Sustainable Aviation Fuels: hope or hype?

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Summary

- The term ‘SAF’ to describe all non-kerosene liquid fuels for aviation, which has been coined by the aviation industry and widely adopted in political and public debate, is unhelpful. The sustainability of alternative fuels needs to be assessed, not assumed.

- We need a better-quality conversation about how alternative fuels work as a tool of climate mitigation, based on the understanding that they deliver no CO_2 reduction at the tailpipe. At the moment there is a risk of greenwash In public discussion, and of goal-setting at a political level that isn’t based on the right information.

- While the discipline of lifecycle analysis (LCA) is deeply entrenched as an approach for appraising fuel sustainability, the LCA score of a fuel can vary hugely depending on the assumptions made, including location, and in some cases can lead to perverse outcomes whereby a fuel is purported to reduce emissions by greater than 100%, even in the absence of any carbon capture component to the fuel’s production. LCA should be only one component of any policy appraisal of potential alternative fuels for aviation.

- AEF’s view is that the ‘additional carbon’ framing has particular merit in appraising which alternative fuels actually deliver additional atmospheric CO_2 reduction in their production and use, rather than those that simply make opportunistic use of waste carbon that would otherwise have other uses or degrade much more slowly. E-fuels produced from Direct Air Capture of carbon would seem to stand out as additional under this approach.

- There is a need for greater transparency about how different systems of carbon accounting align to ensure that no emissions are lost and that no savings are double-counted.

- There is some evidence that alternative fuels may generate lower non-CO_2 impacts than kerosene, but until specific targets are in place for tackling non-CO_2 we should not be creating policy incentives for alternative fuels based on theoretical non-CO_2 benefits.

- If restricted to options that result in additional carbon removal from the atmosphere, the role of alternative hydrocarbons (‘SAFs’) in aviation decarbonisation appears starkly limited. While such fuels could play an important role in tackling the emissions from long haul flight, other options such as the development of zero emission aircraft and measures to incentivise an overall reduction in flying must not be crowded out of discussion by the current enthusiasm for ‘SAF’.

Introduction

“Sustainable Aviation Fuels” have been capturing both media and political attention in recent years. With few options for decarbonisation available to airlines, “SAFs”, as they have come to be called, are an attractive solution for the industry to promote. They can be blended with kerosene; can be used for both long haul and short haul flights (unlike the electric and hydrogen planes that may emerge but will likely cover only short to medium haul routes); are available on the market today; require little modification to existing aircraft or airport infrastructure; and are already acknowledged in by carbon market instruments like the UK emissions trading scheme (ETS) and ICAO’s offsetting scheme, CORSIA.

Prominent politicians currently regard SAFs as an easy answer to the aviation climate problem. When asked about whether he’d be taking a private jet to travel to an environmental event in Scotland, Rishi Sunak responded “if your approach to climate change is to say ‘No one should go on a holiday, no one should take a plane’, I think you are completely and utterly wrong… It’s not about banning flying, it’s about investing in new technologies, like sustainable aviation fuel, that will make flying more sustainable”[1].

[1] https://www.bbc.co.uk/news/uk-scotland-66354478

Typically these fuels feature less in actual policies than the rhetoric might suggest though. The Government's 'Jet Zero' Strategy, for example, sets out what is described as a 'high ambition' (some might say 'high risk') plan for achieving net zero aviation without directly curtailing growth. While alternative fuels certainly make an appearance, they come out in third place in terms of scale of impact, with 'out of sector emissions reductions' (carbon removals) and the demand impact of carbon pricing both delivering a larger share of the emissions abatement in 2050, neither of which is given anything like as much airtime as SAF.

Nevertheless, the UK has consulted at some length on proposals for a 'Sustainable Aviation Fuel' mandate, has committed to at least 10% of aviation fuel being SAF by 2030, and is considering options for providing a funding guarantee to SAF producers. The EU has gone further, introducing mandates as part of the REFUEL initiative for 6% aviation fuel to be 'SAF' by 2030, rising to 70% by 2050, with sub-targets for power-to-liquid SAFs (e-fuels).

But how well do political decision-makers really understand how SAFs work? And what about how they're reported in the media? On 15th March 2021 a BBC story[2] claimed that US scientists had found a way to reduce the emissions from flying by up to 165% compared with using fossil fuels. This gave us pause for thought: a reduction of more than 100% seemed to imply that flying with this fuel would result in a lower level of emissions than not flying! It turned out that much of the reduction arose from supposed savings as a result of preventing methane emissions from rotting waste that would otherwise arise from landfill, together with 'carbon credit incentives' for using energy sources other than fossil fuels. The story highlighted to us the potential for misleading claims to be made about alternative fuels, and in particular the importance of the assumptions underpinning the 'lifecycle analysis' giving rise to these emissions reduction numbers.

A major new report from Cerulogy

With this in mind, AEF commissioned a detailed study from the specialists at Cerulogy: 'Scrutinising the future role of alternative fuels in delivering aviation decarbonisation'. The report is in three parts, the first explaining and exploring the discipline of lifecycle analysis; the second considering policies around waste, which has become a key potential feedstock for UK SAF; and the third looking at aviation decarbonisation more broadly. The report avoids use of the term 'SAF', on the basis that "sustainability is an aspect of a fuel production system that must be assessed, and because there is no single universally accepted metric to identify when a fuel can be considered fully sustainable." It doesn't demonise either alternative fuels or lifecycle analysis, but sets out methodically what LCA scores can and can't tell us, why that often leaves out important parts of the story, what

[2] https://www.bbc.co.uk/news/science-environment-56408603

alternative approaches exist, and some of the likely limits to aviation alternative fuel deployment.

This AEF report draws on Cerulogy's analysis and findings. It sets out our views on the appropriate next steps for policymakers in this area, particularly in terms of communicating how alternative fuels work and considering 'additional carbon' thinking. It doesn't focus on issues around scaling of feedstock supply (See Box 1) nor does it set out our views on financial incentives or on any particular targets for alternative fuel take-up. These issues are important, but need to be based on a sound understanding of concepts like net emissions reductions and whether bundling waste reduction policies with climate policy risks confusion about sustainability. With industry conversations about 'SAF' focused firmly on showing how to increase supply, this report calls for a pause, and a rethink.

Box 1: Alternative fuel supply issues

Part 3 of Cerulogy's work considers some of the challenges related to feedstock availability, costs and infrastructure in relation to SAF supply. The report gives an illustration of the kind of investment commitment that would be required.

- The EU has set a 70% target for alternative aviation fuels by 2050, and the UK has proposed a 50% target. Meeting those targets at the same time would require about 37 million 'tonnes of oil equivalent' of alternative aviation fuel production.
- Based on the 'relatively large' assumed fuel production plant size, an average of about five new commercial scale plant openings a year would be needed from 2025 through to 2050 to meet this targeted EU+UK fuel demand.
- This would require capital investment of over $30 billion, more than $1 billion per year through the period, Cerulogy estimates.

In relation to e-fuel in particular, assuming a third of UK alternative fuel use being e-fuel by 2050 suggests a requirement of around 53 TWh of additional renewable electricity by 2050, equivalent to the total electricity consumption of about 14 million 2012 households.

Are all non-kerosene fuel sustainable?

The terms 'Sustainable Aviation Fuel' and 'SAF' haven't always existed. Somehow, though, we have accepted the use of a term that sweeps up and rebrands as 'sustainable' all of biofuel, synthetic fuels and even fuels produced from the waste products of fundamentally unsustainable industries such as plastic manufacture or intensive meat production. This now makes it more difficult to differentiate fuels that are better from those that are definitely worse when it comes to sustainability. Even more importantly, it has created the impression that there is something qualitatively different about these fuels, when compared to kerosene, that makes them, and the flights that use them, green or low-emission.

In fact, as Cerulogy states clearly, “the combustion CO_2 emissions for carbon-based alternative fuels are the same as the combustion emissions for fossil fuels.” Claims by airlines that these fuels can reduce emissions, ‘by up to 70%’ for example, rely on the assumption that emissions savings are made at the fuel production stage. As touched upon later, SAFs work – if indeed they work – in the same way as a carbon offset, cutting emissions not from flying but through other industrial processes elsewhere in the world and prior to the arrival of SAFs at an airport. From that point on, the tank-to-wake emissions are the same as using kerosene. The figure used for the ‘net reduction’ claimed is derived using a methodology called lifecycle analysis, or LCA, and part 1 of Cerulogy’s report focuses on explaining how this works.

Approaches to LCA?

As the report explains: “It is possible to produce completely different LCA answers for the same batch of fuel based on differences in scope and methodology, both of which may still be correct on their own terms.” The LCA question ‘what are the emissions associated with the processes required to grow feedstock for, produce, and distribute one million litres of biofuel?’ may give a different answer to the LCA question ‘what change in global net GHG emissions is expected if we increase the supply of biofuels by 1 million litres?’ One of the key issues in understanding LCA, the report notes, relates to the significance of whether the analysis focuses narrowly on the inputs and outputs of a given fuel (attributional LCA) or whether it attempts to look more widely at the impacts of using certain energy sources in aviation, rather than either leaving them alone or diverting them from other applications (consequential LCA).

Adopting a strictly attributional approach risks making policy decisions that could actually worsen climate change at a whole system level. One well-recognised example concerns Indirect Land Use Change (ILUC). While growing crops for biofuel may on an attributional approach generate significant emissions reductions compared to kerosene, a consequential approach may want to reflect the risk that growing these crops may mean that farmers who previously grew food on this land will now clear an area of forest to expand the land available for agriculture. The LCA methodology can be adjusted to try to take this into account. “Currently, EU and UK policy do this by using ILUC analysis to inform the level of support offered to food-based fuels, using displacement analysis to identify which wastes and residues should be offered extra incentives, and building e-fuel requirements around the concept of additional renewable electricity”, Cerulogy write. But despite conscientious efforts by policymakers, fundamental questions remain about whether biofuel use has actually been beneficial. “Further work for the European Commission (Laborde, 2011; Valin et al., 2015) on the indirect land use change impacts from EU biofuel policy have failed to resolve the basic question of whether we should believe that EU biofuel policy has delivered net climate benefits."

Similar discussions are now taking place in relation to synthetic aviation fuels produced from captured carbon and green hydrogen. These are widely considered to be the closest possible to a zero carbon aviation fuel on an attributional LCA basis. But consequential thinking highlights that if the fuel is produced by diverting green electricity from other sectors (rather than from additional supply) then the overall effect could be to increase fossil fuel reliance in other sectors. This is particularly important with respect to imported fuels. The Cerulogy report cites estimates that replacing half of the EU's 2050 aviation fuel demand would take about 880 TWh of electricity - more than current total electricity consumption for the whole of Africa (700 TWh). With a potential for electricity demand on such a large scale there is a real risk that renewable power investments intended to supply e-fuels to Europe could end up competing with investments to supply electricity for use in other parts of the world. Only by adopting a 'consequential' approach to LCA does this become evident.

Issues with waste

Some countries, including the UK, are keen to avoid the ILUC issues associated with biofuels by instead focusing policy incentives on the use of waste as an aviation fuel feedstock.

Merging policies for waste emissions with those for fuel emissions can also present problems though. While there are clear advantages to a consequential approach in policy-making it doesn't necessarily prevent the creation of perverse incentives. California's Low Carbon Fuel Standard is a policy designed to incentivise the take-up of alternative fuels for transport. But the scheme is also designed to help incentivise the reduction of methane emissions from manure since these have a strongly warming effect on the climate. The level of reward provided for avoidance of methane is such that turning manure into 'biogas' for road vehicles is credited with a greater than 100% emissions reduction. This approach to carbon accounting suggests that making pointless journeys using biogas should result in a lower level of emissions than not driving. The LCA methodology would seem to be to blame here, for building in some consequential elements but in a partial rather than a whole-system way.

The role of counterfactuals

This highlights a broader issue, namely that the lifecycle analysis for a given fuel can, in a consequential approach, depend enormously on assumptions about counterfactuals: what would have happened to a given feedstock otherwise. Making the wrong assumptions can be problematic.

Some approaches allow claims of emissions 'reduction' that are based only on avoidance. In the same way that you could consider the option of going for a meal in a steak restaurant and then convince yourself that you'd saved both CO_2 and methane emissions (as well as lots of money) by staying home and eating dal for dinner, so some carbon accounting systems allow emissions avoidance to count as a reduction. This is what lay behind the BBC story referred to in the introduction where emissions cuts of more than 100% were being claimed for an aviation fuel in the US. Counterfactuals can of course change in the future. An emissions 'saving' associated with avoided methane, for example, could vanish if effective policy were implemented to cut or capture methane at source.

The Cerulogy report highlights the significance of adopting different counterfactual assumptions when calculating LCAs. The UK Government recently passed legislation to permit Recycled Carbon Fuels, such as Refuse Derived Fuel, to count as renewable for policies such as the proposed Sustainable Aviation Fuel mandate. But what counterfactual should be assumed in estimating the LCA for such a fuel? If the refuse would otherwise be incinerated without energy recovery then using it in a plane could offer you a GHG saving of 79%, Cerulogy estimates. If instead it would otherwise be incinerated with energy recovery then the LCA saving would drop to 51%. But if the alternative was to put the refuse into landfill then there would be no emissions avoidance and you'd get only a 1% saving. Adding CCS to your incineration plant would change the calculation again.

These issues are not just theoretical. ICAO's CORSIA mechanism currently allows for avoided emission credits to be registered for two waste-based fuel pathways, the report notes. The first is a methane avoidance credit for alternative aviation fuel produced from municipal solid waste that contains biogenic material. The credit is based on the estimated methane production had the feedstock been landfilled. The second is a credit for increased recycling for alternative aviation fuel produced from municipal solid waste where it is claimed that feedstock preparation supports the recovery of additional material for recycling.

With some countries adopting very different waste management policies than others, the chance of agreeing a 'correct' counterfactual assumption for alternative aviation fuels at the international level doesn't look promising.

Wrong starting assumptions?

We've seen the importance, in applying LCA, of both accounting for any unintended consequences associated with a given fuel pathway and adopting accurate counterfactual assumptions. There are other important issues that an LCA may not capture. Here we consider challenges related to timeframes, and whether the assumed carbon reductions are 'additional' to what would otherwise have happened.

The standard starting point for both attributional and consequential LCA approaches, the Cerulogy report highlights, is to assume that a fuel could be carbon neutral barring any evidence to the contrary. If no-one notices that evidence, there's clearly a risk of the assumed benefits being too high. This risk is compounded by what the report calls the 'renewability shortcut'. UN accounting rules (reflected in CORSIA) state that biomass combustion or decomposition should be treated in industrial emissions inventories as if it resulted in no carbon dioxide emissions, on the assumption that the CO_2 was recently absorbed in plant matter. Treating alternative aviation fuels as if they have zero CO_2 emissions from combustion allows alternative fuel use to be characterised as an in-sector emission reduction for aviation in the same way that improved aircraft efficiency or operational improvements are.

Under this approach, there would be no distinction between whether this carbon remained in place for a hundred years or was immediately combusted for energy. In reality, however, this does make a difference, particularly given the need for urgent action in order to try to stabilise emissions. Keeping carbon stored in biomass means it is not in the atmosphere heating the planet and if carbon can be stored in biomass on a decadal timescale, this can make a significant climate difference. As it stands, regulatory LCA systems for biofuels do not, however, draw any distinction between the treatment of wastes and residual feedstocks that would have decomposed quickly versus the treatment of materials with medium- or long-term carbon storage potential.

The 'additional carbon' framing

The report invites us, at this point, to consider an alternative approach sometimes described as the 'additional carbon' framing which has been advanced, for example by Tim Searchiner in the context of forest protection. This starts by assuming the world as it is, and seeks to identify, for a given alternative fuel, exactly where in the system a CO_2 benefit would be delivered, either by increasing a carbon sink or reducing a carbon source.

Looking at LCA and alternative fuels through the additional carbon framing, the report argues, "brings out the parallels between GHG reductions from alternative fuels and GHG reductions from the type of land-based carbon offsets that might be used by airlines to comply with their targets under ICAO's CORSIA. Both for alternative fuels and for land-based offsets the GHG benefit is based on additional photosynthetic CO_2 absorption that can occur thousands of miles away from the airport where a plane might be filled with alternative fuel."

This perhaps points to an alternative framework to LCA, or as the report suggests, a different way of thinking that could be adopted in parallel to LCA, that could help sift out only those alternative fuels whose production generates a genuine, additional reduction of atmospheric CO_2 compared to the level today.

Cutting emissions 'today'

The report highlights, as noted above, that LCA can be a blunt tool when it comes to the difference between CO_2 slowly being released from woody waste compared with that CO_2 being released all at once, today, from the tailpipe of an aircraft. But there's another issue that seems important to note when it comes to LCA and timeframes. Airlines or alternative fuel producers sometimes claim that, while zero emission aircraft are not yet commercially available, it is possible to begin cutting aviation emissions today by using waste-based fuel. That's a problematic statement for more than one reason.

First – as set out above – the CO_2 emissions from aircraft are not reduced at all as a result of switching from kerosene to an alternative hydrocarbon, so 'aviation emissions' are not really cut at any time as a result of these fuels. Second, any carbon reduction being claimed cashes in on CO_2 that has been captured at some point in the past (and in the case of waste plastics, it was the very, very distant past!). Counting the use of this fuel as offering a net emissions reduction seems to run counter to the urgent imperative to stop adding to the levels of atmospheric CO_2 now and in the future.

Alternative approaches

The production of alternative liquid hydrocarbons is not, of course, the only approach being considered for delivering the Government's commitment to net zero aviation by 2050. As mentioned in our introduction, the Government's aviation climate plan, the 'Jet Zero Strategy', has ambitions for a range of 'in sector' measures such as efficiency improvements, demand reductions arising from carbon pricing, and – towards 2050 – the commercialisation of some zero emission aircraft (electric or hydrogen). But the largest wedge of emission reduction is assumed to come from 'out of sector' measures – a combination of engineered or nature-based carbon removals that will, it is hoped, be developed at the right scale and at the right speed to balance out all aviation emissions at least by 2050.

We have suggested that alternative hydrocarbons can be understood as a form of offset. This would make the 'out of sector' wedge in the Jet Zero plan even bigger and the in-sector wedge even smaller. There are of course some differences, though, between alternative fuels and offsets or removals. The fact that they would be paid for (barring any subsidies that might be provided - something that UK NGOs firmly oppose) by airlines and could only be counted once they were definitely added to the fuel mix provides, perhaps, more certainty about their deployment than exists in relation to offsets.

E-fuels made using carbon captured from the air and green hydrogen, created using additional renewable energy, are perhaps the only category of 'SAF' under consideration that would pass an 'additional carbon' test. But understanding that these fuels reduce emissions only on a net basis leads to an important question about how strong the case is for producing e-fuel compared to continuing to use fossil jet fuel and balancing the resulting emissions with engineered carbon removals. As noted in the Cerulogy report:

> "Some analysts (e.g. The Royal Society, 2019) and the Climate Change Committee (CCC, 2020) have noted that from a lifecycle emissions perspective capturing CO_2 for e-fuel production delivers a similar net CO_2 emissions benefit as capturing an equivalent amount of CO_2 for storage (CCS) and continuing to use fossil fuels in the air. The aviation industry could buy offsets from CCS projects and it would deliver 'additional carbon' in the same way that e-fuel production does. If the cost and energy requirements of e-fuel production remain higher than the cost of CCS offsets plus fossil fuel consumption, this will pose an important conceptual challenge to the alternative fuel market in aviation, as it is likely that there will be considerable pressure to follow a less costly offsetting route."

Double counting risks? Lack of clarity over alignment

From an accounting perspective, it could be argued that it doesn't matter whether aviation's emissions reductions are 'net' rather than actual, so long as any aviation emissions are matched by an equal level of CO_2 removal. Setting aside any concerns about what counts as an emissions removal, one key question concerns the risk of double counting of any emissions savings. In cases where waste was to be turned into aviation fuel, who should get the credit for any emissions saving – the industry that made the waste, the waste handler or the airline buying the fuel? The answer appears to depend partly on what type of waste is being discussed and what type of accounting system is in place.

As noted above, biomass is generally assumed to generate no emissions when combusted. Under UN guidelines, changes in carbon stock in the biosphere (removing forestry wastes for example) are instead assessed in the land use, land use change and forestry (LULUCF) sector. Carbon stock changes in UK LULUCF inventory emissions are not established by direct measurement, though, but through the use of estimation measures. And "the inventory system is not able to (nor designed to) accurately track shifts in biogenic carbon storage or emission associated with small changes in waste disposition and composition", the report suggests.

Fossil fuel wastes meanwhile are treated differently. Under UNFCCC inventory rules, a CO_2 emission from fossil carbon is recorded at the point of combustion. In general, any non-biogenic waste in SAF should – under the UN inventory approach - be attributed to the airline using it, but there's potential for glitches in the system related to the assumed counterfactuals.

If a company produced plastic waste that went to landfill, no emissions would be reported as the carbon in the waste would not be released. If instead the company sent the plastic to be converted to Recycled Carbon Fuel, then under the UK's proposed 'Renewable Transport Fuel Obligation' (and potentially the Sustainable Aviation Fuel mandate), the user of the fuel would calculate GHG emissions based on an assumption that the plastic would have been combusted for energy recovery if it had not been used for RCF production. The UK Government argues that landfill should not be considered as a counterfactual because it aims to largely eliminate landfilling. Based on these LCA approaches, neither the waste generator nor the RCF producer/consumer would account for the physical CO_2 emissions associated with combustion of the carbon from the plastic waste and "the emissions from combustion of fossil carbon in wastes could 'disappear' from GHG inventories", Cerulogy argues.

While in theory any given system of carbon accounting should capture the emissions somewhere, the complexities of how these systems work – and the fact that some policies provide double credits as incentives - would seem to increase the risk of things going wrong. It is unclear, for example, how emissions from SAF will be accounted for in carbon budgets once international aviation is included in the Climate Change Act. Greater transparency would help here, in relation to how different inventories work and align, particularly if SAF is being imported.

Non-CO_2 impacts

It's long been recognised that aviation has significant and specific climate impacts in addition to the warming from CO_2, as a result of aircraft operating at high altitude. The formation of condensation trails from some flights, and the impact of NOx on concentrations of atmospheric ozone and methane are the most significant effects. A scientific review published in 2021 found that non-CO_2 impacts from aviation were responsible for two thirds of the atmospheric warming to date, with CO_2 accounting for only one third. LCA does not account for these additional warming impacts.

Some modelling studies suggest that alternative aviation fuels may be less likely to increase cloudiness than kerosene as a result of their lower aromatics content, though significant uncertainties remain about this. Increased take-up of alternative fuels is not the only way - and may not be the most effective way - of tackling aviation's non-CO_2 impacts. The aromatic content of fuel could be reduced by 'hydro-treating' kerosene at the oil refinery; an active programme of work exists to identify whether aircraft can be rerouted effectively to avoid the cold air masses where contrails form; and hydrogen aircraft seem likely to generate less non-CO_2 warming than kerosene-powered planes.

As set out in the Cerulogy report:

> The aviation industry is perhaps a little conflicted about advertising the non-CO_2 emissions benefits of alternative aviation fuels. The industry tends to emphasise the uncertainty in estimates of non-CO_2 warming impacts from aviation when it acknowledges them at all, and has used this uncertainty as a basis to argue against developing regulations to manage non-CO_2 effects or to hold aviation accountable for this warming. In this context there is little appetite from industry to offer any quantified regulatory recognition of non-CO_2 benefits from alternative fuels. On the other hand, producers of alternative fuels for aviation reasonably see the non-CO_2 benefit as a significant selling point.

At present, no pricing or other penalty is applied through regulation to aviation's non-CO_2 effects, so while it is worthwhile to conduct further research into the full atmospheric effects of alternative fuels, the case for rewarding any non-CO_2 benefits associated with alternative liquid fuels is weak. Effective non-CO_2 policy and measures addressing all flights are urgently required and must precede any incentives for alternative fuels on the basis of their potentially lower non-CO_2 impacts.

Concluding thoughts

From the outside, once some of the issues set out here start to become apparent, it's tempting to see lifecycle analysis as something of a dark art. Cerulogy's report describes it differently. Done well, and applied correctly, it can have a useful role, the report suggests, in accounting for the inputs and outputs associated with the production and consumption of a fuel in a way that can facilitate comparison with alternative options.

But the report also highlights the many issues that an LCA score can't resolve on its own. An LCA value, particularly an attributional LCA, can't tell us whether the feedstock used could have been better deployed elsewhere. It can't tell us anything about aviation non-CO_2 impacts. And it can't show us the difference, in climate terms, between using biomass for fuel versus leaving it alone. While LCAs can codify lots of bits of data, they can't provide a precise or scientific measurement of some property of a fuel – the results are dependent on a number of subjective decisions and need to be treated carefully.

Most importantly, an LCA score can't – on its own – tell us whether a given fuel is or is not sustainable at a whole-economy level. Moving away from the notion of avoided emissions and focusing only on additional carbon reductions would go a long way, it seems to us, towards good policymaking in the future. The window of time for effective climate action is getting smaller by the day. Flights taking off now will generate CO_2 which could remain in the atmosphere for hundreds if not thousands of years. We don't have time to risk carbon accounting mistakes.