Agrofuels in planes

heating the climate at a higher level

Milieudefensie - Friends of the Earth Netherlands

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Credits

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February 2012

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Don't take off in the wrong direction
Stop Biokerosene

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Management Summary

Aviation has been widely identified as an important and growing driver of climate change[1] responsible for 4.9% of global climate forcing emissions. Airlines routinely refer to the fact that at current levels of demand, aviation accounts for 'only' 2% of global CO_2 emissions. In Europe, aviation accounts for 3.5 % of European CO_2 emissions[2].

Aviation has two major impacts on the climate – one is the global warming impact of carbon dioxide released through aviation fuel combustion, the other is the global warming impact of heat trapped by contrails and aviation-induced cloudiness (AIC). Over a period of 100 years, these effects are of approximately the same magnitude – over a period of 20 years, contrails and AIC dominate the effect.

As the climate impact of planes is double the impact of CO_2 alone, the sector accounts for 7% of European contribution to climate change. For the Netherlands this percentage is over 10%. Unlike other sectors, overall global CO_2 emissions in the transport sector are increasing rather than falling. Within transport, aviation is the fastest growing source of climate forcing emissions. Urgent policy action is therefore necessary.

Aviation in Europe grew 80% since 1990 and a similar growth figure is foreseen by the European Comission till 2020. The aviation industry has committed to 'carbon neutral growth' from 2020, claiming that by using agrofuels and other emission-saving measures, business as usual aviation growth of 4.5% per annum, can have zero additional effect on the climate. However, because alternative aviation fuels (such as agrofuels) will not reduce the formation of contrails or the occurrence of AIC, they can only be used to reduce half of the global warming impact of aviation. When the 'well-to-wake (+)' emissions approach[3] (which accounts for contrails, AIC and other non-CO_2 effects) is applied to aviation agrofuel use, we find that in the growth scenario suggested by the industry, rather than reducing emissions by 45% in 2050 compared to 2010, the climate change impact of aviation would actually increase by 180%. Using the veneer of 'climate neutrality' to justify future aviation growth is therefore highly misleading. Aviation growth will be anything but sustainable – including where agrofuels are used.

Given the risks associated with agrofuel expansion due to the current impossibility to avoid damaging land use change, government and the aviation industry should:

- consider measures to limit growth such as fuel taxation and VAT on tickets;
- investigate as a matter of urgency measures to reduce contrail and AIC formation;
- avoid making misleading claims about the future climate impact from aviation based on metrics that ignore contrails and AIC let alone claiming 'carbon neutral growth';
- withdraw any agrofuel targets as long as agrofuel production inevitably leads to (indirect) land use change, causing carbon emissions, land scarcity and social problems.

1 Lee et al., 2009

2 European Environment Agency 2012

3 Stratton et al., 2011b

1. The history of aviation, science and climate policy

The aviation sector has become an iconic part of Western economies. Although one might have the impression that everybody flies, only a small group uses air transport on a regular basis. Research in the Netherlands showed that only 50% of the population travelled by plane in the period 2004-2006. A few decades ago air travel was an activity for the happy few. The fast growth of aviation in wealthier societies and by individuals worldwide has turned it into a leisure option that makes curbing climate change difficult. Scientists are clear about the problem, but politicians lag behind on this issue.

Science

It has long been recognised that aviation might have climatic impacts beyond those associated with the combustion of carbonaceous fuels. In the late 1960s and early 1970s several papers identified a potential link between contrails and climate[4]. More recently, in the 1980s Paul Crutzen and others initiated research into links between nitrogen oxide or NOx (NO + NO2) emissions and formation of the greenhouse gas tropospheric ozone. Further research has identified a range of links between direct aviation emissions and consequent processes with a climatic forcing impact[5].

But the first serious attempt to combine and quantify all known effects was the 1999 IPCC report 'Aviation and the Global Atmosphere'[6]. Uncertainties remained however, as the effects of aircraft on the climate are complex and difficult to research.

The impact of CO_2 emissions by aircraft is easy to calculate, as it is the same as all other tailpipe CO_2 emissions. Other impacts such as the emission of water vapour, particles and nitrous oxide are more difficult to assess as they last for a short time but have a large effect on the climate. IPCC suggested a mean value of total climate impact of 2.7 times the impact of CO_2 alone, but excluded aircraft induced cloudiness, as too much uncertainty was involved.

In 2005 Sausen et al. published an update[7] of the IPCC report. The most prominent correction they made was the strongly reduced climate effect of contrails. Therefore Sausen et al. came to a lower estimate of the combined climate effect. At the same time the article warned of the effects of aviation induced cloudiness, which had become more clear by that time, but were too difficult to quantify and thus could not be taken into account.

Lee at all published an update[8] in 2009 in which they calculated the global effect of aviation on the climate, including cloud effects, as 4.9% (mean estimate). That is 2.8 times the effect of carbon dioxide emissions alone. Although there have been some adaptations in assessment of individual effects, the overall picture remains the same, as scientific understanding of the mechanisms has grown and measurements in the atmosphere have confirmed the effects. Scientists calculate a climate effect that is at least double the effect of CO2 alone (see appendix 1). The amount of cloudiness that can be attributed to aircraft remains one of the key uncertainties.

The global regulatory framework for the aviation sector

Since the Second World War, the aviation sector has been regulated by the 'Chicago Convention' that was designed to facilitate the new aviation industry. Airlines were considered the way to connect peoples and nations worldwide and to bring about peace and prosperity. It was therefore decided that countries would not impose taxes on each other's airlines. The International Civil Aviation Organisation (ICAO) became the global regulating body. This system is still in place, even though the aviation sector

4 Reinking, 1968; Kuhn, 1970; SMIC, 1971 as quoted in Lee (2009)

5 Prather et al., 1999

6 IPCC 1999

7 Sausen et al., 2005

8 Lee et al., 2009

has become a common economic sector. Airlines have become used to conducting their business without paying taxes on fuel or VAT and without pollution regulations being applied to their flight operations above 300 metres. It is hard to change this situation on a global scale as this would have to be done in the ICAO framework and aviation authorities from all member states would have to agree on new regulations.

In the negotiations on the Kyoto Protocol, it was decided to leave the global shipping and aviation sector to the sectoral UN bodies, which is the ICAO for the aviation sector. Unfortunately, the ICAO never managed to do anything more then suggesting voluntary schemes and issuing optimistic statements on improved efficiency in the sector.

EU climate policy for the aviation sector

The European Union has been hoping and pushing for global action by the ICAO, but started to develop and implement a regional system when it became clear that the ICAO was unable to act. The Union chose to link the aviation sector to the emissions trading scheme (ETS) it had been running for bigger companies such as power companies, steel plants and the chemical industry.

The European Parliament supported a strong ETS but unfortunately the aviation sector successfully lobbied the member states and was able to create several loopholes that made the system ineffective:

- free emission allowances for almost all emissions based on historical emissions;
- the option to buy allowances from other industries without taking into account non-CO_2 emissions that in the aviation sector are responsible for at least half the climate impact;
- agrofuels are regarded as zero emission fuels.

As a result the aviation ETS became an easy way out for the European airlines.

US airlines and other non-EU airlines and governments, however, regard the EU aviation ETS as an attack on the liberties enshrined in the Chicago Protocol. The US and other countries have threatened the EU that they will take action against the ETS. This is a strange situation, as airlines based outside the EU have fewer flights in Europe and therefore fewer ETS costs than airlines based within the EU. Research even predicts windfall profits for US airlines because of their inclusion in the EU ETS[9].

The effect of the EU emission trading system on the use of agrofuels

The aviation ETS motivates airlines to use agrofuels because the ETS falsely assumes that agrofuels have no net greenhouse gas emissions. Using agrofuels therefore makes zero-emission growth possible, on paper at least.

This is a result of the Kyoto Protocol which uses the same calculation method and of the decision to neglect climate effects of aeroplanes other than CO_2 emissions. Under the Kyoto Protocol, emissions related to the production of agrofuels are accounted for in the country where the components are grown. The credit is assigned to the country where the fuel is burned, which assumes that the CO_2 emitted was absorbed from the atmosphere when the fuel components were grown. This seems reasonable, but the problem is that countries that produce agrofuels have no obligations under the Protocol. These agrarian emissions are therefore not accounted for anywhere. This is a big caveat as we will see in Chapter 5.

Another aspect is the non-CO_2 climate impacts of aeroplanes that are responsible for at least half the climate impact of a plane. Those have also been left out of the EU aviation ETS as was explained earlier in this chapter.

9 Malinaa et al., 2012

2. Agrarian fuels - the solution for the aviation sector?

The aviation industry, policy-makers and the producers of agrarian commodities view agrofuels as the solution to growth of the sector. They plan to use about 2 million tonnes of bio-kerosene per year by 2020 in Europe, compared to almost none now. European kerosene consumption was 53 million tonnes in 2010[10], and is expected to increase to about 64 million tonnes by 2020. This means that about 3% of all the kerosene in Europe will be bio-kerosene by 2020.

Airline companies frame the use of agrofuels as a matter of survival. They have several reasons for increasing their use of agrofuels:

- Realising growth: Using agrofuels is seen as the only solution companies have to answer the growth question. Lufthansa stated: ‘As air transport is the only mode of transport that will remain dependent upon liquid fuels for the foreseeable future, the aviation industry and the research community must develop and test alternatives.’ Christoph Franz, CEO of the Lufthansa Group, stated: ‘Fossil raw materials are finite.’ In reality the aviation sector will have the bargaining power to buy fossil fuels made from oil, gas or coal for the foreseeable future.
- Costs: As fossil fuels will become scarcer and prices will rise in the future, agrofuels might be cheaper than conventional oil in the more distant future. Furthermore, under the European ETS system, airlines will have to pay for the CO_2 they emit as of 2012, but won’t have to pay for emissions coming from agrofuels, as they are falsely regarded as emitting zero emissions. The IATA has estimated that the ETS will cost the industry €3.5 billion in the first year alone. Therefore, using agrofuels brings the potential for huge savings in the future.
- Image: Promoting the use of agrofuels will give airline companies a greener image and will make them look better than their competitors.

However, the industry’s desperate search for and development of new ‘green’ fuels to make their expansion affordable and acceptable by providing a green image triggers many effects that harm the climate, people and nature.

10 Flightpad, http://ec.europa.eu/energy/technology/initiatives/doc/20110622_agrofuels_flight_path_technical_paper.pdf

3. The climate impact of agrofuels for planes

In the context of rising carbon dioxide emissions and pressure to make aviation more environmentally sustainable, agrofuels have been identified by many airlines, governments and other organisations as a growth-friendly alternative to the regulating demand for limiting the climate impact of the aviation sector. The US Air Force/Navy have been in the vanguard of introducing agrofuels for military aircraft, while in 2008, Air New Zealand ran the first test flight of a commercial airliner using a 50% blend of agrofuel (specifically 'Bio-SPK', short for Bio-Derived Synthetic Paraffinic Kerosene) and fossil kerosene. In both military and commercial aviation, it is widely assumed that we are on the cusp of significant growth in the use of agrofuels as a fuel of choice.

CO_2 and non-CO_2 emissions

In much of the discussion of the potential for agrofuels to act as a solution to the climate change impacts of aviation, estimates of agrofuel benefits have been quoted in terms of potential net CO_2 emissions reductions[11]. However, standard practice in the lifecycle assessment (LCA) of aviation agrofuels (commonly referred to as 'well-to-wake' LCA) has been to ignore the non-CO_2 effects of aviation.

Modern LCA of aviation agrofuel *production* ignores the climate effects of (indirect) land use change, but generally does include all major non-CO_2 effects (the most important example being accounting for nitrous oxide emissions due to agricultural fertiliser production and utilisation) by assigning 'Global Warming Potentials' to emissions of non-CO_2 radiative forcers that characterise the amount of carbon dioxide emission that would have an equivalent warming effect over a given time period. With this approach, nitrous oxide is assigned an emissions intensity nearly 300 times greater than CO_2 over a 100-year time period. The time horizon is important for such calculations, because many non-CO_2 radiative forcing effects have a relatively short atmospheric lifetime – e.g. methane has a global warming potential (GWP) of 25 over a period of 100 years, but of 72 over a period of 25 years. In the past, this approach has not been extended to the non-CO_2 effects of aviation fuel combustion and the planes themselves in traditional 'well-to-wake' analyses of aviation fuel carbon intensity.

11 Bauen, 2009

While this approach (in which the non-CO_2 effects of aviation are ignored in fuel LCA) can give a useful indication[12] of the tonnage of carbon emissions that can be avoided by using Bio-SPK to replace fossil kerosene assuming no climate effects caused by (indirect) land use change, it can give a misleading impression of the extent to which the use of aviation agrofuels can reduce the overall climate impact of aviation.

Can bio-technology green aviation growth?

Various organisations have implied that the use of aviation agrofuels, coupled with aircraft efficiency measures, etc., will be sufficient to offset the global warming implications of growth in aviation demand. For instance, the World Economic Forum report 'Policies and Collaborative Partnership for Sustainable Aviation'[13], presents a scenario for an industry CO_2 target in which aviation CO_2 emissions could be reduced below 2005 levels by 2050 despite a robust annual growth of 4.5% (Compound Annual Growth Rate).

This gives the impression that with technological improvements and significant use of agrofuels, it would be possible to entirely offset the climate change impact of aviation growth – i.e. robust aviation growth could be compatible with

12 Noting that if significant emissions such as from land use change are ignored then the results could be very misleading

13 WEF, 201,The project steering board for this report consisted of Airbus, the Air Transport Action Group (ATAG), Bombardier Aerospace, Delta Air Lines, Embraer, Etihad Airways, Gulf Air, the International Air Transport Association (IATA), Lockheed Martin, Lufthansa/Swiss, Rolls-Royce and The World Bank

addressing climate change. However, it turns out that according to the best current estimates, the non-CO_2 climate impacts of aviation over 100 years are similar in importance to CO_2 emissions – therefore, efficiency measures and agrofuel use only address half of the problem. Over shorter time periods (for instance from now to 2050) the non-CO_2 effects are dominant, i.e. efficiency measures and agrofuels do not address the most dangerous effects at all.

Lifecycle climate impact analysis of agrofuels for planes

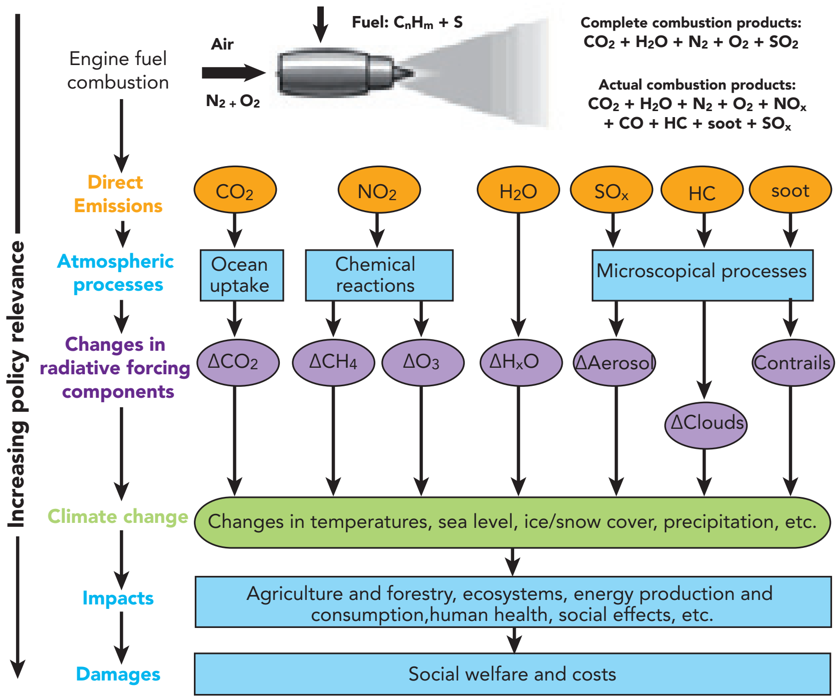
Agrofuel use in aviation will have only a marginal effect on total fuel consumption. Stratton et al. suggest[14] that Bio-SPK has an energy density 0.963 times that of traditional aviation kerosene. Because Bio-SPK is by design a close substitute for fossil kerosene, using Bio-SPK will result in a fairly similar chemical spectrum of direct aviation emissions to using current aviation fuels, i.e. the direct emissions, including carbon dioxide emissions, and processes described in Figure 1 will not be significantly altered (see Table 1).

However, even if one assumes that it might be possible in due course to produce substantial quantities of Bio-SPK with net carbon emissions 90% or more below those of fossil kerosene,[16] it is very important to be clear that it is only the carbon dioxide from aviation that is being offset. The other factors illustrated in Figure 1 (NOx induced methane and ozone, aviation induced cloudiness etc.) are not in general addressed – and hence without further action these components of the climate change impact of aviation will not be changed.[17] In particular, note that Stratton et al. assume[18] that the use of aviation agrofuels will not affect contrail formation or aviation induced cloudiness.

Table 1
Fuel characteristics of SPK relative to conventional jet fuel[15]

Fuel characteristic	ratio of Bio-SPK compared to conventional jet
specific energy	1.023
energy density	0.963
CO2combustion	0.98
water vapour	1.11
sulfate aerosols	0
soot aerosols	0.05-0.4
nitrogen oxides	0.9-1.0
contrails	1.0
Aviation Induced Cloudiness (AIC)	1.0

Figure 1
Aircraft emissions and climate change



The principal emissions from aviation operations and the atmospheric processes that lead to changes in radiative forcing components. Adapted from Lee et al. (2009), who in turn sourced from Prather et al. (1999) and Wuebbles et al. (2007)

14 Stratton et al., 2011b

15 From Stratton et al., 2011b

16 As suggested in WEF, 2011; Bauen, 2009

17 The exceptions being soot and sulfate aerosols, which are substantially altered, see Table 2.

18 Stratton et al., 2011b

Agrofuel use in aviation will have only a marginal effect on total fuel consumption. Because Bio-SPK is by design a close substitute for fossil kerosene, using Bio-SPK will result in a very similar chemical spectrum of direct aviation emissions to using current aviation fuels (Appendix 3 provides an overview of all emissions and of variations in emissions profiles).

Any emission savings from replacing fossil fuels by agrofuels in any sector must be achieved by increasing the terrestrial absorption of atmospheric carbon through additional plant growth.[19] The 'real' net emissions savings available from various agrofuel production pathways remain a subject of keen debate (see chapter 5 and EU impact studies[20]). However, even if one assumes that it is possible to produce substantial quantities of Bio-SPK with net carbon emissions 90% or more below those of fossil kerosene,[21] it is important to remember that it is only the carbon dioxide from aviation that is being offset. The other factors illustrated in Appendix 3 (NOx induced methane and ozone, aviation induced cloudiness etc.) are not in any way compensated for – and hence without further action these components of the climate change impact of aviation will not be changed.

What percentage reduction in climate change effect is achievable with aviation agrofuels?

As noted above, when talking about alternative aviation fuels, and in particular agrofuels, it is normal to talk about the percentage of carbon savings expected by using a given agrofuel instead of conventional fossil based fuels. Based on well-to-wake estimates of carbon savings from agrofuels, we noted that IATA has argued that 'carbon neutral growth' will be possible for the aviation industry from 2020, even with strong growth of 4.5% per annum. This claim is based on assumptions for agrofuels (availability and carbon saving) that are already optimistic, as discussed elsewhere. Let's assume that good agrofuels without indirect land use change (iLUC, see Chapter 5, deforestation) impacts will be available. Would 'global warming neutral' growth be possible in that case, if we expand our definitions to cover all global warming effects using the well-to-wake (+) metric, rather than only considering carbon dioxide emissions?

Stratton et al. show the comparative overall well-to-wake (+) climate effect of several different fuel pathways as illustrated in Figure 2. The well-to-wake component (i.e. excluding non-CO_2 effects) is based on earlier research[22] by Stratton et al. The worst case is coal-to-jet using gasification, which is substantially worse (about 1.7 times) than conventional jet fuel due largely to the increased CO_2 emissions – it is not a great revelation to anyone that coal-to-jet would be worse than conventional jet, however.

Of more interest are the two agrofuel paths considered. The first path, rapeseed oil to hydrogenated renewable jet fuel, would be labelled as providing a savings of around 40%. It's important to note that this assumes that rapeseed oil for jet fuel could be provided with zero land use emissions – results from IFPRI[23] for the European Commission suggest that in reality due to indirect land use change (iLUC), this pathway would actually cause an increase in well-to-wake emissions. Even, however, if iLUC could be avoided, when we look at well-to-wake (+) with the 100-year global warming potentials the saving would not be 40% but less than 20%. The palm pathway is similar. Stratton et al. find lower direct emissions from palm oil production than rapeseed, but once we include the 54 gCO_2e/MJ predicted by IFPRI, this pathway is also worse than conventional jet.

For the switchgrass to jet fuel pathway, which we might consider representative of the 'advanced' biofuel pathways,the saving that would be reported based on well-to-wake methodology would be around 80% (this ignores iLUC, but we would expect iLUC to be lower for switchgrass than for palm oilsome estimates are of the order of 10 gCO_2e/MJ). Again, if we consider all global warming effects using the well-to-wake (+) metric, this saving would be reduced – we would see less than 40%.

In general, using the more comprehensive well-to-wake (+) metric we find that the global warming reduction due to agrofuels is less than half what we would report based solely on the well-

19 Searchinger, 2010

20 http://www.euractiv.com/climate-environment/biodiesels-pollute-crude-oil-leaked-data-show-news-510437 and http://ec.europa.eu/energy/renewables/biofuels/biofuels_en.htm

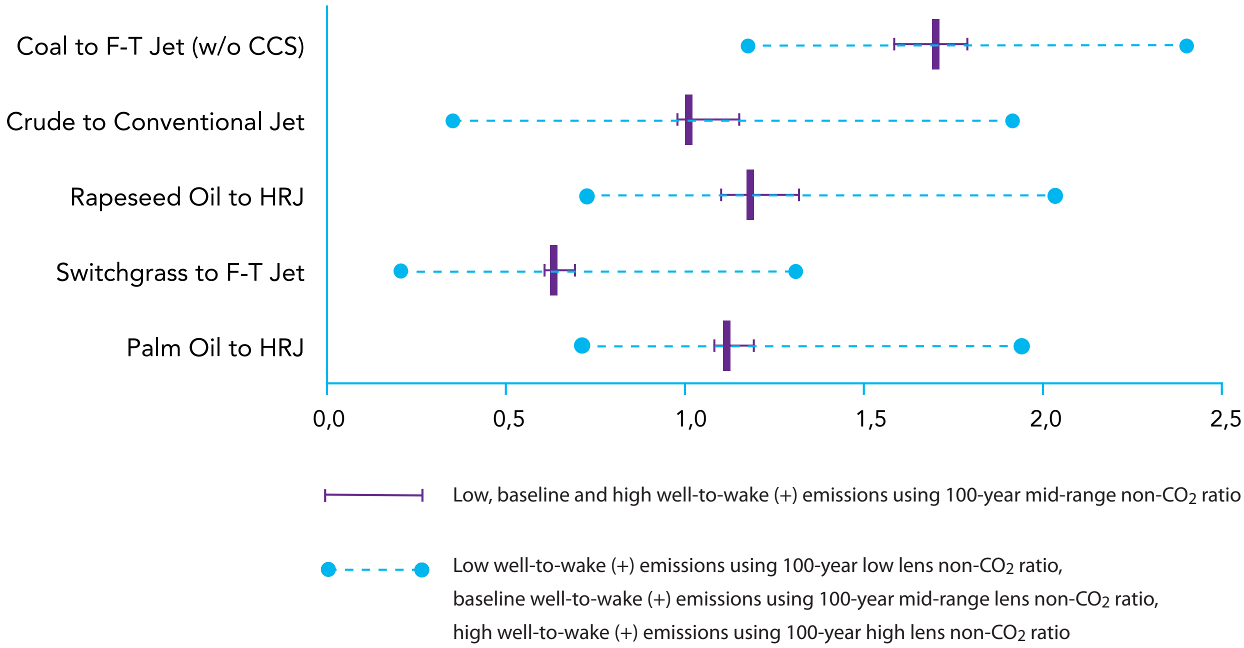
21 Bauen, 2009

22 Stratton et al., 2011a

23 Laborde 2011

to-wake analysis. That is to say, while well-to-wake analyses may give a reasonable impression of the reduction in tonnes of carbon emissions in a scenario where agrofuels are used instead of fossil fuels, they can be seriously misleading if we need to assess the actual effective climate impact of aviation.

Figure 2
Well-to-wake (+) emissions for different fuel pathways [24]



24 from Stratton et al., 2011, Palm oil added and indirect land use change (iLUC) emissions added to the rape-seed and palm oil pathways based on Laborde (2011). The uncertainty in the iLUC emissions is not included in the ranges, but is discussed at length by Laborde

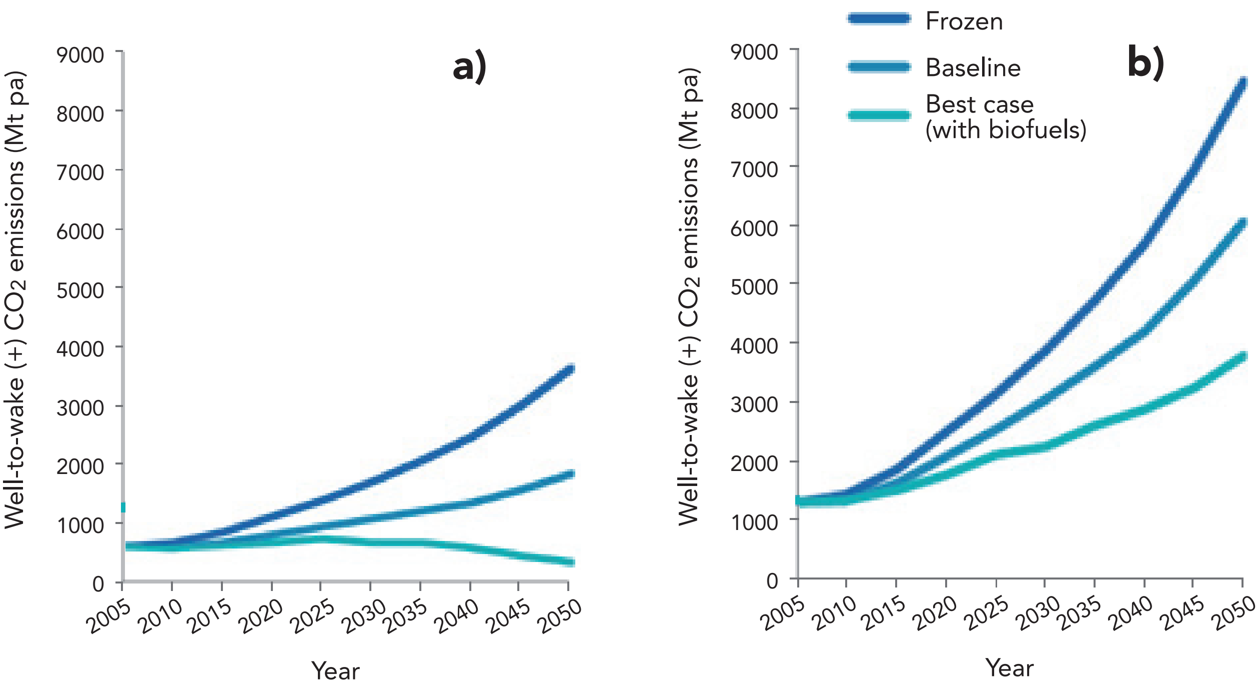
4. Likely global warming effect from aviation given future expansion of agrofuels

The central question here is whether industry targets for global warming neutral aviation growth beyond 2020 are achievable if we consider not only carbon dioxide emissions, but also non-CO_2 effects, primarily contrails and aviation induced cloudiness. First, let us assume that industry expectations for the supply and well-to-wake carbon intensity of aviation agrofuel can be met, i.e. that a plentiful supply of aviation agrofuel will be available by 2050, and that it will have a much lower well-to-wake carbon intensity than conventional jetfuel. The World Economic Forum (WEF) trajectory for global aviation shows how the aviation sector could reach its ambitious CO_2 reduction goals for 2050. This would require a transition to nearly 100% aviation agrofuel use, with an 85% well-to-wake carbon intensity reduction, by 2050. However, to reach this aviation industry long-term CO2 reduction target, 13.6 million barrels of sustainable second-generation aviation agrofuels per day would be required in 2050.

In Figure 3a, below, we have illustrated the 100-year global warming effect of the carbon dioxide from aviation in the coming decades[25]. We see that with these levels of 'good' aviation agrofuel use, the reported CO2 footprint of aviation drops sharply towards 2050 – a 45% reduction compared to 2010. But Figure 3b shows the equivalent trajectories for the overall 100-year global warming effect from aviation. This graph makes it is immediately clear that using the fuller metric of GWP tells a very different story about the climate impact of aviation growth than focusing solely on CO2 emissions. Rather than a 45% reduction in global warming impact from 2005 to 2050, the global warming impact of aviation grows by 180% (2.6% per annum) in this period.

25 Based on the WEF-trajectory, which assumes 4.5% annual aviation growth.
Note that even in the best case as calculated by WEF based on industry figures, carbon neutrality would not occur until around 2025. See appendices for more background on the scenarios.

Figure 3 a & b
Comparing the annual (a) well-to-wake CO_2 emissions; and (b) full well-to-wake (+) 100-year global warming potential of aviation in the WEF frozen, base and industry target emissions cases.



In the context of global attempts to avoid global warming, this would be disastrous. For instance, one target often suggested is that global carbon emissions would need to be reduced to 50% of 1990 levels by 2050 if climate change were to be limited to 2 degrees. In that case, the 2050 annual carbon emissions budget would be about 11,000 Mt – aviation would by then account for 35% of the world's annual 'carbon equivalent budget' even with a 100% shift to sustainable agrofuel, which have no emissions in their production. Many climate scientists now believe that a 50% emissions reduction by 2050 would be inadequate to control global temperatures[26]. In the case of a more ambitious global target to reduce global climate emissions by 80% by 2050, aviation alone would be using fully 86% of the world's carbon equivalent emissions budget, even with 100% sustainable agrofuels (based on the WEF trajectory, Appendix 2)

Aviation emissions in a global emissions perspective

If the world is serious about avoiding dangerous climate change by the middle of this century, it is also important to consider the implications of more intense short-term forcing effects. From now to 2050 is less than 40 years, not 100. When we reach 2050 itself, presumably it will be vital that climate effects should be controlled in the following decades. Unfortunately, because contrails and aviation induced clouds (AIC) have a stronger warming effect in the short term, when we look at the climate impact over the next decade(s) the picture is even more difficult. (See Appendix 2 for a 20-year time frame GWP perspective.)

Using the new and more complete well-to-wake (+) emissions metric, we find that not only will industry targets for the introduction of agrofuels to aviation not achieve global-warming-neutral growth, but that due to the importance of non-CO2 effects, even with a 100% switch to sustainable aviation agrofuels, 4.5% annual aviation growth is completely incompatible with targets for the avoidance of global warming of more than 2 degrees Celsius. This is true if we consider 100-year global warming potentials, and the picture becomes even worse if we focus on shorter term warming impacts (which we argue is appropriate in the context of attempts to avoid catastrophic climate change by 2050).

26 Anderson and Bows, 2011

Aviation in a European emissions perspective

Europe aviation accounts for 3.5 % of European CO2 emissions[27]. For the Netherlands the percentage is even higher, 5.7% of national CO2 emissions excluding international shipping[28]. The European Aviation Industry aligns itself with the global aviation industry policy of using agrofuels as a solution. Air France-KLM sees 'sustainable agrofuels' as 'the most promising route to achieving significant reductions in aviation's CO2 emissions whilst at the same time providing security of supply and exemption from EU-ETS. They will be essential in achieving Air France and KLM's ambitions as well as for the aviation industry as a whole.'[29] Lufthansa sees agrofuels as the key technology to reach their CO2 emissions reduction target[30].

The growth perspective in the mature European aviation market will be below the global average of 4.5% the industry assumes; IATA[31] predicts .5% below the global average. Up to 2008 growth (passenger kilometres) was stable at

27 European Environment Agency, 2012

28 CBS 2012 national emissions database, figures for 2009 and 2010, excluding maritime bunkers

29 Company website: http://corporate.airfrance.com/en/sustainable-development/environment-and-climate/combating-climate-change/renewable-energy-research-support/

30 http://presse.lufthansa.com/fileadmin/downloads/en/policy-brief/07_2011/LH-PolicyBrief-July-2011-agrofuels.pdf

31 http://www.iata.org/whatwedo/economics/Pages/mtaarchives.aspx

4.2% and 5.1%[32]. To be able to assess the future impact of aviation on Europe's climate forcing emissions, we assume a prolonged growth of 4% and the efficiency gains of 1.5% per year which the industry envisages[33].

Therefore, European airlines are expected to use 2.5% more fuel per year. If the aviation industry would fuel its growth entirely by using agrofuels, the effect on emissions would be 2.5% emissions growth due to non-CO2 effects plus 0.6 times 2.5% for climate emissions due to the production of bio-kerosene crops. In many cases, land use change would cause even more emissions related to crop production.

While aviation's share of European climate emissions would rise from 5.5% to 9.8%, airlines would still be able to present this as carbon-neutral growth.

Table 2
The impact of aviation on European climate emissions if growth from 2012 to 2020 would fuelled by agrofuels

EU 27 figures, Mton CO_2(eq)	2009	2010	2020 (forecast)
Total climate emissions	4614	4724	4471
Aviation CO2 emission	139	147	160
Aviation all climate effects	254	294	377
Share of aviation in EU CO2 emissions following ETS logic	2.8%	3.1%	3.6%
Share of aviation in EU climate emisions (excluding maritime bunkers)	5.5%	6.2%	8.4%

If the aviation industry does not use agrofuels, emissions will grow even faster. Note that if we assume a fictive carbon neutral growth, aviation's share would still rise, as other emissions are falling due to climate policies.

32 Operating Economy of AEA Airlines Summary Report 2007, Association of European Airlines, www.aea.be

33 World Economic Forum 2011, Policies and Collaborative Partnership for Sustainable Aviation report , http://www.weforum.org/

5. The impact of agrofuels on the ground

Despite rhetoric on advanced technologies such as algae, in 2020 the major share of aviation agrofuels in Europe is still expected to come from vegetable oil from the tropics, such as palm oil and oil made from jatropha plants. Recent investments in agrofuels for road transport have already taught us several lessons which the aviation industry seem not to take into account by pushing for more agrofuels: agrofuels compete with food, and cause land grabs and deforestation. They require a great deal of land: the projected goal of 3% aviation agrofuels for the European industry in 2020 already requires an amount of land the size of Belgium.[34]

Agrofuels compete with food

The overwhelming majority of agrofuels today are produced from food crops, directly competing with human consumption. Farmers formerly producing food have also switched to energy crops. In April 2008, UN Secretary-General Ban Ki-moon had already called for a comprehensive review of the policy on agrofuels, while a crisis in global food prices unfolded. In 2011, the World Bank, the G20 and EU advisory bodies, along with major food companies like Unilever, all called for an end to public biofuel mandates and fiscal subsidies. According to the UN Special Rapporteur on the Right to Food, Olivier de Schutter, market speculation and agrofuels caused an additional 100 million of people going hungry in 2011.

Agrofuels claim a great deal of land

The bulk of biofuel feedstock needs land to grow. To produce two million tonnes of bio-kerosene, up to 3.5 million hectares of land could be needed, according to a recent study from Friends of the Earth Europe. This is just 3% of the total aviation fuel projected for use in Europe annually by 2020. Moreover, this is in addition to even more ambitious targets for agrofuels for road transport by 2020. The extra need for agricultural land has led to many local land conflicts, and drives the phenomenon of 'land grabbing'.

Agrofuels are a major force behind land grabbing

Small-scale farmers, indigenous people and pastoralists are confronted with large-scale land acquisition, referred to as 'global land grabbing'. Their livelihoods, land rights and way of life are threatened by demand for land from plantation, mining or carbon trading companies. The most comprehensive study of large land acquisitions in developing countries to date, published by the International Land Coalition in December 2011, has found that of 71 million hectares of documented land deals, 78 percent are for agricultural production, of which three quarters are for agrofuels.

Agrofuels cause deforestation

The emerging agrofuels market is a major driver for deforestation and for the conversion of other ecosystems, like grasslands and marsh lands. The main actors are large-scale plantation companies that directly or indirectly (by forcing former land users into new habitats) replace biodiversity-rich areas with mono-cultures like soy, oil palm, sugar cane or industrial eucalyptus plantations. In addition to the loss of biodiversity and ecosystems services, this causes massive greenhouse gas emissions from methane, fertilizer use and carbon loss in soils and vegetation.

Certification for agrofuels is no solution

Despite a limited set of EU sustainability criteria, which do not include social criteria, and that are under constant threat of challenge from the

34 More on the issues in this chapter, including references, can be read in the recent Milieudefensie report 'agrofuels: Take-off in the wrong direction', on www.milieudefensie.nl

WTO, edible vegetable oils and grains will be the main stock for the EU's renewable targets for 2020 if no radical change of direction is made soon. The limits of certification are numerous: unequal power relations, weak law enforcement, corruption, not addressing indirect effects.

Palmolieplantage

6. Conclusion

A maximum of 50% of the climate impact of cruising aircraft is caused by CO2 emissions. Other non-CO2 climate effects are as powerful, or even more powerful when calculated using a 20-year time horizon or shorter. Neglecting these climate impacts, as commonly happens, cannot be justified, especially not for countries where aviation is a major contributor to climate emissions.

Using agrofuels in aviation will deliver only the same – no more, no less – benefits in terms of tonnes of avoided carbon emissions as using agrofuels in other transport modes, but does not address non-CO2-impacts that are particular to aircraft. Adding to that it is always important to take into account that agrofuels often do not even result in a net carbon emissions reduction, due te the large climate effects of indirect land use change.

The use of well-to-wake (+) analysis does not on its own imply that agrofuels cannot deliver any carbon savings from the aviation sector. However, using agrofuels to mitigate the climate impact of aviation growth is practically ineffective, as non-CO2-effects are not affected and will continue to grow. This is the case for the effects on the atmosphere of aircraft on cruise altitude and for the climate effects of increasing feedstocks for agrofuels. The negligible climate effects of bio-kerosene combined with the competition for scarce land, that is now used for food production or biodiversity conservation leads to the conclusion that there is little to win but much to lose.

Our report shows that if catastrophic climate change is to be avoided, it will without doubt be necessary to limit the growth in aviation and to find approaches to substantially reduce aviation's generation of contrails and AIC. Industry aspirations to continue business as usual growth without increasing the net climate effect are a dangerous illusion.

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Appendix 1

Metrics for the non-CO2 impacts of radiation, CO_2-eq and GWP

The IPCC recognises that it is important to consider gasses (and particles) that cause global warming or cooling other than carbon dioxide in making a robust assessment of the contribution of aviation to climate change. This has been done by comparing the radiative forcing effect of these gasses to the effect of CO2. The effect is then expressed in CO2-equivalents (CO2-eq) and all effects then can be combined in a total radiative forcing. This is the effect of gasses currently in the atmosphere, emitted by planes.

This backward-looking CO2-eq-approach is correct when emissions remain constant. A calculating problem appears when we deviate from this assumption, because not all gasses and particles remain in the atmosphere forever. Therefore, scientists have come up with the Global Warming Potential (GWP) that expresses the total climate effect a flight will have in the future. For planes, the GWP is dominated by non-CO2 emissions when a 20-year time frame (or shorter) is used. On a 100-year timescale, the effect of the long lasting greenhouse gas CO2 dominates the climate effect. The GWP is an average of all the climate effects of a set of emissions over a certain period. Therefore, this metric is perfect for comparing impacts. The downside of GWP is that is not used in the official Kyoto documents and calculations.

Lee et al. (2010) provide values for the 20 and 100-year global warming potentials of the constituent parts of 2005 aviation emissions. In Fig-

Figure 4
Global warming potentials for aviation related radiative forcers as calculated in teragrams carbon dioxide equivalent for 2005

Radiative forcer	GWP20 ($TgCO_2$/yr)	GWP100 ($TgCO_2$/yr)	Normalising carbon dioxide effect to 1 (GWP20)	Normalising carbon dioxide effect to 1 (GWP100)
CO2	641	641	1.0	1.0
NOx (lo)	106	-1.9	0.2	0.0
NOx (hi)	415	63	0.6	0.1
H2O	123	35	0.2	0.1
SO4	-25	-7	0.0	0.0
Black carbon	10	2.8	0.0	0.0
Contrails	474	135	0.7	0.2
Aviation induced cloudiness (AIC)	1410	404	2.2	0.6
Total (NOx lo)	2739	1208	4.3	1.9
Total (NOx hi)	3048	1273	4.8	2.0

These GWPs are illustrated in Figures 5 and 6 for both 100 and 20-year time scales.

ure 4 we have listed these values in total 2005 emissions for the first two columns, and then with all values transformed to normalise total CO2 emissions to 1 in the next two columns. For the 100-year GWP, the important forcers are CO2, AIC and contrails – over 20 years, NOx emissions are also potentially important.

Clearly, contrails and AIC are important (and in the short term dominant) contributors to the climate impact of aviation. More detail is provided in Appendix 3. The near-term dominance of non-CO2 effects is of particular importance if we are interested, for instance, in climate change mitigation/avoidance to 2050. While the aviation industry claims to be committed to carbon-neutral growth from 2020[35], the importance of non-CO2 effects make this a rather misleading claim. Even if the aviation industry achieves this (self-imposed and voluntary) aspiration, the actual climate impact of aviation to 2050 will continue to grow at a rate approaching the overall rate of aviation growth.

Stratton et al. address the absence of non-CO_2 effects in well-to-wake lifecycle analysis by defining a new enhanced lifecycle analysis approach for aviation fuels[36] that they call 'well-to-wake (+)'. Using the Aviation Portfolio Management Tool (APMT) and radiative forcing estimates for the various aviation-related climate effects based on the literature[37], Stratton et al. generate 'non-CO_2 ratios' for key climate forcers compared to

35 http://www.iata.org/pressroom/facts_figures/fact_sheets/pages/carbon-neutral.aspx

36 Stratton et al., 2011

37 using global warming potentials for contrails and AIC from Lee et al., 2010

Figure 5
GWP100 by radiative forcer for conventional jet fuel (CO_2 normalised to one). The top segment of the 'Total' bars is carbon dioxide, and can in principle be offset with agrofuels; the lower segment represents non-CO_2 effects and in general cannot.

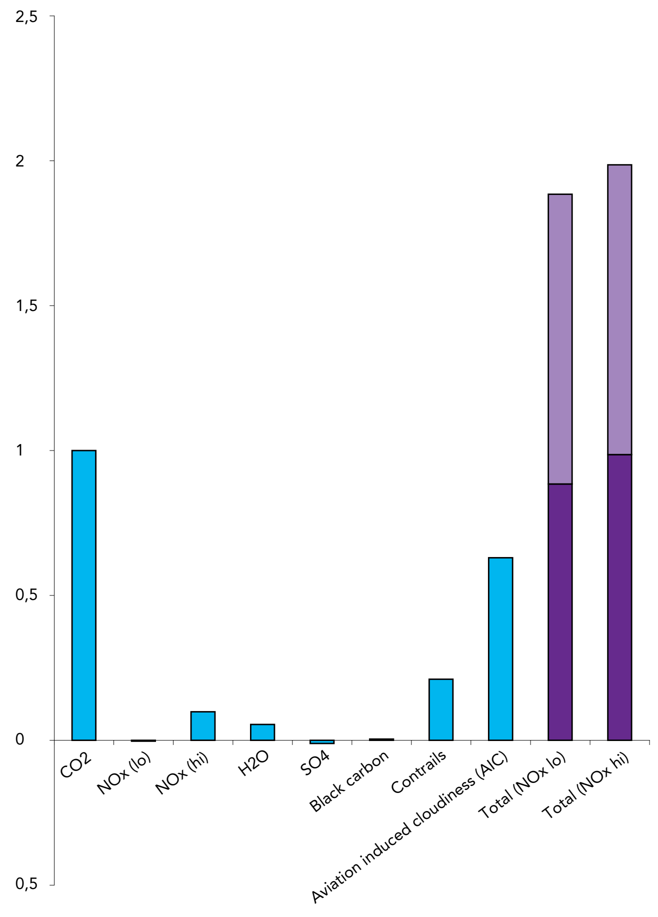
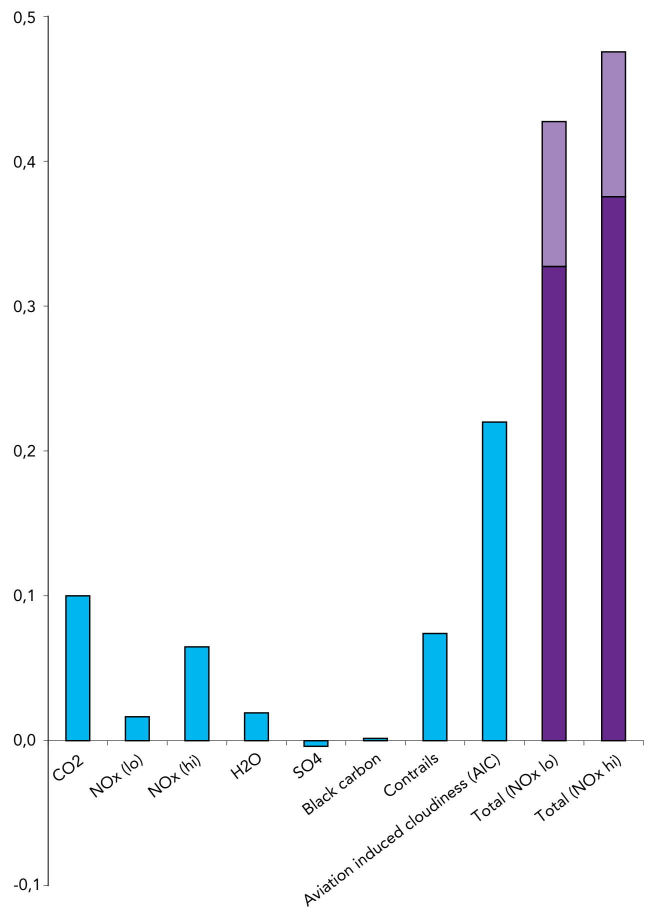


Figure 6
GWP20 by radiative forcer for conventional jet fuel (CO_2 normalised to one). The top segment of the 'Total' bars is carbon dioxide, and can in principle be offset with agrofuels; the lower segment represents non-CO_2 effects and in general cannot.



CO_2 – so a non-CO_2 ratio of 2 would mean that a given effect was twice as important as CO_2 emissions; a ratio of 0.5 would mean an effect was half as important as CO_2 emissions. These non-CO_2 emissions ratios can then be combined with conventional well-to-wake estimates of the 'carbon credit' for using agrofuel to give the enhanced well-to-wake (+) LCA values. This well-to-wake (+) approach provides a metric with which we can assess the overall contribution of alternative fuels to reducing the climate impact of aviation.

Using APMT and central estimates for warming potentials, Stratton et al. find that over 100 years, bio-Synthetic Petroleum Kerosene (bio-SPK, i.e. aviation agrofuel) has a total global warming impact equal to 2.2 times the impact of its combustion CO_2 – this is slightly higher than the total impact of conventional jet, at 2.1 times the impact of its combustion CO_2 (see appendix 3). The marginally higher impact of SPK is ascribed to increased water vapour and reduced sulphate emissions. For high-end estimates of non-CO_2 effects, the ratio could be as high as 3.8. The importance of non-CO_2 is even higher for 20-year impact global warming estimates – in the worst case, the 20-year impact of aviation would be about 11 times the CO_2 impact alone.

Appendix 2

20 year GWP applied to the WEF scenario

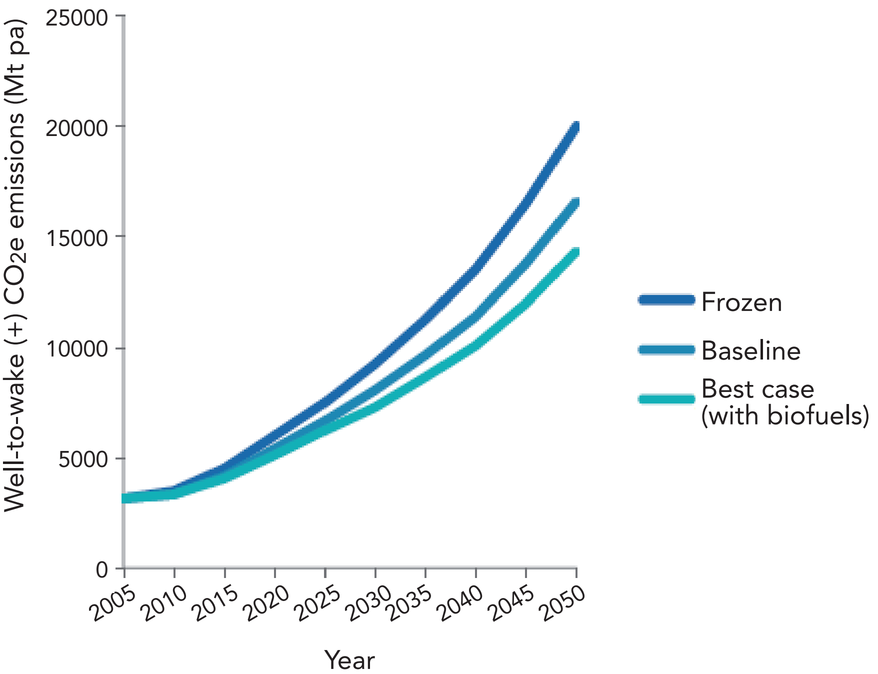
The World Economic Forum has built a growth scenario[38] on the basis of the claims and expectations of the aviation industry as voiced by IATA and Enviro-aero.[39]. The aviation industry aims for 4.5% growth annually. Provided the necessary public-private sharing is enabled, the industry has committed to collective CO_2 emission goals including an annual average 1.5% fuel efficiency improvement through 2020, net carbon neutral growth from 2020, and 50% net CO_2 emission reductions by 2050 compared to 2005 values.

In Figure 7, we see that the 20-year global warming impact of aviation will not be reduced in the WEF best-case industry scenario, nor will growth be global warming neutral, but total impact will actually increase by 330% (3.7% per annum) to 2050. If we were to consider the 20-year warming impact rather than the 100-year, then aviation would on its own overshoot a carbon budget based on 50% of 1990 emissions levels, even if a 100% transition to sustainable agrofuels in aviation takes place.

38 The Policies and Collaborative Partnership for Sustainable Aviation report was produced in February 2011 by the World Economic Forum as a cross-industry report.

39 http://www.enviro.aero/

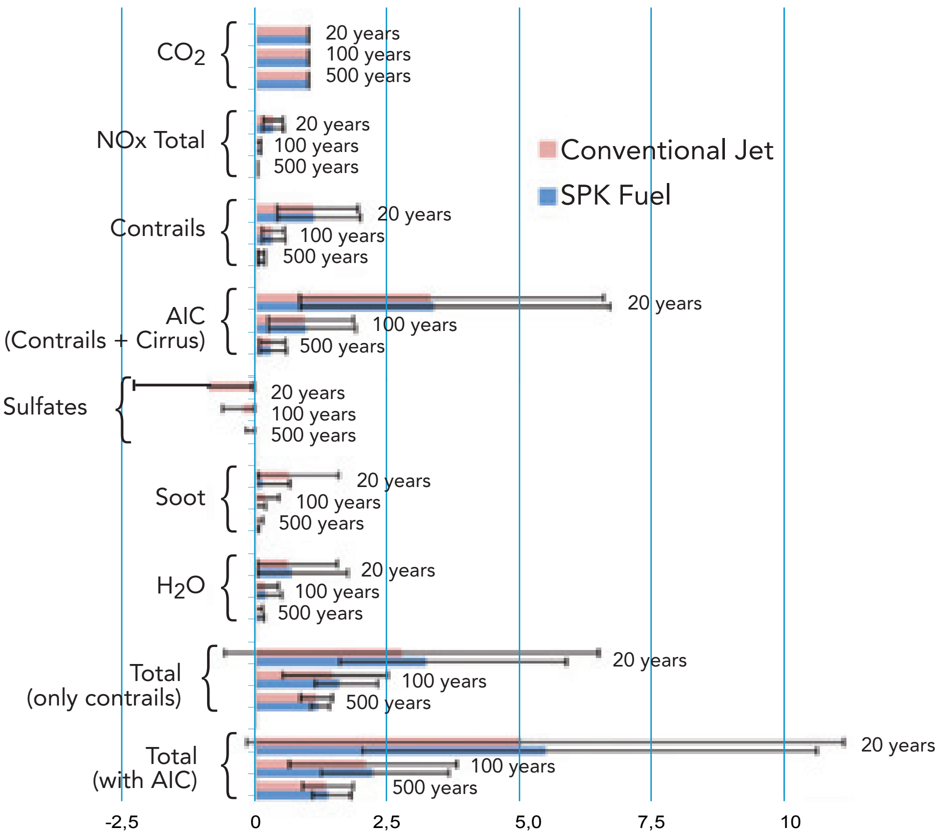
Well-to-wake (+) 20-year global warming potential of aviation in the WEF frozen, base and industry target emissions cases.



Appendix 3

Non-CO_2 climate impacts compared to CO_2 impacts

Figure 8
'Non-CO_2 ratios' from Stratton et al. for various effects of aviation



This diagram shows the effects of all climate forcing emissions from aircraft with CO_2 emissions put at 1, as ratios of warming effect over various periods to warming effects of CO_2 only. Climate forcing is calculated on three timescales: 100 years (most commonly used), 500 years and 20 years (most relevant according to many climate scientists, as worldwide climate forcing has to be turned around within the next 10 years to stop runaway climate change).
Note that sulfates have a cooling effect and the absence of soot in SPK-fuel.
The bars give the most probable magnitude of the effects; the lines indicate the ranges of uncertainty.

40 jaar mensen in beweging

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