Summary

The aviation sector is expected to continue to grow worldwide over the coming decades. Autonomous efficiency improvements, brought about by the deployment of new conventional technologies, cannot prevent CO_2 emissions from aviation from increasing.

In order to decrease the CO_2 emission levels from aviation and thus achieve the global objectives set for CO_2 emissions in 2050, there is a need for additional technological and operational reduction options, including the large-scale use of sustainable bio-kerosene. Owing to various obstacles, however, there is great uncertainty about the feasibility of achieving the full reduction potential of these additional reduction options. If the obstacles cannot be overcome, certain additional measures pertaining to the growth of air traffic are also perhaps required in order to achieve the stated aims.

The government has various policy options at its disposal for stimulating the deployment of reduction options, and thus removing the existing obstacles. An efficient reduction policy should be instituted via two tracks. The first track focuses on making CO_2 emissions more expensive, which, as an incidental effect, steers innovation in the direction of clean technology. The second track focuses on the development of knowledge and innovation, which, as an incidental effect, means that the average costs per avoided ton of CO_2 decreases, whereby greater emission reductions become socially optimal.

Ambitions for sustainable aviation

Aviation is expected to continue to grow worldwide over the coming decades. Aviation's share in the global CO_2 emissions deriving from all human activities is also expected to increase. The aviation sector, governments, and scientists are therefore searching for ways to make aviation more sustainable. The (international) ambitions for this are great. The leading representatives of the aviation industry have collectively set the objective of improving fuel efficiency by 1.5% annually by 2020. Subsequently, aviation should become CO_2-neutral, and, by 2050, emission levels should be 50% lower than in 2005. The International Civil Aviation Organization (ICAO) and the EU have fairly similar ambitions.

Focus on reduction options and policy options

In this quick scan, sustainability is narrowly interpreted (only CO_2), with the emphasis on reduction options and policy options for reducing aviation's CO_2 emissions. The reduction options are all technological and non-technological solutions that limit CO_2 emissions. The policy options are the possible policy instruments that the Dutch government can deploy, or can pursue in the international context, in order to render aviation more sustainable.

CO_2 emissions from aviation can be regarded as a product deriving from three factors: volume, aircraft efficiency, and the CO_2 intensity of fuel. Volume represents the number of kilometres flown by passengers and freight. Aircraft efficiency denotes the energy used per kilometre flown, and CO_2 intensity represents the net contribution that the use of a certain fuel makes toward the total amount of CO_2 in the atmosphere. Each factor has its own reduction options. Policy options pertain to one or more of these factors.

Two types of reduction options

Two types of reduction options can be distinguished: optimistic and futuristic. Optimistic reduction options are those options wherein the functionality is already more or less proven, but in which the aircraft concept, the aircraft use, and/or the fuel substantially differs from the current, conventional aviation system. We call them 'optimistic' because future use of these options is in no way self-evident, owing to the fact that these options differ significantly from existing technology. Futuristic options are those options in which the functionality thereof has not yet or has been unsatisfactorily proven.

The optimistic options are:

1. *Open rotor:* an engine type that, in terms of appearance, looks like a cross between a jet engine and a turboprop engine.
2. *4D ATM:* optimisation of air traffic management (ATM) in the three spatial dimensions and over time (more direct flights, gradual climb and descent). In Europe, this option is being researched within the SESAR-program (Single European Sky ATM Research).
3. *Stopovers*: a concept in which aircraft make stopovers for refuelling at around the halfway point to their final destinations.
4. *Refuelling in air:* a concept in which aircraft refuel in the air at around the halfway point to their final destinations
5. *Formation flying:* aircraft with similar flight directions are grouped together for (part) of the flight, flying in a V-formation.
6. *Sustainable bio-fuel:* a drop-in fuel based on a non-fossil fuel source, for which no changes to the aircraft or engine system are required.

The futuristic options are:

1. *Blended wing body:* an aircraft concept in which the fuselage and wings are merged into one large wing.
2. *Prandtl Concept:* an aircraft concept that has two wings on each side of the aircraft. The front wings more or less look conventionally and have other wings connected to their wing tips that connect to the end of the plane.

A background research study conducted by the National Aerospace Laboratory of the Netherlands (NLR) also studied the 'cruiser-feeders' concept (in which passenger transfers occur in the air), the 'electric aircraft', and the 'hydrogen aircraft' (an aircraft whose electric, propeller-driven engines are powered respectively by hydrogen-based batteries or fuel cells). However, these futuristic options are not expected to be available before 2050.

Reduction potential is present…

CO_2 emissions from aviation are a global problem. Important is the total reduction potential of combinations of reduction options with respect to a reference situation, in which efficiency improvement occurs as well, through continuous fleet renewal with ever improving conventional technology. For conventional technology, the jet engine and the current shape of the airframe remain the starting points; consequently, the focus is namely on the use of more efficient jet engines, improved aerodynamics and weight saving.

The NLR conducted model calculations for the development of CO_2 emissions when applying all optimistic options with and without biofuels, and when applying all optimistic and futuristic options. Moreover, the emissions reduction that is achievable by refuelling in the air, and the emissions reduction that is achievable by stopovers, was only counted once. It was assumed that these options in fact will have an effect on the same group of flights. Because of the higher reduction potential of refuelling in the air, this potential was taken into account.

Compared to the reference situation the optimistic options, without biofuels, offer a possible reduction of 25%. If biofuels are included, this reduction will be 85%. If the futuristic reduction will be deployed as well, an extra 3% percent reduction by 2050 is possible compared to the reference point (88%).

In order to gain insights into the feasibility of achieving the ambitions set for the CO_2 emissions from aviation in 2050, the reference situation is based on three different volume growth scenarios: a growth of 2%, 3.5% and 5% per year. The analyses reveal that, given the assumptions about the reduction potential of each individual option, the various aims for 2050 are only achievable with a 3.5% volume growth per year or less, and this in combination with a large-scale deployment of sustainable biofuels.

….but is threatened by obstructing factors

When estimating the reduction potential, the assumption is that the various obstacles in the way of deploying the reduction options can be overcome.

Obstacles may arise from higher operating costs than with conventional technology, but at present new technologies may also be insufficiently safe, quiet or clean, as compared to conventional technology. Moreover, the use of these new technologies must also coincide with the preferences of passengers: an attractive product, comfortable, and so forth.

Owing to the existing obstacles, the reduction potential of the various options is not a given, and – if the obstacles are not overcome – also cannot be fully exploited. The feasibility of the reduction potential for the optimistic and futuristic range of options is thus in practice highly uncertain.

Policy options can remove obstacles

The Kyoto Protocol, which pertains to the reduction of greenhouse gas emissions, established the International Civil Aviation Organization (ICAO) as the forum in which developed countries will devise an approach for reducing emissions from international aviation. The establishment of effective, global measures for reducing CO_2 emissions from international aviation is in practice a lengthy process, because, in part, countries struggle to agree on a sharing of responsibilities. Consequently, very little progress has been made to date in terms of agreeing to a concrete set of measures.

Although the ICAO is the most important worldwide forum for governments to take steps in the area of sustainable aviation, possibilities also exist on the European and national levels. The potential effectiveness of measures decreases as the geographic scale becomes smaller, while the probability of *carbon leakage* and too large competitive disadvantages increases. In addition, it is important that national and/or European Union regulations do not conflict with international agreements and treaties.

In order to remove obstacles that stand in the way of applying the reduction options, the Dutch government has certain policy instruments at its disposal that can be deployed on the national level, or can be pursued in the international context - ICAO or EU – in order to render aviation more sustainable. Some obstacles can only be removed with innovation; for example, when a reduction option is not yet fully technologically developed, is still too expensive, and/or still has too many undesirable side-effects. The market itself can function to remove these types of obstacles.

In addition, certain types of market failures (externalities) can become obstacles to (sufficient) innovation. As long as the external costs of CO_2 emissions are not charged, the reduction options will remain relatively too expensive, and a socially optimal demand for reduction options will not arise. In innovation processes, externalities (knowledge spillovers) can also play a role, leading to less innovation than is socially optimal.

Roles and policy instruments for government

Governments can act according to various role perceptions. There are four basic roles for the government to play: regulator (compulsory), facilitator (creating conditions), realiser (self-realization) and communicator (informing). Each role has it's appropriate policy instruments.

There are certain conceivable policy instruments that pertain to all factors (volume, aircraft efficiency, and the CO_2 intensity of fuel); for example, emissions trading, emissions taxes, fuel taxes and CO_2 compensation. Numerous policy instruments are also conceivable that specifically pertain to one of these factors, including the integration of the (European) air space (volume), an efficiency standard for aircraft (aircraft efficiency), and a financial incentive (for example, subsidies) for developing knowledge and technology in the field of bio-kerosene (CO_2 intensity of fuel).

It is impossible in advance, to determine which specific policy options are in general the most effective and/or efficient, as this is highly dependent on the objectives to be achieved and the various design choices. In general, it can be stated that financial incentives are often more efficient than standards or regulations. Policy options that apply to multiple factors are also generally more efficient than policy options that only apply to one factor. A good approach usually includes a customised, coordinated, and over time varying deployment of various policy measures.

Efficient reduction policy has two tracks

Because the innovation process includes knowledge spillovers, a CO_2 policy - for example a CO_2 standard or CO_2-pricing - is in itself insufficient for facilitating a CO_2 reduction in aviation in a cost-efficient manner. It is better to set up an efficient reduction policy based on a two-track approach. The first track focuses on making CO2 more expensive and has the additional effect of steering innovation toward clean technology. The second track focuses on stimulating knowledge and innovation. This track has the additional effect of lowering the average costs per avoided ton of CO_2, whereby larger emission reductions become socially optimal. This is to say that for a larger number of reduction options, the costs per avoided ton CO_2 become lower or equal to the damage costs per emitted ton of CO_2.