in scenario 6 are comparable, those in scenarios 5 and 7 are much smaller and occur only between 2042 and 2047. In baseline scenarios 1 to 4 the CO_2 ceiling is not restrictive and does not affect the air pollutant LTO emissions. In this report we have not

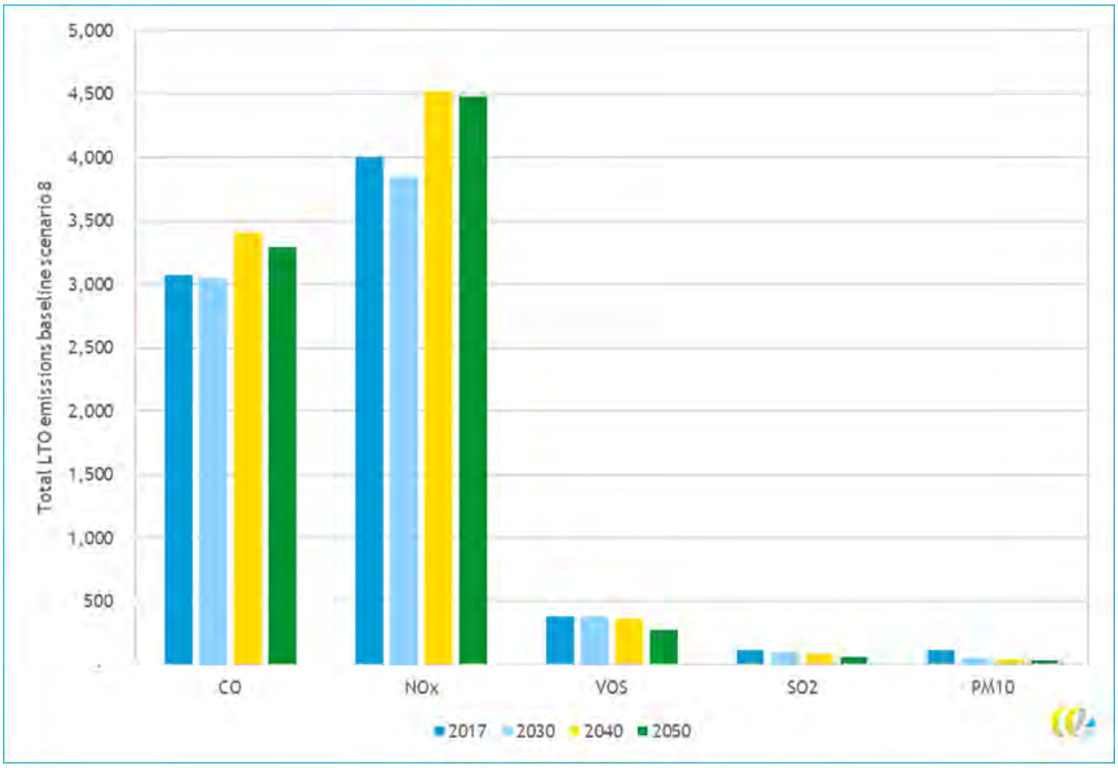
[26] This includes the emissions up to 1 km altitude.

repeated the methodology because the assumptions and method to access the impacts is identical to the main impact assessment.

The effects of air pollution on humans and nature occur on the location where the pollutants are deposited[27]. This is different from the effect of greenhouse gasses, which is relevant globally. The air pollution at foreign airports and during the cruise phase of the flight (within the Dutch air space) are not quantified since these air pollutant emissions are not emitted in the LTO phase at a Dutch airport.
Emissions of air pollutants are affected by the CO_2 ceiling when it results in a change in flight patterns, frequency and operational LTO practices. In addition, enhanced fleet renewal as a result of supply reaction effects may lead to an increase of less polluting airplanes resulting in a decrease of LTO emissions.

Local air pollutant emissions in the baseline of scenario 8 are displayed in Figure 32.
The LTO emissions for all Dutch airports as a total are increasing up to a peak around 2040. Thereafter local emissions are declining. This trend is mainly caused by technological developments and an increasing use of SAF. For some regional airports local emissions will keep rising (slightly) at least until 2050, mainly because the number of flights and/or the average aircraft size increases.

Figure 32 - Development of air pollutant LTO emissions at Dutch airports in baseline scenario 8
(without CO_2 ceiling, tonnes per year)

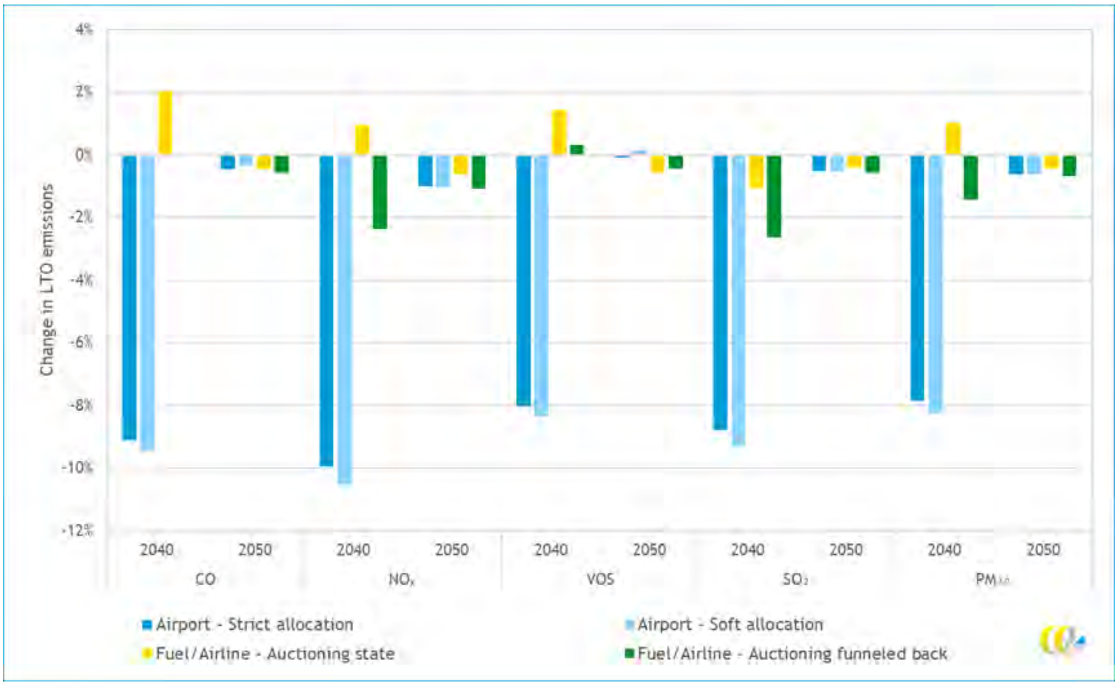


[27] In this study we only quantified the emissions of air pollutants at the source. We did not determine where precisely these pollutants are deposited.

4.7.2 Results

The change in air pollutant LTO emissions for all Dutch airports under the CO_2 ceiling variants compared to baseline scenario 8 are indicated in Figure 33. There are no effect on the LTO emissions in 2030 because the CO_2 ceiling is not restrictive in that year. Even though the CO_2 ceiling is not restrictive anymore in 2050, the CO_2 ceiling has still (small) effects on the LTO emissions compared to the baseline due to airlines adapted choices during the period when the CO_2 ceiling was restrictive. Therefore, we will outline effects in 2050 if there is a difference compared to the baseline scenario caused by the restrictive CO_2 ceiling in earlier years.

Figure 33 - Total changes in LTO emissions at all Dutch airports in the compared to baseline scenario 8 (percentage change per year)



As seen in the introduction of this section, the overall LTO emissions are increasing due to the increase of the number of flights according to the modelling assumptions for the baseline scenario. We can see in Figure 33 that most CO_2 ceiling options results in lower LTO emissions for the total of all Dutch airports compared to the baseline in 2040 and 2050, see also Table 20 for detailed numbers. This is mainly caused by the decrease in emissions from Schiphol. In practice, this means the increasing trend of LTO emissions is tempered. Only in the fuel/airline auctioning state CO_2 ceiling variant some LTO emissions are higher than in the baseline. This is explained by the modelled increase of full-freighter flights to and from Schiphol and Maastricht airport. These aircraft types are heavier and larger than (most) passenger aircraft. Still, the increases are relatively small.

Table 20 - Change for all Dutch airports of air pollutant LTO emissions compared to baseline scenario 8 (tonnes of air pollutant emissions)

Air pollutant	Year	Airport - Strict allocation (3-year cycle)	Airport - Strict allocation (1-year cycle)	Airport - Soft allocation (3-year cycle)	Airline/Fuel supplier - Auctioning state	Airline/Fuel supplier - Auctioning funnelled back	Fuel supplier - no stability
CO	2040	-311 (-464 to -311)	-311 (-477 to -311)	-322 (-474 to -322)	69	-1	69 (58 to 80)
	2050	-15 (-290 to 37)	-15 (-267 to 32)	-11 (-286 to 42)	-15	-19	-15 (-155 to 125)
NO_x	2040	-450 (-650 to -450)	-450 (-668 to -450)	-477 (-675 to -477)	43	-107	0 (-186 to 131)
	2050	-45 (-417 to 26)	-45 (-385 to 20)	-46 (-418 to 24)	-28	-49	43 (29 to 58)
VOS	2040	-30 (-46 to -30)	-30 (-48 to -30)	-30 (-46 to -30)	5	1	-28 (-218 to 163)
	2050	0 (-23 to 4)	0 (-21 to 4)	0 (-22 to 5)	-2	-1	0 (-18 to 13)
SO_2	2040	-8 (-13 to -8)	-8 (-13 to -8)	-9 (-13 to -9)	-1	-3	5 (4 to 6)
	2050	0 (-5 to 0)	0 (-5 to 0)	0 (-5 to 0)	0	-1	-2 (-13 to 10)
PM_{10}	2040	-4 (-6 to -4)	-4 (-7 to -4)	-5 (-7 to -5)	1	-1	0 (-5 to 3)
	2050	0 (-3 to 0)	0 (-3 to 0)	0 (-3 to 0)	0	0	-1 (-1 to -1)

Note: The CO_2 ceiling is no longer restrictive in the year 2050, however aircraft technological choices and network strategies applied during the restricted period of the CO_2 ceiling result in different outcomes to the baseline scenario in which no ceiling would have been in place.

4.8 Impacts on airport noise

4.8.1 Introduction

In this section, we discuss the impact of the different options of the CO_2 ceiling on the airport noise for baseline scenario 8. This is the scenario with the highest demand and the largest effects of the CO_2 ceiling. The effects in scenario 6 are comparable, those in scenarios 5 and 7 are much smaller and occur only between 2042 and 2047. In baseline scenarios 1 to 4, the CO_2 ceiling is not restrictive and does not affect the airport noise.

This section analyses how the implementation of a CO_2 ceiling influences airport noise in the Netherlands. Noise impact is for a large part a function of the composition of the fleet being operated at these airports and the number of flights. The noise impacts at Schiphol airport are directly modelled in AEOLUS and outlined in this section. The model estimates the number of houses within the legally defined 58 dB L_{den}-contour. The noise impacts at the regional airports are quantified using the L_{den} tool[28] using the provided AEOLUS outputs for these airports. In this report we have not repeated the analysis for the regional airports because the assumptions and method to access the impacts is identical to the main impact assessment.

4.8.2 Results for Schiphol

The number of houses within the 58 dB L_{den}-contour is shown in Table 21. In the baseline scenario the number of houses within the contour declines significantly over time due to a new aircraft entering the fleet at Schiphol airport. The noise levels at Schiphol are reduced significantly in the baseline from 2025 onwards due to the new flight volume restrictions.

Table 21 - Change in number of houses within the 58 db L_{den}-contour of Schiphol airport

Year	Baseline scenario 8	Airport - strict allocation	Airport - Soft allocation (3-year cycle)	Fuel supplier/ Airline - auctioning state	Fuel supplier/ Airline auctioning funnelled back
2040	6,830	-530	-660	240	50
2050	2,540	-740	-740	-70	-70

In the Airport options of the CO_2 ceiling the number of houses within the contour decreases. This is caused by further reduction of flights during years the CO_2 ceiling is restrictive.
The largest decline in noise is reached in the Airport - strict allocation and Airport - soft allocation sub-options. In the other sub-options, the reduction in aviation noise is smaller since the reduction of flights is not as large. In the Airline/Fuel supplier policy options the number of houses affected by the 58 db L_{den}-contour increases by a few percent compared to the number of affected houses in the baseline. This increase is due to the increase in the number of full-freight flights departing from Schiphol (which take up slots following a reduction in the number of ICA flights, see Section 3.4 on the impacts on flights).
Only in the Fuel/Airline Auctioning State CO_2 ceiling variant, airport noise is predicted to be higher than in the baseline. This is explained by the modelled increase of full-freighter

28 The L_{den} tool was developed by Adecs Airinfra and by the Netherlands Aerospace Centre in assignment of ministry of Infrastructure and Water Management in order to compute L_{den} noise contours in accordance with the Dutch decree 'Regeling burgerluchthavens'. This tool has been validated by Vital Link Beleidsanalyse in assignment of the ministry of Infrastructure and Water management (Vital Link Beleidsanalyse, 2015).

flights to and from Schiphol and Maastricht airport. These aircraft types are heavier and larger than (most) passenger aircraft - with higher noise emissions and consequently a higher number of households affected. Still, the increases in modelled noise impact are around 3% percent higher compared to the baseline.

5 How do the options compare?

5.1 Introduction

This chapter presents an update of the multi-criteria analysis of the different policy options of the CO_2 ceiling. The method is described in detail in Chapter 7 of the main impact assessment. This multi-criteria analysis compares the different options in a structured way.

In Section 5.2 the criteria for the multi-criteria analysis are described, in Section 5.3 the results of the multi-criteria analysis are described. Conclusions of the comparison of the different options of the CO_2 ceiling are presented in Section 5.4.

5.2 Criteria for comparison

We have defined five criteria to compare the options against, some of which have several components. A distinction should be made between criteria which are related to the main objective of the CO_2 ceiling (to safeguard that the CO_2 emissions targets for Dutch aviation, set by the Government, are not exceeded) and criteria that are related to other effects of the policy choice, such as effects on the aviation sector, environment, economy and safety.

All criteria are scored on a five-point scale, ranging from -- (negative) to ++ (positive) with 0 meaning (almost) no impact. How these are exactly defined differs per criterion.

We did not rank the different criteria on importance. This is because the relative importance of the different criteria is a political choice that should not be made by the research team. For the components that together form a main criterion, we did make an aggregation: this unavoidably involves assigning weights.

Below we introduce the different criteria and accompanying components. Also, Figure 34 provides a schematic overview of the criteria and components. In brackets we indicate whether the results will mainly be based on the main study (main study) or this update (update).

The first criterion (main study) is defined as ‘certainty about the impact on aviation CO_2 emissions’. This criterion is directly related to the aim of the CO_2 ceiling. The criterion has four components:
1. Control which regulated entities have over CO_2 emissions.
2. Predictability of CO_2 emissions.
3. Feasibility of implementation.
4. The international acceptance of the measure which also relates to the risk of retaliation.

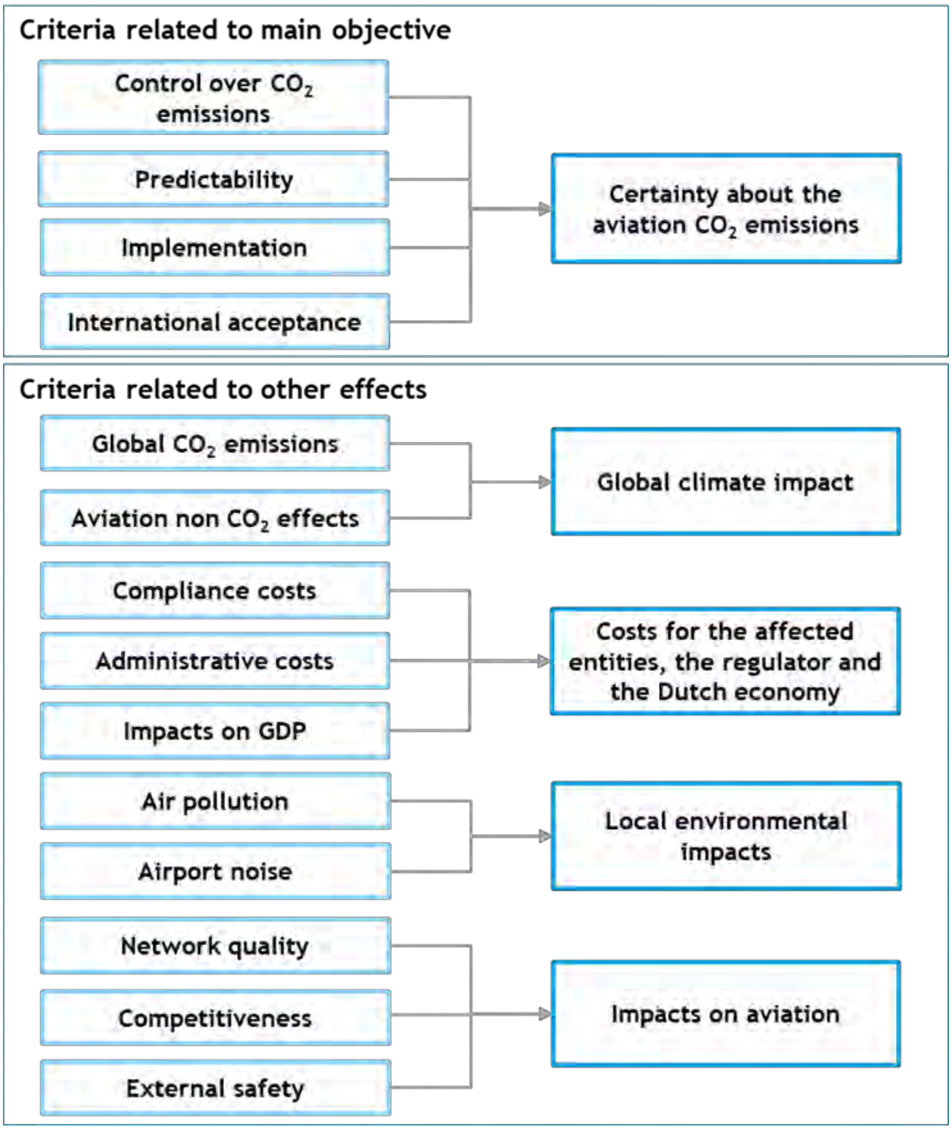
As the CO_2 ceiling is a climate measure, the impacts on GHG emissions, both in the aviation sector and in other sectors, as well as the change in non-CO_2 climate impacts from aviation are also relevant. The ‘global climate impact’ therefore constitutes the second criterion (update).

The third criterion (main study) is the 'cost of the measure' for both the affected entities, the regulator and the Dutch economy. This is translated into the following three subitems:
1. The compliance costs.
2. The administrative costs.
3. The state revenues.

The final two criteria are directly taken from the Aviation Policy White Paper 'luchtvaart-nota', which defines public interests of aviation (next to the interest of reducing the climate impact of aviation). The fourth criterion (update) comprises the 'local environmental impacts: airport noise and LTO emissions of air pollutants'.

The fifth criterion (main study and update) comprises the 'impacts on aviation: network quality, level playing field and aviation safety'. This criterium also consists of three components: network quality, competitiveness and external safety.

Figure 34 - Schematic overview of the criteria and sub criteria



5.3 Outcome of the multi-criteria analysis

In this section, we present an update of the multi-criteria analysis. The discussion of the criteria in this document is relatively brief since most of the conclusions from the main impact assessment are still valid. Therefore, we often refer to the argumentation in the main impact assessment instead of repeating it. Instead, we focus on the differences in effects of the updated baseline scenarios compared to the effects with the baseline scenarios of the main impact assessment and the resulting overall outcomes of the multi-criteria analysis. An overview of the main results is presented in Table 22.

Outcome in scenarios with a non-restrictive ceiling

If the CO_2 ceiling is not restrictive, the only relevant criteria are:
- Certainty of the aviation **CO_2** emissions: Overall, the Airport option scores best on this criterium because of the relatively low risk of international retaliation, the relatively good predictability of future CO_2 emissions of the aviation sector and the relative ease of implementation. However, a downside compared to the other options is that airports have limited control over the CO_2 emissions of airlines. Due to this uncertainty, a three-year compliance period would be helpful for airports such that fluctuations in the CO_2 emissions over multiple years can be averaged out.
- Overall costs: Even if the CO_2 ceiling is not restrictive, there are administrative costs and costs for implementation.

In all baseline scenarios, in which the capacity of Schiphol remains at 440,000 annual flights (baseline scenarios 1, 2, 3 and 4), CO_2 emissions stay below the CO_2 ceiling during the entire period. Therefore, the CO_2 ceiling is not restrictive and the criteria should be interpreted as stated above.

Outcomes in scenarios with a restrictive ceiling

In scenarios where the ceiling is restrictive for some period, there are additional effects of the CO_2 ceiling which are similar to the main impact assessment:
- Certainty of the aviation **CO_2** emissions: Overall, the Airport option scores best on this criterium because of the relatively low risk of international retaliation, the relatively good predictability of future CO_2 emissions of the aviation sector and the relative ease of implementation. However, a downside compared to the other options is that airports have limited control over the CO_2 emissions of airlines. Due to this uncertainty, a three-year compliance period would be helpful for airports such that fluctuations in the CO_2 emissions over multiple years can be averaged out.
- Total climate impacts: There is a net positive total climate effect in all CO_2 ceiling options. The net positive effect is largest in the Fuel supplier and Airline options (see Figure 29). In the main impact assessment, a similar effect was reported for all options in 2030. In the new baseline scenarios, the CO_2 ceiling is not restrictive in 2030. Therefore, we have shifted the focus to 2040. Since the net global CO_2 reduction is significantly smaller in the Airline options, we have chosen to change the score of “++” to “+” compared to the main impact assessment (see Section 7.4 of the main impact assessment). The scores for the non-CO_2 effects remain equal, which implies that the total score for “total climate impacts” are adjusted from “++” to “+” in the ceiling per Airport options.
- Overall costs. If the CO_2 ceiling is restrictive, there are both administrative and compliance costs. However, since the compliance costs are much larger than the administrative costs, these become most relevant. Both the administrative costs and

compliance costs are lowest in the ceiling per Airport options, mainly because there are no allowance costs for the sector.

- Local environmental impacts: A reduction in the number of flights due to a restrictive ceiling has a positive effect on both local air quality and noise. However, the fuel/airline variant auctioning state indicate an increase in full-freighter flights, which may have a small negative effect on local air pollution emissions. If the CO_2 emission is achieved by means of additional SAF blending, there are also positive effects on local air quality.
- Impacts on aviation sector: If the ceiling is restrictive, the Airport option has the most negative effects on the aviation sector. This is because, compared to the other options the number of flights is restricted more significantly to achieve the necessary CO_2 reduction. Also, the aviation sector will put less focus on fleet renewal and there is no additional SAF blending. Therefore, a fewer number of flights can be accommodated within the available CO_2 emission limits.

In baseline scenarios 5 and 7, where Schiphol can grow after 2029 and low socio-economic development is assumed (WLO Low), the CO_2 ceiling is exceeded from 2042 until 2047 by a few percent. Therefore, there will be limited effects in these years. In baseline scenarios 6 and 8, where Schiphol can grow after 2029 and high socio-economic development is assumed (WLO High), the CO_2 ceiling is exceeded by up to 21% and for a longer period of time. This is between 2035 and 2048 if Lelystad airport will not be opened and between 2032 and 2048 if opening of Lelystad is assumed.

5.4 Conclusion

If the ceiling is never restrictive, the Airport option scores best on the specified criteria due to the relative ease of implementation and relatively low administrative costs compared to the other options.

If the ceiling is restrictive for some years, the score on the multi-criteria analysis is not as conclusive. As mentioned, the Airport options scores best on the certainty about aviation CO_2 emissions and overall costs. However, the Fuel supplier- and Airline options have the least impact on the aviation sector. On the other hand, the positive effects on the local environment of airports are the highest in the ceiling per Airport option due to the reduction in aircraft movements.

A combined outcome of the multi-criteria analysis should consider how likely it is that the ceiling will be restrictive for some period. In the baseline scenarios where the capacity at Schiphol airport remains constant at 440,000 flights per year, the ceiling never becomes restrictive. However, it should be noted that the scenarios that are accessed in this study do not explore all uncertainties. If for instance the SAF blending obligations in the Fit for 55 proposals will be reduced or worldwide SAF production is not able to supply the demand, the ceiling might become restrictive.

If the capacity at Schiphol airport is allowed to increase from 2030 onward (following the assumed path as outlined in Annex A.1), the ceiling becomes significantly restrictive in the WLO High scenario. In the WLO Low scenario, the ceiling only becomes restrictive for a couple of years. In this case it should also be noted that the scenarios do not fully explore all uncertainties. Like mentioned above, the realisation of the assumed SAF blending is crucial here, which is dependent on the legislator and the availability of SAF.

When considering the near future (until 2030), the scenarios of this update show that it is very unlikely that the CO_2 ceiling will become restrictive. This is a direct consequence of the announced capacity reduction at Schiphol. Therefore, it can be argued that if a short-term perspective is applied, the Airport option with a three-year compliance period scores best.

If a longer-term perspective is applied, the uncertainty of the future capacity limits at Schiphol airport and the uncertain opening of Lelystad make it reasonably likely that the ceiling becomes restrictive for some period. Therefore, the optimal policy choice in these scenarios is less clear: both the Airport option with a three-year compliance period and the Fuel supplier option with a stability mechanism (with auctioning incomes that are either for the state or funnelled back) are options that score well. However, both have different advantages and disadvantages. Therefore, it is not possible to identify a preferred option without assigning relative values to the different criteria. This is a political choice and therefore not part of this impact assessment.

We conclude that the outcomes of the multi-criteria analysis as presented in the earlier impact assessment (as summarised in Table 22) are still largely valid. The only adjustment that we made is that we changed the score on the criteria "total climate effects" from "++" to "+" for the ceiling per Airport option.

Table 22 - Comparison of all the criteria in the multi-criteria analysis

	Airport - Strict allocation (3-year cycle)	Airport - Strict allocation (1-year cycle)	Airport - Soft allocation (3-year cycle)	Fuel supplier - Auctioning state	Fuel supplier - Auctioning funnelled back	Fuel supplier - no stability	Airline - Auctioning state	Airline - Funnelled back
Certainty about aviation CO_2 emissions	+	0	+	0	0	0	0	0
Total climate impacts	+	+	+	++	++	++	++	++
Overall costs	0	0	0	0	-	0	-	-
Overall impact on the local environment of airports	++	++	++	+	+	+	+	+
Impacts on aviation sector	-	-	-	-	0	-	-	0

6 Overall conclusions

The aim of the CO_2 ceiling is to safeguard that the CO_2 emissions targets for Dutch aviation, set by the Government in the Civil Aviation Policy Memorandum 'luchtvaartnota', are not exceeded. Apart from this main aim, the CO_2 ceiling could also affect the aviation sector, the economy, the environment and external safety.

Could a CO_2 ceiling effectively ensure that the emission targets are not exceeded?

The conclusion of the main IA was that a national CO_2 ceiling for aviation could be an effective instrument to ensure that the agreed CO_2 emissions are not surpassed.
This conclusion still holds, based on the calculations in this update. For this update, a new set of plausible baseline scenarios has been developed to take the latest policy changes into account (capacity reduction Schiphol, Fit for 55 and CORSIA).

The new baseline scenarios show that in the scenarios where the capacity of Schiphol stays constant at 440,000 flights, the CO_2 ceiling will not be exceeded. However, in the scenarios where the capacity of Schiphol is allowed to grow after 2029, the CO_2 ceiling is exceeded for either a few years in scenarios with low socio-economic growth (WLO Low) or for over ten years in scenarios with high socio-economic growth (WLO High). In the highest growth scenario, the CO_2 ceiling is estimated to be restrictive from 2032 to 2048. In the years before and after this time period, the CO_2 emissions of Dutch aviation is modelled to be lower than the absolute amount of CO_2 emissions the ceiling allows for.

Therefore, it can be concluded that, without government action, aviation emissions could exceed the CO_2 targets, even when the proposals of the Fit for 55 package are implemented as proposed. This would go against the policy goals as stated in the Civil Aviation Policy Memorandum and undermine the credibility of the Dutch efforts.

Ensuring that the CO_2 emissions of Dutch aviation do not exceed the ceiling provides certainty to market actors with regards to supply and demand of sustainable aviation fuels and aircraft innovation. It also provides clarity to the aviation sector about the limits within which growth is possible according to the policy framework set by the Dutch government.

For these reasons, it can be concluded that a national CO_2 ceiling for aviation could be an effective instrument to ensure that the agreed CO_2 emission limits are not surpassed.

Different policy options for the CO_2 ceiling

There are various choices that can be made when designing the CO_2 ceiling. The most important choice is which entity is regulated: the airports, the fuel suppliers or the airlines? We defined those as our main policy options. Furthermore, a range of more detailed choices needs to be made. In our analysis we distinguished eight sub-options.

For the option where airports are the regulated entity, we defined three sub-options:
1. Strict allocation of the CO_2 budget to airports; 3-year compliance cycle.
2. Strict allocation of the CO_2 budget to airports; 1-year compliance cycle.
3. Soft allocation of the CO_2 budget to airports; 3-year compliance cycle.

For the option where fuel suppliers are the regulated entity, we defined three sub-options:
1. Auctioning revenues are retained as fiscal income for the state; a market stability mechanism is introduced.
2. Auctioning revenues are funnelled back to the aviation sector; a market stability mechanism is introduced.
3. Auctioning revenues are retained as fiscal income for the state; there is no market stability mechanism.

For the option where airlines are the regulated entity, we defined two sub-options:
1. Auctioning revenues are retained as fiscal income for the state.
2. Auctioning revenues are funnelled back to the aviation sector.

Impact of the CO_2 ceiling if it is not restrictive

In baseline scenarios 1 to 4, in which the capacity at Schiphol does not grow above 440,000, CO_2 emissions of commercial international flights departing from Dutch airports will remain below the CO_2 ceiling. In those scenarios, there are no impacts other than the implementation of the system, administrative costs and the risk of retaliation from the international community.

Impacts of the CO_2 ceiling if it is restrictive

In scenarios where Schiphol is allowed to grow after 2029, business-as-usual scenarios exceed the CO_2 ceiling. In those cases, regulated entities need to take action to reduce emissions to the level of the ceiling, with impacts on aviation, the environment and the economy. In this study, we compare the effects of the CO_2 ceiling compared to baseline scenario 8 (which can be seen as an upper bound). Therefore, when we speak of negative effects, we mean that the effects are negative in comparison to this baseline[29].

The impacts are largely in line with the impacts as described in the main impact assessment. Here we give a short summary of the impacts:
- Impacts on the aviation sector are that airlines will either have to limit the growth of the number of flights or fly in a more sustainable manner. Both options would likely lead to an increase in ticket prices and freight rates because of increased scarcity and additional costs (for example extra use of SAF) made by the airlines. Also, a restrictive ceiling would be a driver for additional fleet renewal towards a more efficient fleet. Impacts on fuel consumption would be that either less fuel is used (reduction of flights or shorter flights) or a shift from fossil kerosene to SAF is made. If the growth of the total number of flights is limited to prevent surpassing the ceiling, there are, compared to the baseline, negative effects on both the European and intercontinental network quality. If the total number of flights stays equal but additional costs are made (for example because of the use of extra SAF), then a shift in the network is observed: the intercontinental network becomes smaller due to more emissions per passenger, whereas the European network improves.

[29] Note that in the reference scenario and most other scenarios, the number of flights can keep growing compared to current levels in all subvariants. Therefore, if we speak of negative effects on the aviation sector, these should be interpreted as negative in comparison to the baseline. In absolute terms the network quality and other aspects do still improve compared to the current situation.

- The economic impacts of the CO_2 ceiling consist of compliance costs, administrative costs, auctioning revenues, fiscal impacts, cost of enforcement as well as upstream and downstream effects. Of these, the impacts of compliance costs are most significant. The compliance costs - specifically the fuel costs - in most policy options actually decrease due to the decrease in number of flights or increased share of shorter (intra-EEA) flights. For the options where regulated entities have to buy CO_2 certificates and the revenues go to the state, the compliance costs can be relatively high. The allowance revenues for the state are therefore a positive fiscal impact. The administrative costs and enforcement costs are negligible compared to the compliance costs.
- The environmental impacts are in general positive if the number of flight decreases: less aviation means lower climate impacts (both from CO_2 and non-CO_2 effects), less local air pollution and less noise in the surrounding of airports. For the CO_2 emissions, a significant share of the emissions that are reduced by the Dutch aviation sector are still emitted elsewhere due to evasion of flights to foreign airports, a shift to land transport or additional emissions in other EU ETS sectors. Still, a net positive climate effect remains. However, this effect is smallest in the ceiling per Airport option.
  If the emission reduction is used by means of SAF blending instead of reduction of the aviation volumes, this does not cause evasion. Therefore, the net climate effects are larger if this happens. Also, some positive effects on air pollution are obtained by blending SAF. However, this would not significantly reduce airport noise.
- Social impacts were defined in this study as the impacts on external safety and jobs in the Dutch aviation sector. The impacts on external safety are positive if the number of flights decreases, since this reduces accident risks. The effects on jobs in the Dutch aviation sector are small in all policy options. In 2030, when the CO_2 ceiling is most restrictive, in the Airport options the employment in the sector might be several percent lower compared to the volume of employment in the baseline.

In this study, we have tried to account for the uncertainty of future developments by defining eight different distinct baseline scenarios. Each presents a unique possible future. However, even these baseline scenarios do not cover all possible developments.
The 54 baseline scenarios that were studied in the main impact assessment (REF) provide additional insight in the effects of more/less ambitious European and national climate policy. It can be concluded that more ambitious and effective climate policy reduces the probability that the CO_2 ceiling will become restrictive and less ambitious climate policy increases the probability that the CO_2 ceiling will become restrictive.

There are also uncertainties that have neither been analysed in this study nor in the main impact assessment. Two important aspects are:
1. More ambitious international climate policy for the aviation sector. In our analysis we defined different scenarios for EU and Dutch climate policy. However, in all scenarios it is assumed that outside of the EU the ambitions are limited. If other regions in the world (such as the USA or China) or the international community agree on stricter climate policy for aviation, the level playing field is less disturbed by a Dutch CO_2 ceiling.
2. **CO_2** ceilings, other climate measures or reduced airport capacities in neighbouring countries. If neighbouring countries also limit the amount of aviation (by additional taxes, capacity restrictions, …), the possibility for evasion would be reduced. Therefore, the net climate effects would benefit from such developments.

How do the options compare?

The main objective of the CO_2 ceiling is to safeguard that the emission limits, which were set by the Dutch government, are not surpassed. In general, all sub-options are able to meet this requirement. However, the Airport option with a 3-year enforcement cycle (either soft- or strict allocation) scores slightly better compared to the alternatives on this point in the multi-criteria analysis. This is mainly because the implementation is reasonably simple (within the existing airport permits) and the risk of international retaliation is comparably low. In addition, the number of regulated entities (Dutch airports) is small (compared to the airlines in the Airline option) and all entities are situated in the Netherlands. However, the regulated entities have less direct control over CO_2 emissions than fuel suppliers and airlines. Because of the limited flexibility the Airport option with a one-year enforcement cycle scores lower than the Airport options with strict allocation.

The CO_2 ceiling is designed to achieve its main objective, but by doing so it also causes other effects. When comparing the options with respect to the other effects, it becomes clear that different sub-options perform well on different criteria. All options lead to a significant overall CO_2 reduction. In the Airport option this is mainly achieved by a reduction in the number of aircraft movements at Dutch airports, whereas in the Fuel supplier option and the Airline option blending additional SAF contributes significantly to the additional CO_2 reduction. The ceiling per airport sub-options scores well on overall costs and local environmental impacts. Furthermore, there are differences between the sub-options where the auctioning income is for the state versus the sub-options where the income is funnelled back: the latter scores better on overall costs and impacts on the aviation sector. Also, the impacts on the Dutch GDP are negative for these sub-options. It is important to consider that the state revenues that are generated in sub-options of the Fuel supplier and the Airline option can be used for other purposes, for instance to subsidise the development of sustainable aviation or contribute to other benefits for the society.

A fundamental difference between the options is who benefits from measures that decrease CO_2 emissions. In the Airport option the benefits are collectively distributed, which means that more slots become available for the collective of airlines operating at Dutch airports. In the Fuel supplier and Airline options airlines are individually stimulated to decrease emissions, because additional costs are attached to CO_2 emissions. In case the collective stimulus would lead to unintended reactions of the airlines, the Dutch government could decide to implement additional measures to correct these unintended effect.

In all baseline scenarios in which the capacity of Schiphol remains at 440,000 annual flights (baseline scenarios 1, 2, 3 and 4) CO_2 emissions stay below the CO_2 ceiling during the entire period. Therefore, the CO_2 ceiling is not restrictive. In those scenarios, only the feasibility of implementation, administrative costs and the risk of retaliation are relevant. Only if the ceiling would be surpassed in the baseline, the CO_2 ceiling has additional impacts on the aviation sector, the environment and the economy. This is the case if the capacity at Schiphol airport is allowed to increase from 2030 onward (baseline scenarios 5, 6, 7 and 8).

In this study we did not determine a preferred policy option, since this implies that relative weights are given to the different criteria. This is a political decision that should not be made by the research team. The main arguments in favour of the Airport option are the rather straight forward implementation in the existing airport permits and the relatively low risk of international retaliation. The main arguments in favour of the Fuel supplier and the Airline option are that the regulated entities have better possibilities to control over the CO_2 emissions and that airlines are individually stimulated to reduce their CO_2 emissions.

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A Changes in modelling assumptions

A.1 Changes due to new policy assumptions

In Section 2.1 we discussed the changes in policy assumptions compared to the main impact assessment. In this Annex it is explained how we translated these policy changes to concrete modelling assumptions.

- Schiphol airport capacity: we assumed a constant airport capacity of 440,000 flights per year in the period 2025-2029. In the year 2024, a capacity of 470,000 was assumed[30]. In the constant capacity scenarios, we assumed that this capacity limit remains until 2050. In the scenarios where growth can be earned, we assumed that 50% of noise reduction due to technological developments can be used for additional flights[31]. In this way, the people who live within the noise contours of the airport and the aviation sector benefit equally much from these improvements. It should be noted that this is a modelling assumption which is not based on concrete policy, since the mechanism through which capacity growth can be earned still needs to be defined. We have determined the maximum number of flights that corresponds to the previous 50/50-rule in 2050 and implemented a linear growth path of the capacity between 2029 and 2050. In addition to this criterium, an operational limit of 630.000 aircraft movements is implemented. This limit ensures that not more than 630.000 flights per year are possible during the entire period of this study.
- ReFuelEU Aviation blending limits: the old and new blending limits that we assumed are summarised in Table 23.
- ETD Fuel Tax: We have assumed that there will be no fuel tax due to the ETD revision.
- CORSIA: We now assumed that, due to COVID recovery, the aviation CO_2 emissions will reach 85% of the 2019-levels in 2024. Therefore, until 2024 no compensation is necessary. After 2024, we assume that the share of the total CO_2 emissions that needs to be offset linearly increases to 100% in 2050[32]. Officially, the CORSIA programme is not defined after 2035. However, due to the Long Term Aspirational Goal (LTAG) we concluded that it is unlikely that the system will not be continued after 2035. Due to the uncertainties and the difficulty of the system this simple modelling approach was chosen.
- Flight tax: we updated the flight tax with the latest proposals. We now assume that the flight tax is increased from € 8.48 to 26.43 starting in 2023. In the main impact assessment we assumed a flight tax of € 23.85, based on preliminary data.
- Lelystad airport: in the scenarios where Lelystad airport does open, the following capacity limits were assumed:
  - 2025: 4,000 flights;
  - 2030: 25,000 flights;
  - 2050: 45,000 flights.

[30] This choice was made to keep the discontinuous "shock" to the AEOLUS model to a minimum, since the model works best with continuous transitions.

[31] In reality, it is likely that other environmental constraints will be relevant as well. The choice to focus on airport noise was made because this is most practical for the modelling.

[32] This is in line with the recently agreed on "Long Term Aspirational Goal" of net-zero emissions in 2050.

Table 23 - ReFuelEU Aviation blending limits for departing flights in the EEA

Year	Old assumption	New assumption
2030	5%	6%
2040	32%	32%
2050	63%	63%

A.2 Other changes

A couple of other changes were made in the modelling compared to the main impact assessment:

1. An updated version of AEOLUS was used. This version has also been used for the estimations of the CO_2 emissions in the main impact assessment. The evasion module of AEOLUS was updated to also include evasion worldwide (not just to the Catchment area) and evasion of transfer passengers. This enables us to more accurately project passenger or CO_2 evasion effects to other parts of the world.
2. We improved two minor inaccuracies in the modelling:
   a. The EU ETS price were modelled to be slightly higher than intended due to double-counting of one component in the EU ETS price.
   b. For CORSIA, we initially applied offsetting costs to all CO_2 emissions for flights which are not covered by the EU ETS. This should have been limited to the share of emissions that exceeds the “carbon neutral growth” levels. We now corrected this mistake and adjusted the CORSIA assumptions due to the outcomes of the 41st ICAO Assembly.

We have studied the impacts of these methodological adjustments and concluded that the impacts of the changes in the calculation of EU ETS and CORSIA costs on the results are very limited. The impacts of using the updated AEOLUS model are more significant, especially on evasion to foreign airports. In the August update of the main impact assessment, we compared evasion results of the old and new version of AEOLUS. The model update is a significant enhancement of AEOLUS.

B AEOLUS update

Updated impacts of a CO_2 ceiling for Dutch aviation

Aan
Stefan Grebe (CE Delft)

Van
Gijs van Eck (Significance)

Datum
29 november 2022

Aanleiding

Wanneer de kosten voor vliegen via Nederlandse luchthavens omhoog gaan, zal een deel van de reizigers uitwijken naar alternatieven. Reizigers die in dat geval niet meer via een Nederlandse luchthaven reizen kunnen besluiten (1) niet meer te reizen, (2) te reizen via een buitenlandse luchthaven of (3) over land reizen (binnen Europa). Uit eerdere studies is gebleken dat de verhouding tussen de mate waarin naar deze alternatieven wordt uitgeweken grofweg 35% (niet meer reizen), 50% (vliegen via buitenlandse luchthavens) en 15% (reizen over land is). In een aantal runs met AEOLUS is echter naar voren gekomen dat het gemodelleerde uitwijkgedrag hier behoorlijk van kan afwijken. Dit speelt met name bij het doorrekenen van wat extremere toekomstscenario's. Omdat inzicht in het uitwijkgedrag in veel studies een belangrijke rol speelt, is er voor gekozen het AEOLUS luchtvaartmodel aan te passen op dit punt.

Aanpassingen

Om het probleem op te lossen is de passagiersmodule van AEOLUS allereerst grondig doorgelicht. In deze module wordt de totale vraag naar vliegen via Nederlandse luchthavens gemodelleerd. Hiervoor worden discrete keuzemodellen toegepast voor de hoofdvervoerwijzekeuze, de vliegroutekeuze en de vervoerwijzekeuze in het voor- en natransport. Op basis van de uitgevoerde analyse op deze vraagmodellen zijn de volgende vier aanpassingen aan AEOLUS gemaakt:

- Meenemen schaduwprijzen bij berekening vraag transferreizigers. De ontwikkeling van de kosten voor vliegen hebben invloed op de ontwikkeling van de vraag. Bij capaciteitsschaarste bestaan deze kosten naast de reguliere ticketprijzen ook uit schaduwprijzen. Door deze schaduwprijzen wordt de vraag gedrukt, zodat het aantal benodigde vliegbewegingen onder de capaciteitsgrens blijft. Voor transferreizigers werden deze schaduwprijzen niet meegenomen in de berekening van de ontwikkeling van het aantal transferreizigers. Dit is gecorrigeerd in de nieuwe versie van het model.
- Meenemen schaduwkosten in de hoofdvervoerwijzekeuze. Voor relaties binnen Europa wordt in AEOLUS ook de hoofdvervoerwijzekeuze gemodelleerd. Reizigers kunnen er naast vliegen ook voor kiezen om met de auto of per trein te reizen. Deze keuze wordt mede bepaalt door de reiskosten die bij deze alternatieven horen. Bij de implementatie van

AEOLUS is er om praktische redenen (geheugenbeperkingen) voor gekozen om eerder genoemde schaduwprijzen voor vliegen hierbij niet mee te nemen. Inmiddels is dit rekentechnisch wel haalbaar. In de nieuwe versie spelen schaduwprijzen daarom ook een rol in de hoofdvervoerwijzekeuze.

- Wegnemen samenstellingseffect in berekening gemiddelde ticketprijzen. Voor elke relatie worden gemiddelde ticketprijzen berekend over alle vliegroutes tussen de betreffende herkomst en bestemming. De ontwikkeling van deze gemiddelde ticketprijzen speelt een rol in de modellering van de totale vraag naar vliegen. Bij het berekenen van de gemiddelde ticketprijzen wordt gewogen naar de aandelen van elke route. Deze aandelen veranderen echter jaar op jaar, waardoor een samenstellingseffect ontstond. Om dit te ondervangen wordt nu gerekend met de routeaandelen uit het voorgaande jaar. Hiermee is het samenstellingseffect in de gemiddelde ticketprijzen in de nieuwe versie van AEOLUS weggenomen.
- Correctie berekening totaal aantal reizen. Op relaties waar het marktaandeel vliegen klein is, komt het voor dat bij een prijstoename de afname van het totaal aantal reizigers groter is dan de afname van het aantal luchtreizigers. Dit was het gevolg van een inconsistentie tussen de kostengevoeligheden van de vraagontwikkelingsmodule (aantal reizen) en het hoofdvervoerwijze-keuze model. Deze inconsistentie is verholpen door een correctie in de vraagontwikkelingsmodule die alleen effect heeft op relaties met een klein marktaandeel vliegen.

Resultaat modelwijzigingen

Het effect van deze aanpassingen is getoetst door middel van een serie testruns. Hierin is gekeken welke impact (1) capaciteitsrestricties, (2) een vliegbelasting voor OD-reizigers, (3) een vliegbelasting voor transferreizigers en (4) de opening van luchthaven Lelystad hebben op het uitwijkgedrag. Ook is gekeken naar de effecten bij het combineren van deze beleidsmaatregelen. Om vast te stellen welk uitwijkgedrag als plausibel kan worden verondersteld is uitgegaan van een vliegbelastingstudie uit 2007, een ex-post analyse van het KIM uit 2011 (uitgevoerd enige tijd na de afschaffing van de vliegbelasting destijds) en van expert judgement. Uit de uitgevoerde tests blijkt dat de orde van grootte van het uitwijkgedrag nu goed overeen komt met de eerder genoemde percentages (35% niet meer reizen, 50% vliegen via buitenland en 15% reizen over land). Op de prognoses van het aantal vluchten op Nederlandse luchthavens is de impact van de wijzigingen relatief beperkt. Meest opvallende verschillen zijn een kleine verschuiving van transfer naar OD op Schiphol en iets langzamere ontwikkeling van de vraag op de regionale luchthavens. Deze kleine verschillen zijn rechtstreeks verklaarbaar vanuit de doorgevoerde aanpassingen.

C Additional projections baseline scenarios

Section 2.3 summarised the development of Dutch aviation in the various baseline scenarios. This Annex presents additional projections for the Dutch aviation development in the baseline scenarios.

The figures indicate the following variables:
- Figure 35 - Number of European passenger flights to and from Schiphol airport in the baseline scenarios
- Figure 36 - Number of intercontinental passenger flights to and from Schiphol airport in the baseline scenarios
- Figure 37 - Number of flights to and from regional airports in the baseline scenarios
- Figure 38 - Number of passengers travelling via Dutch airports in the baseline scenarios
- Figure 39 - Number of OD passengers travelling via Schiphol airport in the baseline scenarios
- Figure 40 - Number of transfer passengers travelling via Schiphol airport in the baseline scenarios
- Figure 41 - Number of passengers travelling via regional airports in the baseline scenarios

Figure 35 - Number of European passenger flights to and from Schiphol airport in the baseline scenarios

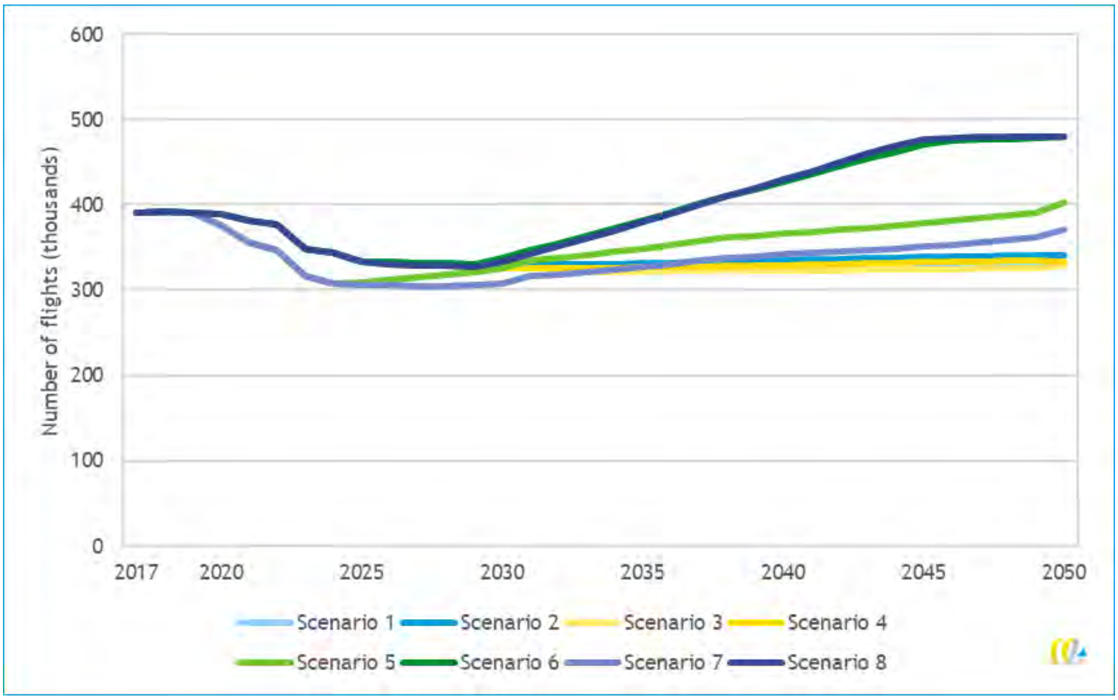


Figure 36 - Number of intercontinental passenger flights to and from Schiphol airport in the baseline scenarios

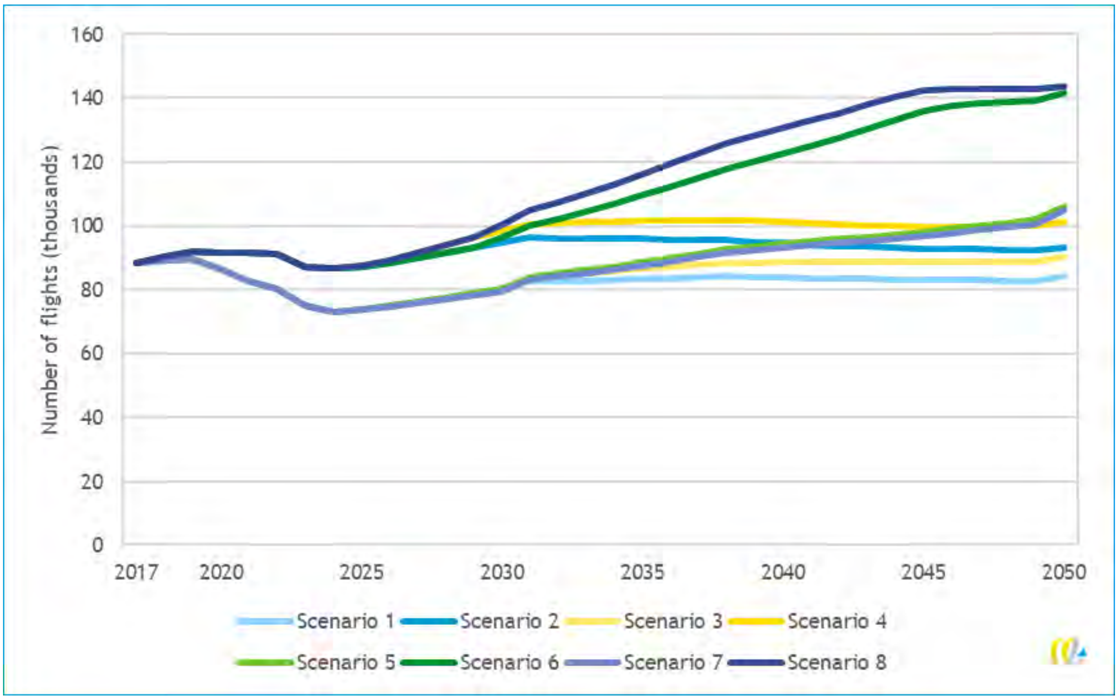


Figure 37 - Number of flights to and from regional airports in the baseline scenarios

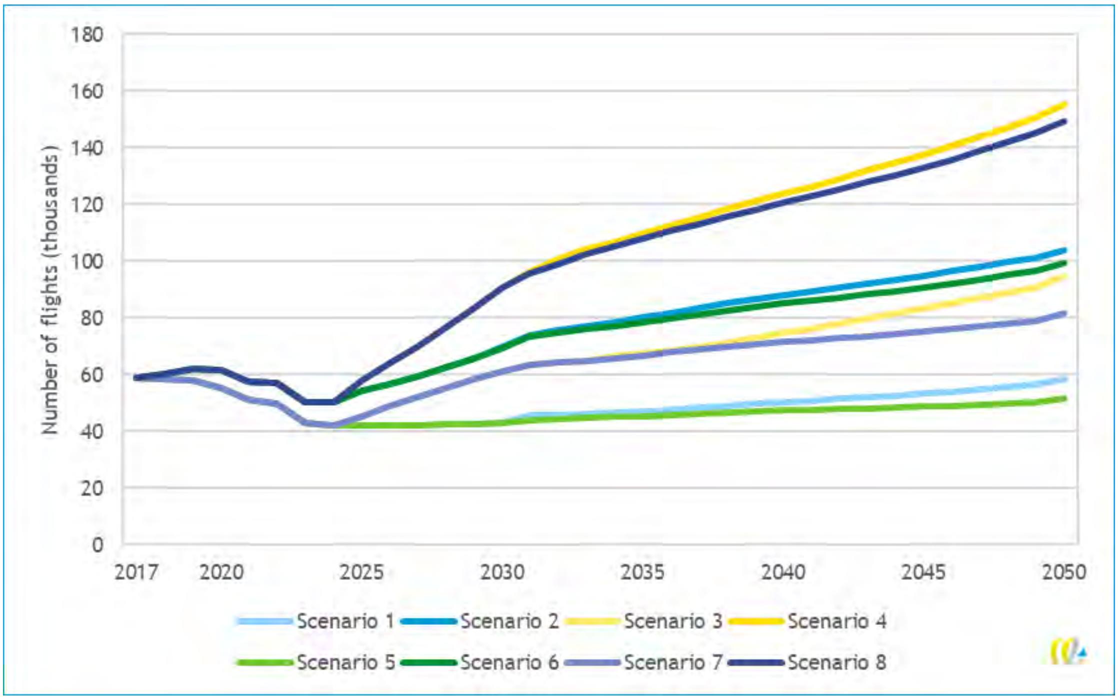


Figure 38 - Number of passengers travelling via Dutch airports in the baseline scenarios

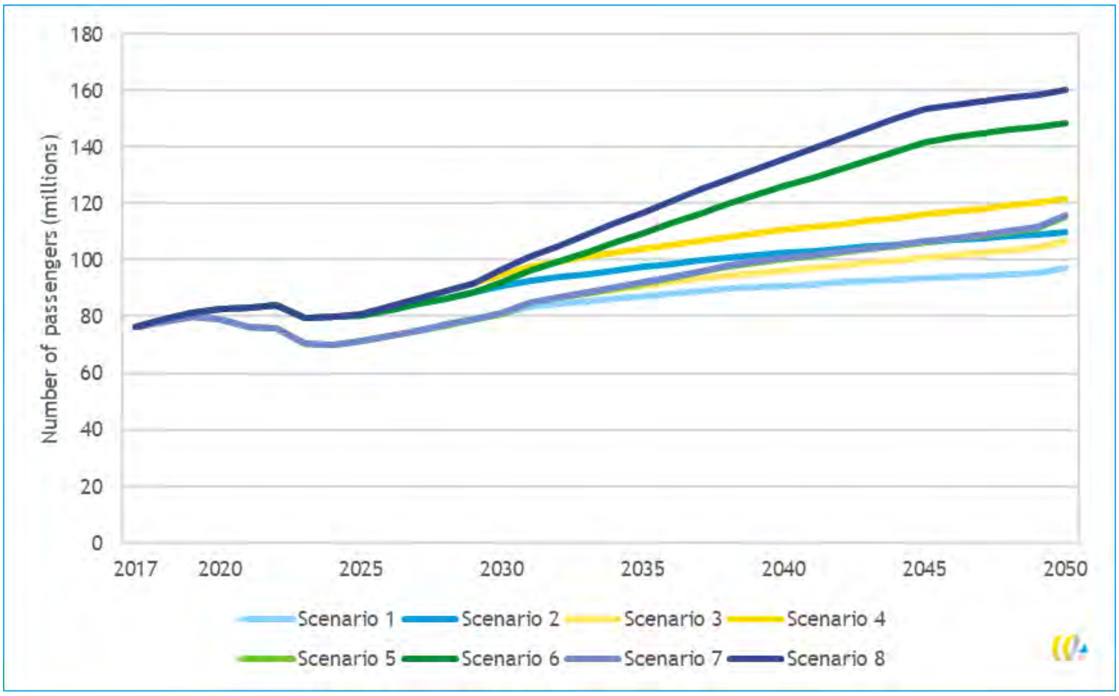


Figure 39 - Number of OD passengers travelling via Schiphol airport in the baseline scenarios

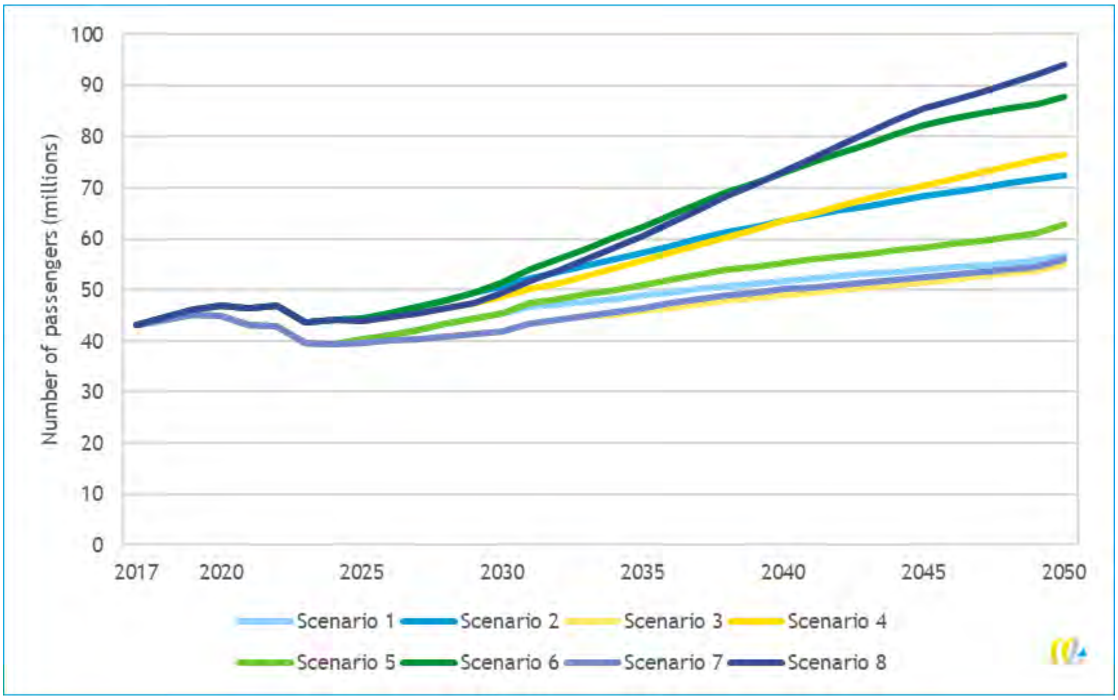


Figure 40 - Number of transfer passengers travelling via Schiphol airport in the baseline scenarios

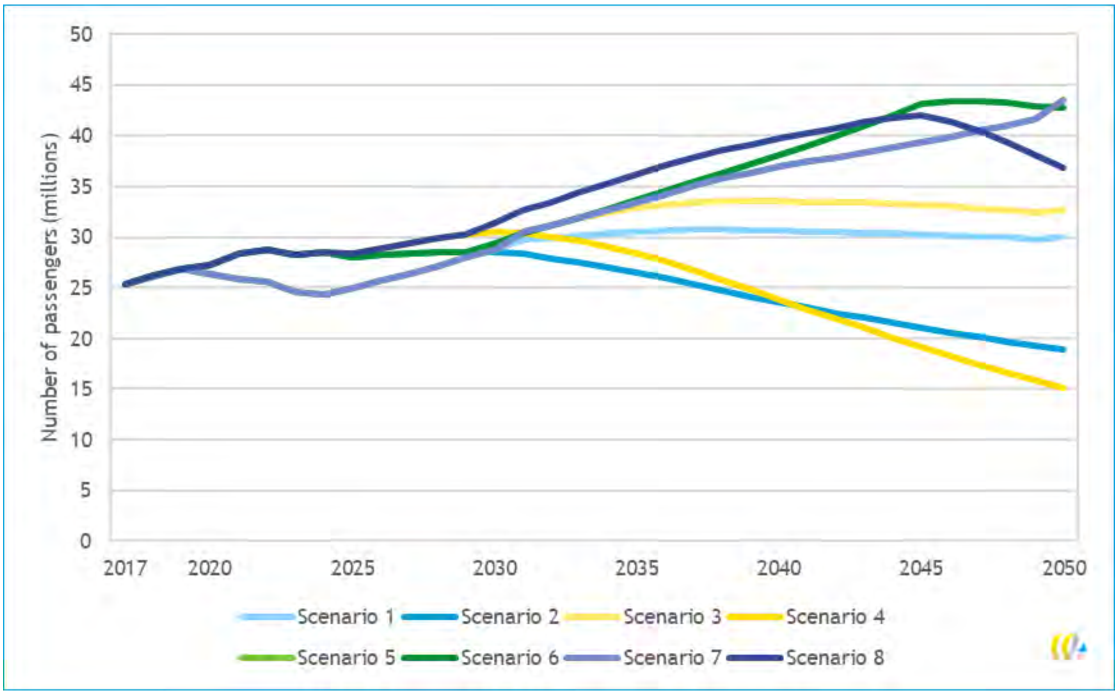
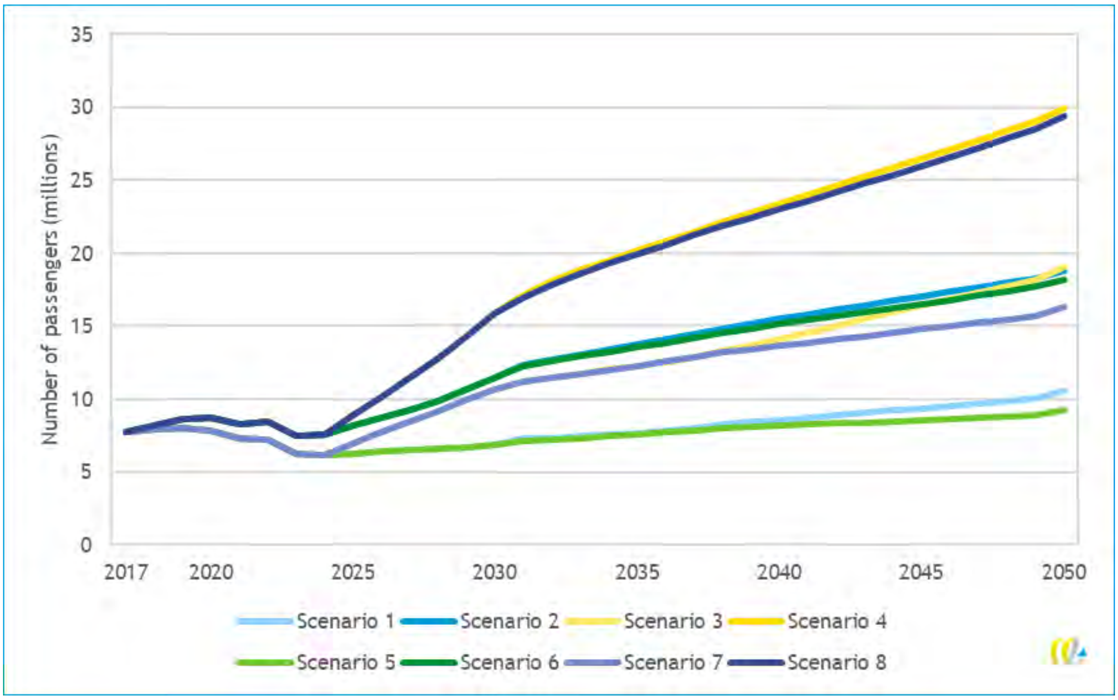


Figure 41 - Number of passengers travelling via regional airports in the baseline scenarios



D Update on economic effects

In Chapter 3 of the main impact assessment the economic impact of the CO_2 ceiling has been analysed in detail. Since most of the economic impacts are not systematically affected by the update (the magnitude of effects is affected indeed), this part of the impact assessment is not entirely updated in this report. In this Annex, we provide a short interpretation of the economic effects of the CO_2 ceiling and describe where effects are expected to be different than estimated in the main study.

As a result of the changed assumptions in the baseline scenarios, the CO_2 ceiling is expected to be restrictive from 2033 to 2048 in the most restrictive scenario (baseline scenario 8). The effects in scenario 6 are comparable, those in scenarios 5 and 7 are much smaller and occur only between 2042 and 2047. In baseline scenarios 1 to 4 the CO_2 ceiling is not restrictive and has only effect on administrative costs.

Compliance cost

Fuel cost

In the updated baseline scenarios, similar effects on fuel use and SAF uptake apply due to the effects of the CO_2 ceiling on fuel prices. In the Airport option there is no effect on the fuel costs. In both, the Fuel supplier and Airline options fuel prices until 2040 increase due to costs for emission rights and after 2040 due to additional SAF blending. Since the increase in price scales with the amount of CO_2 that has to be supressed, the effect is largest around 2045.

ETS and CORSIA cost

The effect on ETS and CORSIA costs/revenues is proportional to the restrictiveness of the CO_2 ceiling. Hence, the results of the main impact assessment can be scaled to determine the effects in this update.

Fuel tax cost

The assumption that no European fuel tax (ETD) will be implemented means the aviation sector does not pay a fuel tax in all projected years. This implies that the CO_2 ceiling can also no longer influence the ETD revenues.

Allowance cost

The cap of the CO_2 is unchanged in absolute terms and the allowance costs are determined by the marginal cost for reduction of CO_2 emissions. Due to difference in ETS and CORSIA cost, there is a difference in the marginal reduction cost on intra-EU and extra-EU flights. However, under equal SAF prices we can expect similar allowance prices and consequent auctioning revenues. Under the changed modelling assumptions on capacity restrictions and growth rules airlines may change the number of flights to intra-EU and extra-EU destinations. Therefore, there might be a small deviation in the allowance prices and auctioning costs for the airlines due to a possible different ratio of aviation traffic on intra-EU and extra-EU flights under the changed assumptions.

Administrative costs

The administrative costs are not directly dependent on the changes in the number of flights and passengers, or the changed modelling assumptions for the ETD and blending rates. Therefore, the administrative costs are similar as described in Section 4.3 of the main impact assessment.

Allowance price and auctioning revenue

The cap of the CO_2 is unchanged in absolute terms. This means that for similar SAF prices and cost of other CO_2 reduction options we can expect similar allowance prices and consequent auctioning revenues if demand and supply are unchanged. Under the capacity restrictions and growth rules airlines may change the number of flights to intra-EU and extra-EU destinations. Therefore, there will be deviation in the allowance prices and auctioning revenues due to a possible different ratio of aviation traffic on intra-EU and extra-EU flights under the changed framework conditions.

Fiscal effects

The changes in tax revenues related to the number of passengers (general aviation tax and indirectly corporate taxes) are proportionally to the reduced number of passengers on departing OD flights under the CO_2 ceiling. The expected changes in tax revenues related to the volume of aviation traffic (EU ETS revenues, CO_2 ceiling auctioning revenues) under the CO_2 ceiling are equal to the effects as described in main impact assessment. This is also the case for the revenues from the auctioning of the CO_2 ceiling allowances, as described earlier in this section. The assumption that European fuel tax (ETD) will not be implemented results in zero fuel tax revenue. Equal mechanisms apply for changes in indirect taxes (user taxes: VAT, excise duties, etc.) caused by Dutch passengers spending more in the national economy and foreign passengers spending less in the Netherlands, as described in the fiscal effects section of the main study.

Enforcement cost

The expected enforcement costs for the CO_2 ceiling are identical as outlined in the main impact assessment, as the changed assumptions are not related to the enforcement cost. We refer to Section 4.6 in the main study for the enforcement cost of the CO_2 ceiling.

Upstream and downstream effects

The implications for the upstream and downstream effects as outlined in Section 4.7 in the main impact assessment are still valid for this update. The changed assumptions do not fundamentally change the implications for the agglomeration effects if a CO_2 ceiling is implemented. This is valid for the passenger as well as for the cargo segment. Moreover, we consider the CO_2 ceiling will have identical effects on consumer spending as outlined in the main impact assessment. Depending on the strictness of the CO_2 ceiling - the amount of reduction that will need to be achieved in a certain year, compared to baseline emissions of that particular scenario - the mutations in consumer spending by the different passenger groups can be slightly higher or lower. Still, similar mechanisms apply under the CO_2 ceiling.

Innovation

The changed modelling assumptions do not directly influence the development of innovation in the aviation sector as described in Section 4.8 of the main impact assessment. As mentioned, the CO_2 ceiling options will imply higher costs for CO_2. From an airline perspective, higher costs for CO_2 has the same implication as an increase in fuel cost due to the direct relation between fuel use and CO_2. The drive for operators to reduce costs by implementing novel technologies within their fleet will be to reduce fuel consumption in general, with the additional benefit of reducing costs relating to CO_2 emissions.
The incentive for airlines to implement novel technologies or renew their fleet, is pending on the associated costs. If the costs do not outweigh the benefit, a government incentive as the CO_2 ceiling can enforce this change.